2017

District of Columbia
Energy Conservation Code

GOVERNMENT OF THE DISTRICT OF COLUMBIA
MURIEL BOWSER, MAYOR

dcra

ICC INTERNATIONAL CODE COUNCIL

2017

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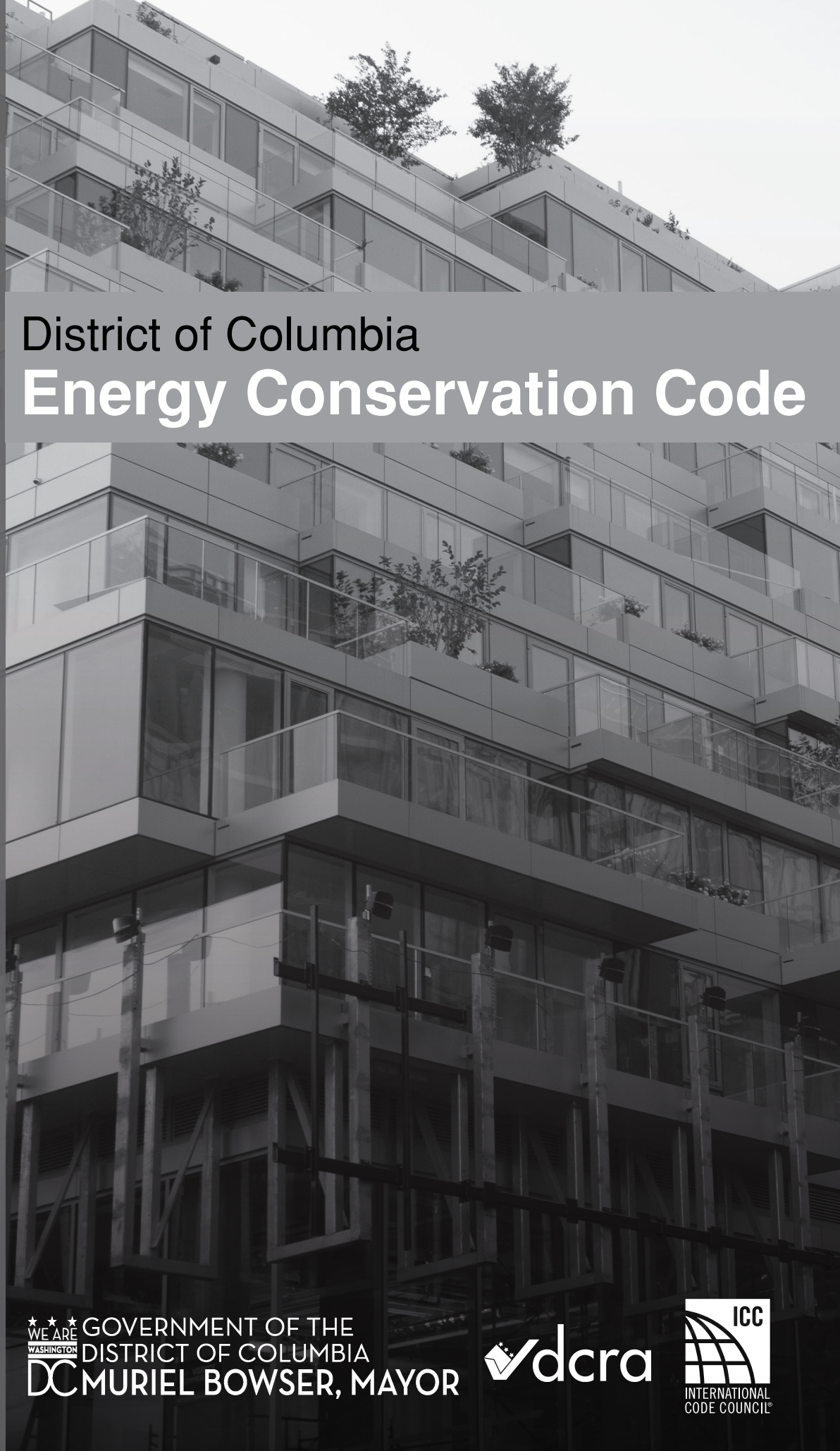
Energy Conservation Code



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2017 District of Columbia Energy Conservation Code

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PREFACE

Background

The 2017 *District of Columbia Construction Codes,* effective May 29, 2020, consist of the following 12 codes:

- 2017 *District of Columbia Building Code* [2015 edition of the *International Building Code*® published by the International Code Council (ICC) as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12A, Building Code Supplement)].[1]
- 2017 *District of Columbia Residential Code* [2015 edition of the *International Residential Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12B, Residential Code Supplement)].
- 2017 *District of Columbia Electrical* [2014 edition of the *National Electrical Code* published by the National Fire Protection Association (NFPA) as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12C, Electrical Code Supplement)].
- 2017 *District of Columbia Fuel Gas Code* [2015 edition of the *International Fuel Gas Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12D, Fuel Gas Code Supplement)].
- 2017 *District of Columbia Mechanical Code* [2015 edition of the *International Mechanical Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12E, Mechanical Code Supplement)].
- 2017 *District of Columbia Plumbing Code* [2015 edition of the *International Plumbing Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12F, Plumbing Code Supplement)].
- 2017 *District of Columbia Property Maintenance Code* [2015 edition of the *International Property Maintenance Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12G, Property Maintenance Code Supplement)].
- 2017 *District of Columbia Fire Code* [2015 edition of the *International Fire Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12H, Fire Code Supplement)].
- 2017 *District of Columbia Energy Conservation Code* [2013 edition of the Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI/ASHRAE/IES 90.1-2013) published by ASHRAE (formerly known as the American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.) and the 2015 edition of the *International Energy Conservation Code*®—Residential Provisions published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12I, Energy Conservation Code Supplement)].
- 2017 *District of Columbia Existing Building Code* [2015 edition of the *International Existing Building Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12J, Existing Building Code Supplement)].
- 2017 *District of Columbia Green Construction Code* [2012 edition of the *International Green Construction Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017* (DCMR 12K, Green Construction Code Supplement)].
- 2017 *District of Columbia Swimming Pool and Spa Code* [2015 edition of the *International Swimming Pool and Spa Code*® published by the ICC as amended by the *District of Columbia Construction Codes Supplement of 2017,* 12 DCMR L, Swimming Pool and Spa Code Supplement)].

1. The District of Columbia Municipal Regulations (DCMR) is the official compilation of rules and regulations issued by government agencies and the Council and is available online at: http://dcregs.dc.gov/.

The ICC, ASHRAE and NFPA Codes have been extensively amended by the District of Columbia to address specific District of Columbia policies and statutes, and unique characteristics of the District of Columbia.

The ICC and NFPA Codes provide a comprehensive, coordinated set of building safety and fire codes that have been adopted by 50 states and the District of Columbia at the jurisdictional or state level. The ICC's consensus-based code development process involves a broad range of stakeholders, including construction industry representatives and code regulators, to ensure that the model codes incorporate the latest technical advancements, while addressing industry and regulatory concerns. The ICC Codes also provide helpful resources, such as interpretive commentary and history of amendments, which provide a basis for interpreting the *District of Columbia Construction Codes*.

In 1791, President George Washington issued the first building guidelines in Washington, DC. These guidelines largely emphasized aesthetics in order to ensure that new buildings complemented Pierre L'Enfant's plan for the city. By 1872, during a period of rapid change and expansion after the Civil War, the District of Columbia adopted the first comprehensive set of building regulations focusing on health and safety concerns. The 1872 regulations, introduced by the Congressionally established Board of Public Works, required building permits for the first time. Nineteenth century building regulation also included The Height of Buildings Act, enacted by Congress in 1899 to address safety concerns about the use of steel framing. The greater building heights achieved by steel-framed structures raised concerns about the city's ability to extinguish fires, and the possibility of structural collapse.

Consistent with the growing national trend towards nationally-recognized model building codes, in 1986 the District of Columbia adopted five of the 1984 codes published by the Building Officials Code Administrators (BOCA) International along with model codes published by the Council of American Building Officials and the National Fire Protection Association. In 1994, after BOCA combined with other model code groups to establish the ICC with a common goal of developing a single coordinated set of national model building codes, the District of Columbia began transitioning to the ICC's International Codes® (I-Codes®). Beginning in 1999 the District of Columbia adopted the 1996 *International Mechanical Code* and 1995 *International Plumbing Code*, and completed the transition to the I-Codes in 2003, when nine of the 2000 edition of the I-Codes were adopted.

Following the 2008 update of the *District of Columbia Construction Codes*, and in recognition of the need for a more robust, responsive and ongoing code development process in the District of Columbia, a new Construction Codes Coordinating Board (CCCB) was created by Mayoral Order in March 2009 to replace the Building Code Advisory Committee.[2] The members of the CCCB are appointed by the Mayor (except for one member appointed by the DC Council) and represent various stakeholders in the code development process, including architects, engineers, government regulators, representatives of the construction and housing industries and city residents. The CCCB is supported administratively by the District of Columbia Department of Consumer and Regulatory Affairs (DCRA) and has been delegated authority by the Mayor to issue rules to amend the Construction Codes and to adopt the model codes pursuant to procedures set forth in the DC Official Code, §6-1409.

In considering adoption of the ICC, ASHRAE and NFPA codes and reviewing local code change proposals, the CCCB considers relevant criteria and policies including:

- Minimum performance standards and requirements for construction and construction materials, consistent with nationally accepted standards of engineering, fire, and life safety.
- Unique District of Columbia characteristics, policies or statutes.
- The use of modern technical methods, devices and improvements.
- Elimination of restrictive, obsolete, conflicting, duplicative, and unnecessary regulations and requirements.
- Standards to make buildings and facilities accessible to and usable by physically disabled persons.

2. Mayor's Order 2009-22 (February 25, 2009), as amended by Mayor's Order 2012-32 (February 29, 2012).

Consideration of the 2012 I-Codes and the 2011 *National Electrical Code* began in October 2011 at the direction of Mayor Vincent C. Gray who tasked the CCCB with meeting Mayor Gray's stated goal of making the District of Columbia the healthiest, greenest and most livable city in the United States. By adopting the 2012 *International Green Construction Code* and the 2012 *International Energy Conservation Code* as mandatory codes applicable to public and private sector buildings, the District of Columbia has taken a national leadership role in establishing a regulatory framework for fostering green building practices.

Development of the next update to the DC Construction Codes began in 2015 with a review of the 2015 I-Codes, 2013 *ANSI/ASHRAE/IES 90.1-2013* and 2014 *National Electrical Code*. Initiated by Mayor Muriel Bowser, the CCCB was tasked with simplifying the codes for both project teams and enforcement staff, while continuing to advance the District's energy efficiency goals embodied in the Sustainable DC plan.

The Code Development Process

Although administered by DCRA, the code development process reached well beyond the agency's corridors. In addition to the Board members who met frequently, often weekly, over a four year period, more than 100 individuals, including architects, engineers, contractors, property managers, real estate developers and government regulators, contributed countless hours attending technical advisory group meetings, as they pored over the model codes and developed code change amendments to reflect and incorporate local District of Columbia policies and concerns.

This process resulted in more than 500 code change proposals, incorporated into the 2017 *District of Columbia Construction Codes Supplement*. Two rounds of public comment were sought through a rulemaking process, consisting of a Notice of Proposed Rulemaking (65 DCR 40-Part 2, September 28, 2018) and a Second Notice of Proposed Rulemaking (66 DCR 31-Part 2, July 26, 2019).

Final recommendations were sent by DCRA to the Mayor and subsequently introduced to the District of Columbia Council on January 30, 2020. The Codes were passively approved by the Council on April 9, 2020 and became effective on May 29, 2020 when a Notice of Final Rulemaking was published in the DC Register (67 DCR 23-Part 2, May 29, 2020).

Structure of the 2017 District of Columbia Construction Codes

Since the District of Columbia Construction Codes consist of the ICC, ASHRAE and NFPA model codes as modified by the *District of Columbia Construction Codes Supplement*, the model codes and the local supplement must be consulted together to determine the complete text of the *District of Columbia Construction Codes*. The I-Codes are available on the ICC's website at http://publicecodes.cyberregs.com/icod. ASHRAE 90.1-2013 is available at https://www.techstreet.com/ashrae/standards/ashrae-90-1-2013-si?gateway_code=ashrae&product_id=1865967.

The *District of Columbia Construction Codes Supplement* contains the local District of Columbia amendments and modifications and is codified in Title 12 of the DCMR. Title 12 can be viewed online on the website hosted by the Office of Documents and Administrative Issuances (ODAI): http://www.dcregs.dc.gov [3]

To assist the public, three of the District of Columbia Construction Codes may also be viewed in an integrated version, published by the ICC, which consolidates the respective ICC codes, ANSI/ASHRAE/IES 90.1-2013 and the District of Columbia amendments. The three integrated codes are available to the public through a link on the DCRA website, which enables online reading and limited downloading. These codes are as follows:

- 2017 *District of Columbia Building Code*
- 2017 *District of Columbia Energy Conservation Code*
- 2017 *District of Columbia Green Construction Code*

3. Title 12 of the DCMR is also available on the DCRA website.

A solid vertical line in the margin within the body of the integrated Energy Conservation Code published by the ICC indicates a District of Columbia change in the text of the respective model code. A deletion arrow (➡) is provided in the margin where an entire section, paragraph, exception or table has been deleted or an item in a list of items or a table has been deleted.

Consistent with prior practice in the District of Columbia, Chapter 1 of the *District of Columbia Building Code* contains administrative and enforcement provisions that apply to all the individual codes that comprise the District of Columbia Construction Codes, with the exception of the *Property Maintenance Code* and the *Fire Code*. Administrative and enforcement provisions for the *Property Maintenance Code* and the *Fire Code* are set forth in 12-G DCMR, Chapter 1, and 12-H DCMR, Chapter 1, respectively.

Effective Date

The 2017 *District of Columbia Construction Codes* became effective May 29, 2020, and apply to all new and existing construction and buildings in the District of Columbia, unless otherwise excepted or excluded, subject to the transition provisions set forth in Section 123 of the Building Code, which allows continued use of the 2013 *Construction Codes* under specified circumstances.

Citation

The *District of Columbia Construction Codes* should be cited by referencing the ICC, ASHRAE or NEC provision if applicable, or the local District of Columbia amendment set forth in 12 DCMR. Alternatively, a specific provision can be cited by referencing the applicable District of Columbia Construction Code, e.g., 2017 *District of Columbia Property Maintenance Code*, Section 404.1.

Codes Maintenance

At the national level, the model codes are kept current through the review of proposed changes submitted to the organizing body by code enforcement officials, industry representatives, design professionals and other interested parties. Proposed changes are considered through an open code development process in which all interested and affected parties may participate. New model codes are issued on a three-year cycle.

Abbreviations and Notations

The following is a list of common abbreviations and units of measurement used in this code. Some of the abbreviations are for terms defined in Chapter 2. Others are terms used in various tables and text of the code.

AFUE	Annual fuel utilization efficiency
bhp	Brake horsepower (fans)
Btu	British thermal unit
Btu/h-ft^2	Btu per hour per square foot
C-factor	See Chapter 2—Definitions
CDD	Cooling degree days
cfm	Cubic feet per minute
cfm/ft^2	Cubic feet per minute per square foot
ci	Continuous insulation
COP	Coefficient of performance
DCV	Demand control ventilation
°C	Degrees Celsius
°F	Degrees Fahrenheit
DWHR	Drain water heat recovery
DX	Direct expansion
E_c	Combustion efficiency
E_v	Ventilation efficiency
E_t	Thermal efficiency
EER	Energy efficiency ratio
EF	Energy factor
ERI	Energy Rating index
F-factor	See Chapter 2—Definitions
FDD	Fault detection and diagnostics
FEG	Fan efficiency grade
FL	Full load
ft^2	Square foot
gpm	Gallons per minute
HDD	Heating degree days
hp	Horsepower
HSPF	Heating seasonal performance factor

HVAC	Heating, ventilating and air conditioning
IEER	Integrated energy efficiency ratio
IPLV	Integrated Part Load Value
Kg/m^2	Kilograms per square meter
kW	Kilowatt
LPD	Light power density (lighting power allowance)
L/s	Liters per second
Ls	Liner system
m^2	square meters
MERV	Minimum efficiency reporting value
NAECA	National Appliance Energy Conservation Act
NPLV	Nonstandard Part Load Value
Pa	Pascal
PF	Projection factor
pcf	Pounds per cubic foot
psf	Pounds per square foot
PTAC	Packaged terminal air conditioner
PTHP	Packaged terminal heat pump
R-value	See Chapter 2—Definitions
SCOP	Sensible coefficient of performance
SEER	Seasonal energy efficiency ratio
SHGC	Solar Heat Gain Coefficient
SPVAC	Single packaged vertical air conditioner
SPVHP	Single packaged vertical heat pump
SRI	Solar reflectance index
SWHF	Service water heat recovery factor
U-factor	See Chapter 2—Definitions
VAV	Variable air volume
VRF	Variable refrigerant flow
VT	Visible transmittance
W	Watts
w.c.	Water column
w.g.	Water gauge

ACKNOWLEDGMENTS

The efforts of the following individuals and entities who contributed to the development of the 2017 *District of Columbia Construction Codes* are gratefully acknowledged.

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ORGANIZATIONS

Apartment and Office Building Association (AOBA); Associated Builders and Contractors, District of Columbia Building Industry Association (DCBIA)

The code development process involved the work of hundreds of people. Every effort was made to include all who participated.

Any errors or omissions in the Acknowledgments are entirely unintended.

TABLE OF CONTENTS

DC ENERGY CONSERVATION CODE—COMMERCIAL PROVISIONS

CONTENTS

ANSI/ASHRAE/IES Standard 90.1-2013,
Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

The original Standard 90.1 was published in 1975, and revised editions were published in 1980, 1989, and 1999 using the ANSI and ASHRAE periodic maintenance procedures. Based upon these procedures, the entire standard was publicly reviewed and published in its entirety each time. As energy prices and technology began changing more rapidly, the ASHRAE Board of Directors voted in 1999 to place the standard on continuous maintenance, permitting the standard to be updated several times each year through the publication of approved addenda to the standard. As of the 2001 edition, the standard is now published in its entirety in the fall of every third year. This schedule allows the standard to be submitted and proposed by the deadline for inclusion or reference in model building and energy codes. All approved addenda and errata are included in the new edition issued every three years. This procedure allows users to have some certainty of the timing of publication of new editions.

The 2013 edition of the standard includes numerous energy-saving measures resulting from continuous maintenance proposals from the public and from volunteers on the committee. The Project Committee welcomes suggestions for improvement, and users are encouraged to use the continuous maintenance proposal (CMP) form included in the back of this standard to submit recommended changes. The committee takes formal action on every CMP received.

More than 110 addenda were processed by the committee and approved by the ASHRAE and IES Boards of Directors and are included in this edition. This edition also corrects all known typographical errors in the 2010 standard. Appendix F gives brief descriptions and publication dates of the addenda to Standard 90.1-2010 that are incorporated into this new edition.

The most significant changes included are as follows:

a. ***Building Envelope.*** *Opaque elements and fenestration requirements have been revised to increase stringency while maintaining a reasonable level of cost-effectiveness. Opaque and fenestration assemblies in Tables 5.5-1 through 5.5-8 are revised in most climates. These changes include*

   1. *criteria requiring double-glazed fenestration in many climates;*
   2. *minimum VT/SHGC ratio to enable good daylighting with minimum solar gain, while not restricting triple and quadruple glazing; and*
   3. *simplification of the skylighting criteria.*

b. ***Lighting.*** *These changes include improvements to daylighting and daylighting controls, space-by-space lighting power density limits, thresholds for toplighting, and revised controls requirements and format.*

c. ***Mechanical.*** *Equipment efficiencies were revised upward for heat pumps, packaged terminal air conditioners (PTAC), single-package vertical heat pumps and air conditioners (SPVHP and SPVAC), and evaporative condensers. Also, fan efficiency requirements were introduced for the first time. Additional provisions that have been included address commercial refrigeration equipment, improved controls on heat rejection and boiler equipment, requirements for expanded use of energy recovery, small motor efficiencies, and fan power control and credits. Control revision requirements were added to the standard, such as DDC controls in many applications. Finally, the 2013 edition completes the work that was begun on equipment efficiencies for chillers in the 2010 edition.*

d. ***Energy Cost Budget (ECB) and Modeling.*** *Improvements were made to the ECB and Appendix G provisions in the standard to clarify the use of the prescriptive provisions when performing building-energy-use modeling. In addition, these sections were revised to enhance capturing daylighting when performing the modeling calculations.*

Another important change for the 2013 edition is the first alternate compliance path in Section 6. Section 6.6 was added to the 2010 edition to provide a location for alternate methods of compliance with the standard. The first such alternate path has been developed for computer room systems and was formulated with the assistance of the data center technical committee (TC9.9). This path uses the PUE (Power Usage Effectiveness) metric that was established by that industry. This alternate efficiency path format provides a framework that could be considered for other energy-using facets of buildings not easily covered in the prescriptive provisions of the standard. Also new to the standard are requirements for operating escalators and moving walkways at minimum speed, per ASME A17.1, when not conveying passengers.

Standard 90.1 is a fluid document. As technology evolves, the project committee is continually considering new changes and proposing addenda for public review. When addenda are approved, notices will be published on the ASHRAE and IES websites. Users are encouraged to sign up for the free ASHRAE and IES Internet listserv for this standard to receive notice of all public reviews and approved and published addenda and errata.

The Chair and Vice-Chairs extend grateful thanks to the committee volunteers, public review commenters, and all involved throughout the open, consensus-building process.

1. PURPOSE

1.1 INTENT. The intent of the *Energy Conservation Code—Commercial Provisions* shall be as defined in Chapter 1 of Title 12-A DCMR.

2. SCOPE

2.1 SCOPE. The scope of the *Energy Conservation Code—Commercial Provisions* shall be as defined in Chapter 1 of Title 12-A DCMR.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 GENERAL. Certain terms, abbreviations, and acronyms are defined in this section solely for the purposes of the *Energy Conservation Code—Commercial Provisions* (the ECC[CE]). These definitions are solely applicable to all sections of the ECC[CE], and not to any other *Construction Codes* as defined in 12-A DCMR Section 101.1. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used.

3.2 DEFINITIONS

above-grade wall: see *wall.*

access hatch: see *door*.

addition: an extension or increase in floor area or height of a building outside of the existing building envelope.

adopting authority: the agency or agent that adopts this standard.

air economizer: see *economizer, air*.

air system balancing: see *balancing, air system*.

airflow, minimum outdoor: the outdoor airflow provided by a ventilation system to meet requirements for indoor air quality, excluding any additional outdoor air intake to reduce or eliminate the need for mechanical cooling.

alteration: a replacement or addition to a building or its systems and equipment; routine maintenance, repair, and service, or a change in the building's use classification or category shall not constitute an alteration.

annual fuel utilization efficiency (AFUE): an efficiency descriptor of the ratio of annual output energy to annual input energy as developed in accordance with the requirements of U.S. Department of Energy (DOE) 10 CFR Part 430.

astronomical time switch: a device that turns the lighting on at a time relative to sunset and off at a time relative to sunrise, accounting for geographic location and day of year.

attic and other roofs: see *roof*.

authority having jurisdiction: the agency or agent responsible for enforcing this standard.

automatic: self-acting, operating by its own mechanism when actuated by some nonmanual influence, such as a change in current strength, pressure, temperature, or mechanical configuration.

automatic control device: a device capable of automatically turning loads off and on without manual intervention.

balancing, air system: adjusting airflow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc., or by using automatic control devices, such as constant-air-volume or variable-air-volume (VAV) boxes.

balancing, hydronic system: adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves or by using automatic control devices, such as automatic flow control valves.

ballast: a device used in conjunction with an electric-discharge lamp to cause the lamp to start and operate under the proper circuit conditions of voltage, current, wave form, electrode heat, etc.

> ***electronic ballast:*** a ballast constructed using electronic circuitry.
>
> ***hybrid ballast:*** a ballast constructed using a combination of magnetic core and insulated wire winding and electronic circuitry.
>
> ***magnetic ballast:*** a ballast constructed with magnetic core and a winding of insulated wire.

baseline building design: a computer representation of a hypothetical design based on the proposed building project. This representation is used as the basis for calculating the baseline building performance for rating above-standard design or when using the performance rating method as an alternative path for minimum standard compliance in accordance with Section 4.2.1.1.

baseline building performance: the annual energy cost for a building design intended for use as a baseline for rating above-standard design or when using the performance rating method as an alternative path for minimum standard compliance in accordance with Section 4.2.1.1.

below-grade wall: see *wall*.

boiler: a self-contained, low-pressure appliance for supplying steam or hot water.

> ***modulating boiler:*** a boiler that is capable of more than a single firing rate in response to a varying temperature or heating load.
>
> ***packaged boiler:*** a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls, and that is usually shipped in one or more sections. A packaged boiler includes factory-built

boilers manufactured as a unit or system, disassembled for shipment, and reassembled at the site.

boiler system: one or more boilers and their piping and controls that work together to supply steam or hot water to heat output devices remote from the boiler.

branch circuit: the circuit conductors between the final overcurrent device protecting the circuit and the outlet(s); the final wiring run to the load.

bubble point: the refrigerant liquid saturation temperature at a specified pressure.

budget building design: a computer representation of a hypothetical design based on the actual proposed building design. This representation is used as the basis for calculating the energy cost budget.

building: a structure wholly or partially enclosed within exterior walls, or within exterior and party walls, and a roof, affording shelter to persons, animals, or property.

building entrance: any doorway, set of doors, revolving door, vestibule, or other form of portal that is ordinarily used to gain access to the building or to exit from the building by its users and occupants. This does not include doors solely used to directly enter mechanical, electrical, and other building utility service equipment rooms.

building envelope: the exterior plus the semi-exterior portions of a building. For the purposes of determining building envelope requirements, the classifications are defined as follows:

exterior building envelope: the elements of a building that separate conditioned spaces from the exterior.

semi-exterior building envelope: the elements of a building that separate conditioned space from unconditioned space or that enclose semiheated spaces through which thermal energy may be transferred to or from the exterior, to or from unconditioned spaces, or to or from conditioned spaces.

building envelope trade-off schedules and loads: the schedules and internal loads[1], by building area type, to be used in the building envelope trade-off option simulations described in Appendix C.

building exit: any doorway, set of doors, or other form of portal that is ordinarily used only for emergency egress or convenience exit.

building grounds lighting: lighting provided through a building's electrical service for parking lot, site, roadway, pedestrian pathway, loading dock, or security applications.

building material: any element of the building envelope, other than air films and insulation, through which heat flows and that is included in the component U-factor calculations.

1. Schedules and internal loads, by building area type, are located at http://sspc901.ashraepcs.org/content.html.

building official: the officer or other designated representative authorized to act on behalf of the authority having jurisdiction.

building project: a building, or group of buildings, and site that utilize a single submittal for a construction permit or that are within the boundary of contiguous properties under single ownership or effective control. Phased development that is permitted over a period of five years for the same building shall be considered a single project.

C-factor: see *thermal conductance*.

circuit breaker: a device designed to open and close a circuit by nonautomatic means and to open the circuit automatically at a predetermined overcurrent without damage to itself when properly applied within its rating.

class of construction: for the building envelope, a subcategory of roof, above-grade wall, below-grade wall, floor, slab-on-grade floor, opaque door, vertical fenestration, or skylight. (See *roof*, *wall*, *floor*, *slab-on-grade floor*, *door*, and *fenestration*.)

classroom: a space primarily used for scheduled instructional activities.

climate zone: see Section 5.1.4.

code official: see *building official*.

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), heat pump—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.

commissioning authority (CxA): an entity identified by the owner who leads, plans, schedules, and coordinates the commissioning team to implement the building *commissioning process*. (See *commissioning (Cx) process*.)

commissioning (Cx) plan: a document that outlines the organization, schedule, allocation of resources, and documentation requirements of the building *commissioning process*. (See *commissioning (Cx) process*.)

commissioning (Cx) process: a quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the *owner's project requirements*. (See *owner's project requirements*.)

computer room: a room whose primary function is to house equipment for the processing and storage of electronic data and that has a design electronic data equipment power density exceeding 20 W/ft^2 of conditioned floor area.

computer room energy: annual energy use of the data center, including all IT equipment energy, plus energy that supports the IT equipment and computer room space, calculated in accordance with industry-accepted standards defined as Total Annual Energy (see Informative Appendix E).

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

conditioned floor area, gross: see *floor area, gross*.

conditioned space: see *space*.

conductance: see *thermal conductance*.

construction: the fabrication and erection of a new building or any addition to or alteration of an existing building.

construction checklist: a form used by the contractor to verify that appropriate components are on site, ready for installation, correctly installed, and functional.

construction documents: drawings and specifications used to construct a building, building systems, or portions thereof.

continuous air barrier: the combination of interconnected materials, assemblies, and sealed joints and components of the building envelope that minimize air leakage into or out of the building envelope.

continuous daylight dimming: method of automatic lighting control using daylight photosensors, where the lights are dimmed continuously, or using at least four preset levels with at least a five-second fade between levels, where the control turns the lights off when sufficient daylight is available.

continuous insulation (c.i.): insulation that is uncompressed and continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope.

control: to regulate the operation of equipment.

control device: a specialized device used to regulate the operation of equipment.

cooldown: reduction of space temperature down to occupied setpoint after a period of shutdown or setup.

cooled space: see *space, conditioned space*.

cooling degree-day, base (CDD): see *degree-day*.

cooling design temperature: the outdoor dry-bulb temperature equal to the temperature that is exceeded by 1% of the number of hours during a typical weather year.

cooling design wet-bulb temperature: the mean coincident outdoor wet-bulb temperature utilized in conjunction with the cooling design dry-bulb temperature, often used for the sizing of cooling systems.

critical circuit: the hydronic circuit that determines the minimum differential pressure that the pump must produce to satisfy the zone loads (e.g., the circuit with the most-open valve). The critical circuit is the one with the highest pressure drop required to satisfy its load. At part-load conditions, the critical circuit can change based on zone loads.

daylight area:

daylight area under roof monitors: the daylight area under roof monitors is the combined daylight area under each roof monitor within each space. The daylight area under each roof monitor is the product of

a. the width of the vertical fenestration above the ceiling level plus, on each side, the smallest of
   1. 2 ft,
   2. the distance to any 5 ft or higher vertical obstruction, or
   3. the distance to the edge of any primary sidelighted area

and

b. the smaller of the following horizontal distances inward from the bottom edge of the vertical fenestration (see Figure 3.2-1):
   1. The monitor sill height (MSH) (the vertical distance from the floor to the bottom edge of the monitor glazing)
   2. The distance to the nearest face of any opaque vertical obstruction, where any part of the obstruction is farther away than the difference between the height of the obstruction and the monitor sill height (MSH – OH).

daylight area under skylights: the daylight area under skylights is the combined daylight area under each skylight within a space. The daylight area under each skylight is bounded by the opening beneath the skylight and horizontally in each direction (see Figure 3.2-2), the smaller of

a. 70% of the ceiling height (0.7 × CH), or
b. the distance to the nearest face of any opaque vertical obstruction, where any part of the obstruction is farther away than 70% of the distance between the top of the obstruction and the ceiling (0.7 × [CH – OH], where CH = the height of the ceiling at the lowest edge of the skylight and OH = the height to the top of the obstruction).

sidelighted area: Each sidelighted area is directly adjacent to vertical fenestration below the ceiling.

a. The sidelighted area width is the width of the vertical fenestration plus, on each side, the smaller of:
   1. 3 ft, or
   2. the distance to any 5 ft or higher opaque vertical obstruction.

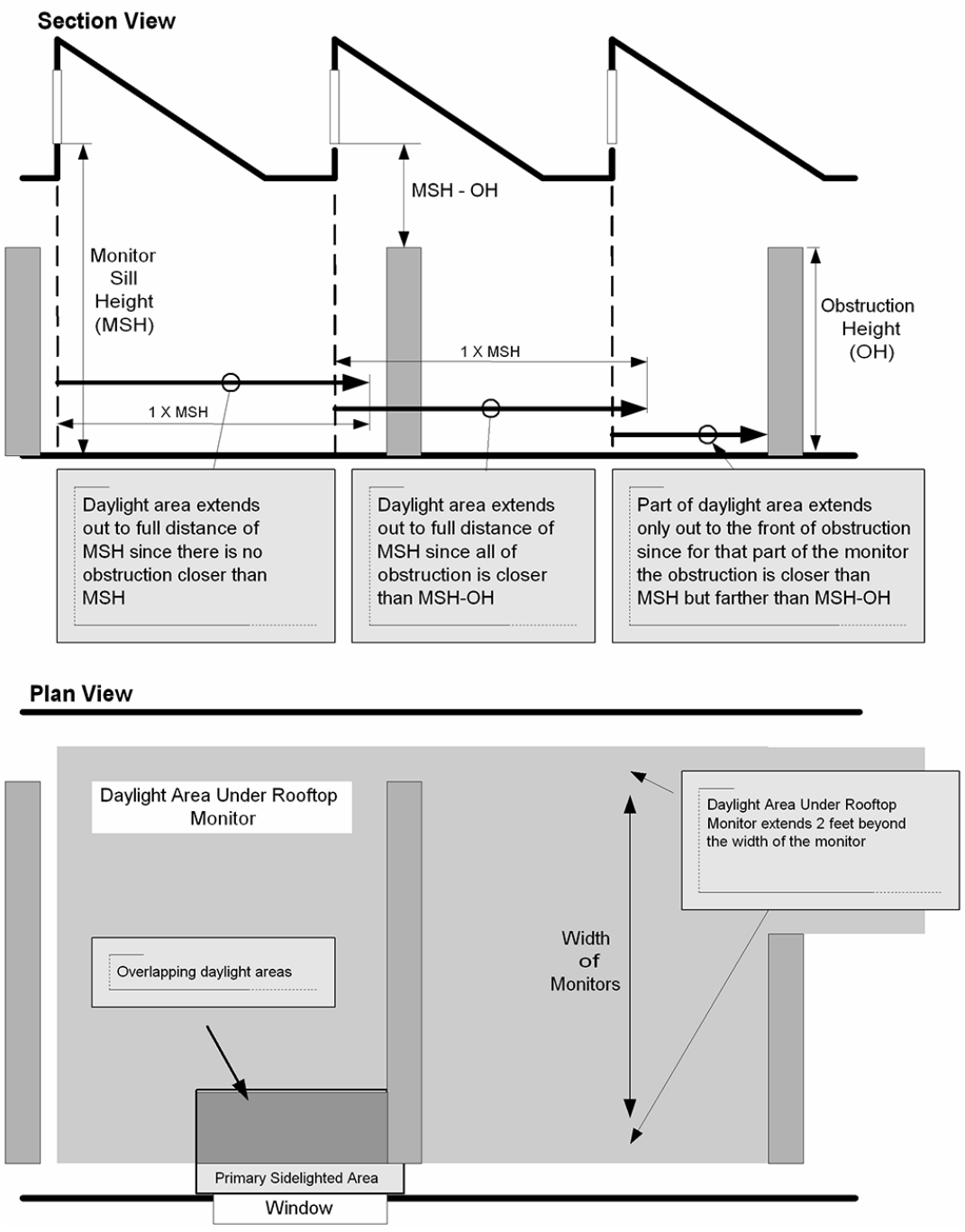


Figure 3.2-1. Computing the daylight area under roof monitors.

b. The sidelighted area depth is the horizontal distance perpendicular to the vertical fenestration which is the smaller of:

   1. 15 ft, or
   2. the distance to any 5 ft or higher opaque vertical obstruction.

daylight hours: the period from 30 minutes after sunrise to 30 minutes before sunset.

daylighted area: the floor area substantially illuminated by daylight.

dead band: the range of values within which a sensed variable can vary without initiating a change in the controlled process.

decorative lighting: see *lighting, decorative*.

dedicated replacement air: see *makeup air*.

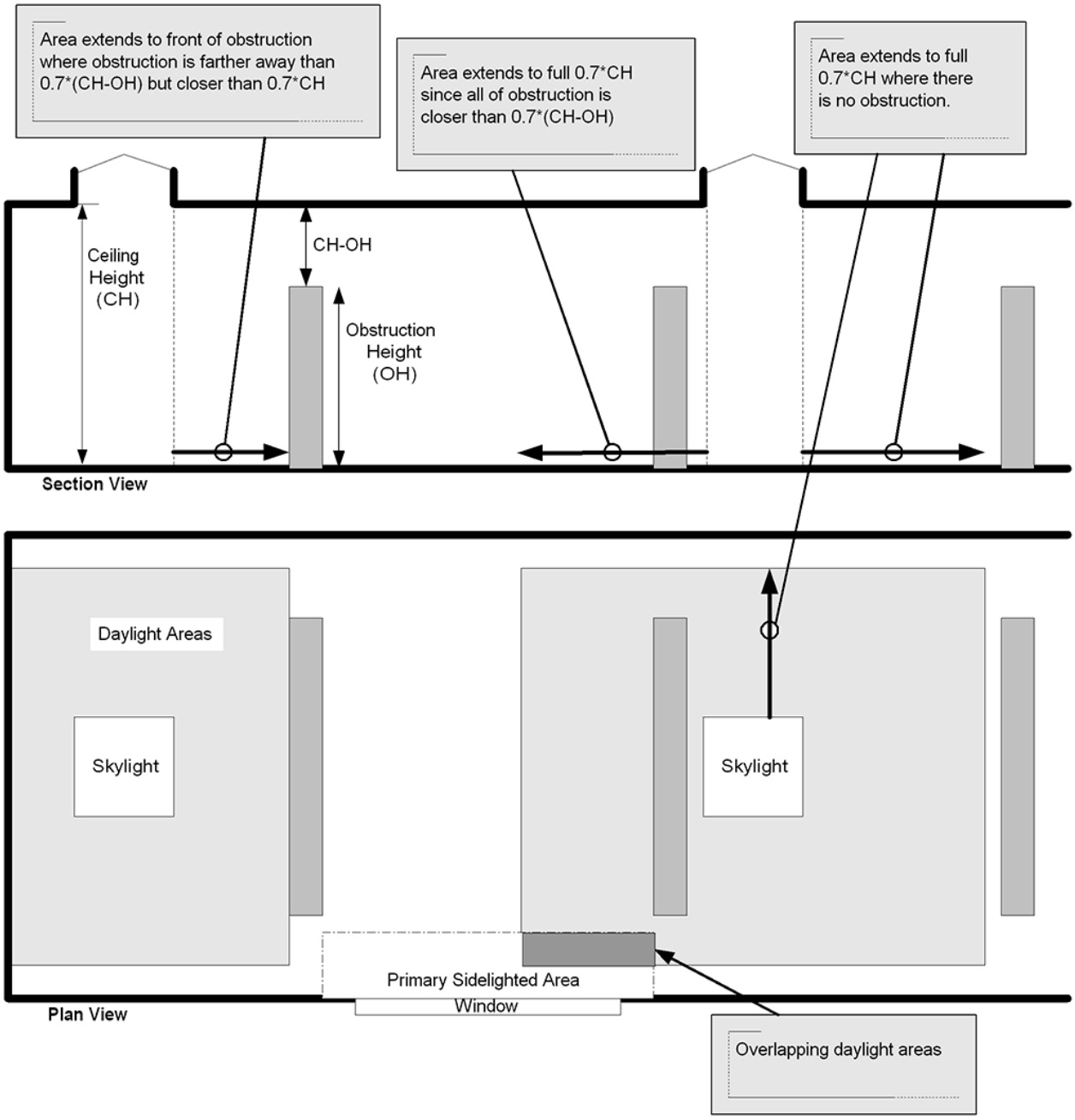


Figure 3.2-2. Computing the daylight area under skylights.

degree-day: the difference in temperature between the outdoor mean temperature over a twenty-four-hour period and a given base temperature. For the purposes of determining building envelope requirements, the classifications are defined as follows:

cooling degree-day base 50°F (CDD50): for any one day, when the mean temperature is more than 50°F, there are as many degree-days as degrees Fahrenheit temperature difference between the mean temperature for the day and 50°F. Annual cooling degree-days (CDDs) are the sum of the degree-days over a calendar year.

heating degree-day base 65°F (HDD65): for any one day, when the mean temperature is less than 65°F, there are as many degree-days as degrees Fahrenheit temperature difference between the mean temperature for the day and 65°F. Annual heating degree-days (HDDs) are the sum of the degree-days over a calendar year.

demand: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

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.

densely occupied space: those spaces with a design occupant density greater than or equal to 25 people per 1000 ft^2 (100 m^2).

design capacity: output capacity of a system or piece of equipment at design conditions.

design conditions: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate.

design energy cost: the annual energy cost calculated for a proposed design.

design professional: an architect or engineer licensed to practice in accordance with applicable state licensing laws.

direct digital control (DDC): a type of control where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices.

disconnect: a device or group of devices or other means by which the conductors of a circuit can be disconnected from their source of supply.

distribution system: conveying means, such as ducts, pipes, and wires, to bring substances or energy from a source to the point of use. The distribution system includes such auxiliary equipment as fans, pumps, and transformers.

door (access hatch): all operable opening areas (that are not fenestration) in the building envelope, including swinging and roll-up doors, fire doors, and access hatches. Doors that are more than one-half glass are considered fenestration (see fenestration). For the purposes of determining building envelope requirements, the classifications are defined as follows:

> ***metal coiling door:*** an upward-acting, nonswinging door assembly consisting of interlocking horizontal slats or sheets that, upon opening the door, roll up around a horizontal barrel above the door opening.
>
> ***nonswinging door:*** roll-up, metal coiling, sliding, and all other doors that are not swinging doors.
>
> ***swinging door:*** all operable opaque panels with hinges on one side and opaque revolving doors.

door area: total area of the door measured using the rough opening and including the door slab and the frame. (See *fenestration area*.)

ductwork: a system of ducts for distribution and extraction of air.

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 glazing system/glazing infill that has the fully reversible ability to change its performance properties, including U-factor, solar heat gain coefficient, or visible transmittance. This includes, but is not limited to, shading systems between the glazing layers and chromogenic glazing.

economizer, air: a duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

economizer, water: a system by which 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.

effective panel surface: see *thermally effective panel surface*.

efficacy (of a lamp): the ratio of the total luminous output of a lamp to the total power input to the lamp, typically expressed in lm/W.

efficiency: performance at specified rating conditions.

electric resistance: see *resistance, electric*.

electronics: computers and accessories; monitors; printers; and other equipment, such as scanners, fax machines, electric typewriters, cell phones, telephones, answering machines, shredders, postage machines, televisions, VHS/DVD players, portable cassette/CD players with radio devices, and stereo equipment.

emittance: the ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

enclosed space: a volume substantially surrounded by solid surfaces, such as walls, floors, roofs, and openable devices, such as doors and operable windows.

energy: the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical (Btu).

energy cost budget: the annual energy cost for the budget building design intended for use in determining minimum compliance with this standard.

energy efficiency ratio (EER): the ratio of net cooling capacity (Btu/h) to total rate of electric input in watts under designated operating conditions. (See coefficient of performance [COP]—cooling.)

energy factor (EF): a measure of water heater overall efficiency.

entrance door: see *fenestration*.

envelope performance factor: the trade-off value for the building envelope performance compliance option calculated using the procedures specified in Section 5. For the purposes of determining building envelope requirements, the classifications are defined as follows:

base envelope performance factor: the building envelope performance factor for the base design.

proposed envelope performance factor: the building envelope performance factor for the proposed design.

equipment: devices for comfort conditioning, electric power, lighting, transportation, or service water heating, including but not limited to furnaces, boilers, air conditioners, heat pumps, chillers, water heaters, lamps, luminaires, ballasts, elevators, escalators, or other devices or installations.

essential facility: those portions of a building serving one of the following functions:

a. Hospitals and other health care facilities having surgery or emergency treatment facilities

b. Fire, rescue, and police stations and emergency vehicle garages

c. Designated earthquake, hurricane, or other emergency shelters

d. Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response

e. Power-generating stations and other public utility facilities required as emergency backup facilities for other essential facilities

f. Structures containing highly toxic materials where the quantity of the material exceeds the maximum allowable quantities

g. Aviation control towers, air traffic control centers, and emergency aircraft hangars

h. Buildings and other structures having critical national defense functions

evaporation design wet-bulb temperature: the outdoor wet-bulb temperature utilized in conjunction with the mean coincident dry-bulb temperature, often used for the sizing of evaporative systems such as cooling towers.

existing building: a building or portion thereof that was previously occupied or approved for occupancy by the authority having jurisdiction.

existing equipment: equipment previously installed in an existing building.

existing system: a system or systems previously installed in an existing building.

exterior building envelope: see *building envelope*.

exterior lighting power allowance: see *lighting power allowance, exterior*.

eye adaptation: the process by which the retina becomes accustomed to more or less light than it was exposed to during an immediately preceding period. It results in a change in the sensitivity to light.

F-factor: the perimeter heat loss factor for slab-on-grade floors (Btu/h·ft·°F).

façade area: area of the façade, including overhanging soffits, cornices, and protruding columns, measured in elevation in a vertical plane parallel to the plane of the face of the building. Nonhorizontal roof surfaces shall be included in the calculation of vertical façade area by measuring the area in a plane parallel to the surface.

fan brake horsepower (bhp): the horsepower delivered to the fan's shaft. Brake horsepower does not include the mechanical drive losses (belts, gears, etc.).

fan efficiency grade (FEG): the fan efficiency without consideration of drives, as defined in AMCA 205.

fan system brake horsepower (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 airflow rate to conditioned spaces served by the system.

fan system motor nameplate horsepower (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.

feeder conductors: the wires that connect the service equipment to the branch circuit breaker panels.

fenestration: all areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, roof monitors, skylights, doors that are more than one-half glass, and glass block walls. (See *building envelope and door*.)

field-fabricated fenestration: fenestration whose frame is made at the construction site of materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior glazed door. Field-fabricated fenestration does not include site-built fenestration designed to be glazed or assembled in the field using specific factory-cut or otherwise factory-formed framing and glazing units, such as storefront systems, curtain walls, and atrium roof systems.

skylight: a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenes-

tration, even if mounted on the roof of a building, is considered vertical fenestration.

vertical fenestration: all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 12 in. of a mass wall, are considered walls, not fenestration.

fenestration area: total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area. (See *door area*.)

fixed: see *vertical fenestration*.

fixture: the component of a luminaire that houses the lamp or lamps or positions the lamp, shields it from view, and distributes the light. The fixture also provides for connection to the power supply, which may require the use of a ballast.

floor: that lower portion of the building envelope, including opaque area and fenestration, that has conditioned or semiheated space above and is horizontal or tilted at an angle of less than 60 degrees from horizontal but excluding slab-on-grade floors. For the purposes of determining building envelope requirements, the classifications are defined as follows:

mass floor: a floor with a heat capacity that exceeds (1) 7 Btu/ft^2·°F or (2) 5 Btu/ft^2·°F, provided that the floor has a material unit mass not greater than 120 lb/ft^3.

steel-joist floor: a floor that (1) is not a mass floor and (2) has steel joist members supported by structural members.

wood-framed and other floors: all other floor types, including wood-joist floors.

(See *building envelope*, *fenestration*, *opaque*, and *slab-on-grade floor*).

floor area, gross: the sum of the floor areas of the spaces within the building, including basements, mezzanine and intermediate-floored tiers, and penthouses with a headroom height of 7.5 ft or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

gross building envelope floor area: the gross floor area of the building envelope, but excluding slab-on-grade floors.

gross conditioned floor area: the gross floor area of conditioned spaces.

gross lighted floor area: the gross floor area of lighted spaces.

gross semiheated floor area: the gross floor area of semiheated spaces.

(See *building envelope*, *floor*, *slab-on-grade floor*, and *space*.)

flue damper: a device in the flue outlet or in the inlet of or upstream of the draft control device of an individual, automatically operated, fossil-fuel-fired appliance that is designed to automatically open the flue outlet during appliance operation and to automatically close the flue outlet when the appliance is in a standby condition.

fuel: a material that may be used to produce heat or generate power by combustion.

fossil fuel: fuel derived from a hydrocarbon deposit such as petroleum, coal, or natural gas derived from living matter of a previous geologic time.

general lighting: see *lighting, general*.

general purpose electric motor (subtype I): a general purpose electric motor that

a. is a single-speed induction motor;

b. is rated for continuous duty (MG1) operation or for duty type SI (IEC);

c. contains a squirrel-cage (MG1) or cage (IEC) rotor;

d. has foot-mounting that may include foot-mounting with flanges or detachable feet;

e. is built in accordance with NEMA T-frame dimensions or their IEC metric equivalents, including a frame size that is between two consecutive NEMA frame sizes or their IEC metric equivalents;

f. has performance in accordance with NEMA Design A (MG1) or B (MG1) characteristics, or equivalent designs, such as IEC Design N (IEC);

g. operates on polyphase alternating current 60 Hz sinusoidal power and

   1. is rated at 230 or 460 V (or both), including motors rated at multiple voltages that include 230 or 460 V (or both) or

   2. can be operated on 230 or 460 V (or both); and

h. includes, but is not limited to, explosion-proof construction.

general purpose electric motor (subtype II): any general purpose electric motor that incorporates the design elements of a general purpose electric motor (subtype I) and that is configured in one or more of the following ways:

a. Is built in accordance with NEMA U-frame dimensions, as described in NEMA MG-1-1967, or in accordance with the IEC metric equivalents, including a frame size that is between two consecutive NEMA frame sizes or their IEC metric equivalents

b. Has performance in accordance with NEMA Design C characteristics, as described in MG1, or an equivalent IEC design(s) such as IEC Design H

c. Is a close-coupled pump motor

d. Is a footless motor

e. Is a vertical, solid-shaft normal thrust motor (as tested in a horizontal configuration) built and designed in a manner consistent with MG1

f. Is an 8-pole motor (900 rpm)

g. Is a polyphase motor with voltage rating of not more than 600 V, is not rated at 230 or 460 V (or both), and cannot be operated on 230 or 460 V (or both)

generally accepted engineering standard: a specification, rule, guide, or procedure in the field of engineering, or related thereto, recognized and accepted as authoritative.

geothermal energy: heat extracted from the Earth's interior and used to produce electricity or mechanical power or provide thermal energy for heating buildings or processes. *Geothermal energy* does not include systems such as heat pumps that use energy independent of the geothermal source to raise the temperature of the extracted heat.

grade: the finished ground level adjoining a building at all exterior walls.

gross floor area: see *floor area, gross*.

gross lighted area (GLA): see *floor area, gross*.

gross roof area: see roof *area, gross*.

gross wall area: see *wall area, gross*.

growth media: an engineered formulation of inorganic and organic materials including but not limited to heat-expanded clays, slates, shales, aggregate, sand, perlite, vermiculite, and organic material including but not limited to compost worm castings, coir, peat, and other organic material.

heat capacity (HC): the amount of heat necessary to raise the temperature of a given mass 1°F. Numerically, the HC per unit area of surface (Btu/ft^2·°F) is the sum of the products of the mass per unit area of each individual material in the roof, wall, or floor surface multiplied by its individual specific heat.

heat trace: a heating system where the externally applied heat source follows (traces) the object to be heated (e.g., water piping).

heated space: see *space*.

heating degree-day, base: see *degree-day*.

heating design temperature: the outdoor dry-bulb temperature equal to the temperature that is exceeded at least 99.6% of the number of hours during a typical weather year.

heating seasonal performance factor (HSPF): the total heating output of a heat pump during its normal annual usage period for heating (Btu) divided by the total electric energy input during the same period.

high efficacy lamps: *LEDs, compact fluorescent lamps, T-5 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.*

high-frequency electronic ballast: ballasts that operate at a frequency greater than 20 kHz.

high-speed door: a non-swinging door used primarily to facilitate vehicular access or material transportation, and having an automatic closing device with an opening rate of not less than 32 in/s (810 mm/s) and a closing rate of not less than 24 in/s (610 mm/s).

historic: a building or space that has been specifically designated as historically significant by the adopting authority, or is listed in The National Register of Historic Places or has been determined to be eligible for such listing by the U.S. Secretary of the Interior.

hot-water supply boiler: a boiler used to heat water for purposes other than space heating.

humidistat: an automatic control device used to maintain humidity at a fixed or adjustable setpoint.

HVAC system: the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating, or air conditioning to a building or portion of a building.

HVAC zone: a space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor).

hydronic system balancing: see *balancing, hydronic system*.

indirectly conditioned space: see *space*.

ineffective panel surface: see *thermally ineffective panel surface*.

infiltration: the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between supply and exhaust air systems.

installed exterior lighting power: the power in watts of all site, landscape, and building lighting systems for exterior luminaires.

installed interior lighting power: the power in watts of all general, task, and furniture lighting systems for interior luminaires.

integrated energy efficiency ratio (IEER): a single-number figure of merit expressing cooling part-load EER efficiency for commercial unitary air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

integrated part-load value (IPLV): a single-number figure of merit based on part-load EER, COP, or kW/kW expressing part-load efficiency for air-conditioning and heat-pump equipment on the basis of weighted operation at various load capacities for the equipment.

interior lighting power allowance: see *lighting power allowance*.

isolation devices: devices that isolate HVAC zones so that they can be operated independently of one another. Isolation devices include, but are not limited to, separate systems, isolation dampers, and controls providing shutoff at terminal boxes.

IT equipment energy: annual energy used for computer storage and network equipment along with supplemental equipment represented by the uninterruptible power supply (UPS) output calculated in accordance with industry-accepted standards (see Informative Appendix E).

joist, steel: any structural steel member of a building or structure made of hot-rolled or cold-rolled solid or open-web sections.

kilovolt-ampere (kVA): where the term *kilovolt-ampere* is used in this standard, it is the product of the line current (amperes) times the nominal system voltage (kilovolts) times 1.732 for three-phase currents. For single-phase applications, kVA is the product of the line current (amperes) times the nominal system voltage (kilovolts).

kilowatt (kW): the basic unit of electric power, equal to 1000 W.

labeled: equipment or materials to which a symbol or other identifying mark has been attached by the manufacturer indicating compliance with specified standards or performance in a specified manner.

lamp: a generic term for a man-made light source often called a bulb or tube.

> ***compact fluorescent lamp:*** a fluorescent lamp of a small compact shape, with a single base that provides the entire mechanical support function.
>
> ***fluorescent lamp:*** a low-pressure electric discharge lamp in which a phosphor coating transforms some of the ultraviolet energy generated by the discharge into light.
>
> ***general service lamp:*** a class of incandescent lamps that provide light in virtually all directions. General service lamps are typically characterized by bulb shapes such as "A," standard; "S," straight side; "F," flame; "G," globe; and "PS," pear straight.
>
> ***high-intensity discharge (HID) lamp:*** an electric discharge lamp in which light is produced when an electric arc is discharged through a vaporized metal such as mercury or sodium. Some HID lamps may also have a phosphor coating that contributes to the light produced or enhances the light color.
>
> ***incandescent lamp:*** a lamp in which light is produced by a filament heated to incandescence by an electric current.
>
> ***reflector lamp:*** a class of incandescent lamps that have an internal reflector to direct the light. Reflector lamps are typically characterized by reflective characteristics such as "R," reflector; "ER," ellipsoidal reflector; "PAR," parabolic aluminized reflector; "MR," mirrorized reflector; and others.

light-to-solar gain ratio (LSG): the ratio of the center-of-glass visible transmittance to the center-of-glass solar heat gain coefficient.

lighting, decorative: lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting.

lighting, general: 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.

lighting power allowance, exterior: the maximum lighting power in watts allowed for the exterior of a building.

lighting power allowance, interior: the maximum lighting power in watts allowed for the interior of a building.

lighting power density (LPD): the maximum lighting power per unit area of a building classification of space function.

lighting system: a group of luminaires circuited or controlled to perform a specific function.

lighting zone (LZ): an area defining limitations for outdoor lighting.

> ***LZ0:*** undeveloped areas within national parks, state parks, *forest land*, rural areas, and other undeveloped areas as defined by the *AHJ*.
>
> ***LZ1:*** developed areas of national parks, state parks, *forest land*, and rural areas.
>
> ***LZ2:*** areas predominantly consisting of *residential* zoning, neighborhood business districts, light industrial with limited night time use, and *residential* mixed-use areas.
>
> ***LZ3:*** all areas not included in *LZ0*, *LZ1*, *LZ2*, or *LZ4*.
>
> ***LZ4:*** high-activity commercial districts in major metropolitan areas as designated by the local jurisdiction.

liner system (Ls): a continuous vapor barrier liner installed below the purlins and uninterrupted by framing members.

low-rise residential buildings: single-family houses, multifamily structures of three stories or fewer above grade, manu-

factured houses (mobile homes), and manufactured houses (modular).

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

makeup air (dedicated replacement air): outdoor air deliberately brought into the building from the outside and supplied to the vicinity of an exhaust hood to replace air, vapor, and contaminants being exhausted. Makeup air is generally filtered and fan-forced, and it may be heated or cooled depending on the requirements of the application. Makeup air may be delivered through outlets integral to the exhaust hood or through outlets in the same room.

manual (nonautomatic): requiring personal intervention for control. Nonautomatic does not necessarily imply a manual controller, only that personal intervention is necessary. (See *automatic*.)

manufacturer: the company engaged in the original production and assembly of products or equipment or a company that purchases such products and equipment manufactured in accordance with company specifications.

mass floor: see *floor*.

mass wall: see *wall*.

mean temperature: one-half the sum of the minimum daily temperature and maximum daily temperature.

mechanical cooling: reducing the temperature of a gas or liquid by using vapor compression, absorption, desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic cycle. Indirect or direct evaporative cooling alone is not considered mechanical cooling.

mechanical heating: raising the temperature of a gas or liquid by use of fossil fuel burners, electric resistance heaters, heat pumps, or other systems that require energy to operate.

metal building: a complete integrated set of mutually dependent components and assemblies that form a building, which consists of a steel-framed superstructure and metal skin.

metal building roof: see *roof.*

metal building wall: see *wall.*

metering: instruments that measure electric voltage, current, power, etc.

motor power, rated: the rated output power from the motor.

multilevel occupancy sensor: an occupancy sensor having an automatic OFF function that turns off all the lights, and either an automatic or a manually controlled ON function capable of activating between 30% and 70% of the lighting power. After that event occurs, the device shall be capable of all of the following actions when manually called to do so by the occupant:

a. Activating alternate sets of lights

b. Activating 100% of the lighting power

c. Deactivating all lights

multiscene control: a lighting control device or system that allows for two or more predefined lighting settings, in addition to all off, for two or more groups of luminaires to suit multiple activities in the space, and allows the automatic recall of those settings.

nameplate horsepower (hp): the nominal motor horsepower rating stamped on the motor nameplate.

nameplate rating: the design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

networked guest-room control system: an energy management control system, accessible from the hotel/motel front desk or other central location, that is capable of identifying reserved rooms according to a timed schedule and is capable of controlling each hotel/motel guest room separately.

nonautomatic: see *manual*.

nonrecirculating system: a domestic or service hot-water distribution system that is not a recirculating system.

nonrenewable energy: energy derived from a fossil fuel source.

nonresidential: all occupancies other than residential. (See *residential*.)

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 AHRI standard rating conditions.

nonswinging door: see *door*.

nonweatherized space constrained single-package vertical unit: a single-package vertical air conditioner (SPVAC) or single-package vertical heat pump (SPVHP) that meets all of the following requirements:

a. Is for indoor use only

b. Has rated cooling capacities no greater than 36,000 Btu/h

c. Is a single-package unit requiring opening in an exterior wall with overall exterior dimensions that requires or uses an existing sleeve that meets one of the following criteria:

   1. Has a width of less than 32 in. and height of less than 45 in.

   2. Fits inside an existing 1310 $in.^2$ opening

d. Is commonly installed in site-built commercial buildings

e. Is of a similar cooling capacity and, if a heat pump, similar heating capacity

f. Draws outdoor air for heat exchange directly through an existing opening, used for both inlet and outlet, in the exterior wall

g. Is restricted to applications where an existing air conditioner, heat pump, or gas/electric unit, installed in an existing exterior wall opening, is to be replaced

h. Bears a permanent "Replacement" marking, conspicuously placed, and clearly indicating that its application is limited to installations where an existing air conditioner or heat pump is to be replaced

north-oriented: facing within 45 degrees of true north in the northern hemisphere (however, facing within 45 degrees of true south in the southern hemisphere).

occupant sensor: a device that detects the presence or absence of people within an area and causes lighting, equipment, or appliances to be regulated accordingly.

on-site renewable energy: energy generated from renewable sources produced at the building site.

on-site renewable energy system: photovoltaic, solar thermal, geothermal energy, biogas, wastewater thermal and wind systems used to generate energy and located on the *building project*.

opaque: all areas in the building envelope, except fenestration and building service openings such as vents and grilles. (See *building envelope* and *fenestration*.)

operable: see *vertical fenestration*.

optimum start controls: controls that are designed to automatically adjust the start time of an HVAC system each day with the intention of bringing the space to desired occupied temperature levels immediately before scheduled occupancy.

orientation: the direction an envelope element faces, i.e., the direction of a vector perpendicular to and pointing away from the surface outside of the element.

outdoor (outside) air: air that is outside the building envelope or is taken from outside the building that has not been previously circulated through the building.

overcurrent: any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

owner: as term is defined in Section 202, Title 12-A DCMR.

owner's project requirements (OPR): a written document that details the functional requirements of a project and the expectations of how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

packaged terminal air conditioner (PTAC): a factory-selected wall sleeve and separate unencased combination of heating and cooling components, assemblies, or sections. It may include heating capability by hot water, steam, or electricity and is intended for mounting through the wall to serve a single room or zone.

packaged terminal heat pump (PTHP): a PTAC capable of using the refrigerating system in a reverse cycle or heat pump mode to provide heat.

party wall: a fire wall on an interior lot line used or adapted for joint service between two buildings.

performance rating method: a calculation procedure that generates an index of merit for the performance of building designs that substantially exceeds the energy efficiency levels required by this standard or when using the performance rating method as an alternative path for minimum standard compliance in accordance with Section 4.2.1.1.

permanently installed: equipment that is fixed in place and is not portable or movable.

photosensor: a device that detects the presence of visible light, infrared (IR) transmission, and/or ultraviolet (UV) energy.

piping: the pipes or tubes interconnecting the various parts of a fluid distribution system, including all elements that are in series with the fluid flow, such as pumps, valves, strainers, and air separators, but not including elements that are not in series with the fluid flow, such as expansion tanks, fill lines, chemical feeders, and drains.

plenum: a compartment or chamber to which one or more ducts are connected, that forms a part of the air distribution system, and that is not used for occupancy or storage. A plenum often is formed in part or in total by portions of the building.

pool: any structure, basin, or tank containing an artificial body of water for swimming, diving, or recreational bathing. The term includes, but is not limited to, swimming pool, whirlpool, spa, and hot tub.

power roof/wall ventilators (PRV): a fan consisting of a centrifugal or axial impeller with an integral driver in a weather-resistant housing and with a base designed to fit, usually by means of a curb, over a wall or roof opening.

power usage effectiveness (PUE): computer room energy divided by IT equipment energy calculated in accordance with industry-accepted standards (see Informative Appendix E).

power usage effectiveness—category 0 (PUE_0): peak electric demand (kW) for the entire computer room, including IT equipment and supporting infrastructure, divided by peak electric demand (kW) of the IT equipment.

power usage effectiveness—category 1 (PUE_1): annual energy consumption (kWh) for the entire computer room, including IT equipment and supporting infrastructure, divided by annual energy consumption (kWh) of the IT equipment.

process energy: energy consumed in support of a manufacturing, industrial, or commercial process other than condi-

tioning spaces and maintaining comfort and amenities for the occupants of a building.

process load: the load on a building resulting from the consumption or release of process energy.

projection factor (PF): the ratio of the horizontal depth of the external shading projection divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.

proposed building performance: the annual energy cost calculated for a proposed design.

proposed design: a computer representation of the actual proposed building design, or portion thereof, used as the basis for calculating the design energy cost.

public facility restroom: a restroom used by the transient public.

pump system power: the sum of the nominal power demand (nameplate horsepower) of motors of all pumps that are required to operate at design conditions to supply fluid from the heating or cooling source to all heat transfer devices (e.g., coils, heat exchanger) and return it to the source.

purchased energy: energy or power purchased for consumption and delivered to the building site.

purchased energy rates: costs for units of energy or power purchased at the building site. These costs may include energy costs as well as costs for power demand as determined by the adopting authority.

R-value: see *thermal resistance*.

radiant heating system: a heating system that transfers heat to objects and surfaces within the heated space primarily (greater than 50%) by infrared radiation.

rated motor power: see motor power, rated.

rated R-value of insulation: the thermal resistance of the insulation alone as specified by the manufacturer in units of $h \cdot ft^2 \cdot °F/Btu$ at a mean temperature of 75°F. Rated R-value refers to the thermal resistance of the added insulation in framing cavities or insulated sheathing only and does not include the thermal resistance of other building materials or air films. (See thermal resistance.)

rating authority: the organization, building official, or agency that adopts, enforces, or sanctions use of this rating methodology.

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, chairs, etc. In public facilities, accessibility may be limited to certified personnel through locking covers or by placing equipment in locked rooms.

recirculating system: a domestic or service hot-water distribution system that includes a closed circulation circuit designed to maintain usage temperatures in hot-water pipes near terminal devices (e.g., lavatory faucets, shower heads) in order to reduce the time required to obtain hot water when the terminal device valve is opened. The motive force for circulation is either natural (due to water density variations with temperature) or mechanical (recirculation pump).

recooling: lowering the temperature of air that has been previously heated by a mechanical heating system.

record drawings: drawings that record the conditions of the project as constructed. These include any refinements of the construction or bid documents.

reflectance: the ratio of the light reflected by a surface to the light incident upon it.

refrigeration system, low-temperature: systems for maintaining food products in their frozen state in refrigeration applications.

refrigeration systems, medium-temperature: systems for maintaining food products above their frozen state in refrigeration applications.

refrigerant dew point: the refrigerant vapor saturation temperature at a specified pressure.

reheating: raising the temperature of air that has been previously cooled either by mechanical refrigeration or an economizer system.

repair: the reconstruction or renewal of any part of an existing building for the purpose of its maintenance.

replacement air: outdoor air that is used to replace air removed from a building through an exhaust system. Replacement air may be derived from one or more of the following: makeup air, supply air, transfer air, and infiltration. However, the ultimate source of all replacement air is outdoor air. When replacement air exceeds exhaust, the result is exfiltration.

reset: automatic adjustment of the controller setpoint to a higher or lower value.

residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.

resistance, electric: the property of an electric circuit or of any object used as part of an electric circuit that determines for a given circuit the rate at which electric energy is converted into heat or radiant energy and that has a value such that the product of the resistance and the square of the current gives the rate of conversion of energy.

roof: the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60 degrees from horizontal. For the pur-

poses of determining building envelope requirements, the classifications are defined as follows:

attic and other roofs: all other roofs, including roofs with insulation entirely below (inside of) the roof structure (i.e., attics, cathedral ceilings, and single-rafter ceilings), roofs with insulation both above and below the roof structure, and roofs without insulation but excluding metal building roofs.

metal building roof: a roof that

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

roof with insulation entirely above deck: a roof with all insulation

a. installed above (outside of) the roof structure and
b. continuous (i.e., uninterrupted by framing members).

single-rafter roof: a subcategory of attic roofs where the roof above and the ceiling below are both attached to the same wood rafter and where insulation is located in the space between these wood rafters.

roof area, gross: the area of the roof measured from the exterior faces of walls or from the centerline of party walls. (See roof and wall.)

roof covering: the topmost component of the roof assembly intended for weather resistance, fire classification, or appearance.

roof recovering: the process of installing an additional roof covering over an existing roof covering without removing the existing roof covering.

roof monitor: that part of a building that projects above the plane of the roof and whose walls contain vertical fenestration for lighting the interior.

room air conditioner: an encased assembly designed as a unit to be mounted in a window or through a wall or as a console. It is designed primarily to provide direct delivery of conditioned air to an enclosed space, room, or zone. It includes a prime source of refrigeration for cooling and dehumidification and a means for circulating and cleaning air. It may also include a means for ventilating and heating.

room cavity ratio (RCR): a factor that characterizes room configuration as a ratio between the walls and ceiling and is based upon room dimensions.

saturated condensing temperature: the saturation temperature corresponding to the measured refrigerant pressure at the condenser inlet for single component and azeotropic refrigerants, and the arithmetic average of the dew-point and bubble-point temperatures corresponding to the refrigerant pressure at the condenser entrance for zeotropic refrigerants.

seal class A: a ductwork sealing category that requires sealing all transverse joints, longitudinal seams, and duct wall penetrations. Duct wall penetrations are openings made by pipes, holes, conduit, tie rods, or wires. Longitudinal seams are joints oriented in the direction of airflow. Transverse joints are connections of two duct sections oriented perpendicular to airflow.

seasonal coefficient of performance—cooling (SCOPC): the total cooling output of an air conditioner during its normal annual usage period for cooling divided by the total electric energy input during the same period in consistent units (analogous to SEER but in I-P or other consistent units).

seasonal coefficient of performance—heating (SCOPH): the total heating output of a heat pump during its normal annual usage period for heating divided by the total electric energy input during the same period in consistent units (analogous to HSPF but in I-P or other consistent units).

seasonal energy efficiency ratio (SEER): the total cooling output of an air conditioner during its normal annual usage period for cooling (Btu) divided by the total electric energy input during the same period (Btu).

sectional garage door: an upward-acting, nonswinging door assembly made of two or more horizontal panels hinged together vertically.

semi-exterior building envelope: see *building envelope*.

semiheated floor area: see *floor area, gross*.

semiheated space: see *space*.

sensible cooling panel: a panel designed for sensible cooling of an indoor space through heat transfer to the thermally effective panel surfaces from the occupants and/or indoor space by thermal radiation and natural convection.

sensible heating panel: a panel designed for sensible heating of an indoor space through heat transfer from the thermally effective panel surfaces to the occupants and/or indoor space by thermal radiation and natural convection.

sensible recovery effectiveness: change in the dry-bulb temperature of the outdoor air supply divided by the difference between the outdoor air and return air dry-bulb temperatures, expressed as a percentage.

service: the equipment for delivering energy from the supply or distribution system to the premises served.

service agency: an agency capable of providing calibration, testing, or manufacture of equipment, instrumentation, metering, or control apparatus, such as a contractor, laboratory, or manufacturer.

service equipment: the necessary equipment, usually consisting of a circuit breaker or switch and fuses and accessories, located near the point of entrance of supply conductors to a building or other structure (or an otherwise defined area) and intended to constitute the main control and means of cutoff of the supply. Service equipment may consist of circuit breakers or fused switches provided to disconnect all under-grounded conductors in a building or other structure from the service-entrance conductors.

service water heating: heating water for domestic or commercial purposes other than space heating and process requirements.

setback: reduction of heating (by reducing the setpoint) or cooling (by increasing the setpoint) during hours when a building is unoccupied or during periods when lesser demand is acceptable.

setpoint: point at which the desired temperature (°F) of the heated or cooled space is set.

SHGC: see *solar heat gain coefficient*.

shading coefficient (SC): the ratio of solar heat gain at normal incidence through glazing to that occurring through 1/8 in.-thick clear, double-strength glass. SC does not include interior, exterior, or integral shading devices.

simulation program: a computer program that is capable of simulating the energy performance of building systems.

single-line diagram: a simplified schematic drawing that shows the connection between two or more items. Common multiple connections are shown as one line.

single-package vertical air conditioner (SPVAC): a type of air-cooled small or large commercial package air-conditioning and heating equipment; factory assembled as a single package having its major components arranged vertically, which is an encased combination of cooling and optional heating components; is intended for exterior mounting on, adjacent interior to, or through an outside wall and is powered by single or three-phase current. It may contain separate indoor grille(s), outdoor louvers, various ventilation options, or indoor free air discharge, ductwork, wall plenum, or sleeve. Heating components may include electrical resistance, steam, hot water, gas, or no heat, but may not include reverse-cycle refrigeration as a heating means.

single-package vertical heat pump (SPVHP): an SPVAC that utilizes reverse-cycle refrigeration as its primary heat source, with secondary supplemental heating by means of electrical resistance, steam, hot water, or gas.

single-rafter roof: see *roof*.

single-zone system: an HVAC system serving a single HVAC zone.

site-recovered energy: waste energy recovered at the building site that is used to offset consumption of purchased fuel or electrical energy supplies.

site-solar energy: thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site and used to offset consumption of purchased fuel or electrical energy supplies. For the purposes of applying this standard, site-solar energy shall not include passive heat gain through fenestration systems.

skylight: a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration.

skylight effective aperture: the overall amount of visible transmittance of the roof via skylights. Skylight effective aperture is calculated according to the following formula:

$$\text{Skylight effective aperture} = \frac{0.85 \times \text{skylight area} \times \text{skylight VT} \times \text{WF}}{\text{daylight area under skylight}}$$

where

skylight area = total fenestration area of skylights

skylight VT = area weighted average visible transmittance of skylights as determined in accordance with Section 5.8.2.6.

WF = area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 ft, or 0.7 if light well depth is 2 ft or greater. Light well depth is measured vertically from the underside of the lowest point on the skylight glazing to the ceiling plane under the skylight.

skylight well: the shaft from the skylight to the ceiling.

slab-on-grade floor: that portion of a slab floor of the building envelope that is in contact with the ground and that is either above grade or is less than or equal to 24 in. below the final elevation of the nearest exterior grade.

> ***heated slab-on-grade floor:*** a slab-on-grade floor with a heating source either within or below it.
>
> ***unheated slab-on-grade floor:*** a slab-on-grade floor that is not a heated slab-on-grade floor.

small electric motor: a NEMA general purpose, alternating current, single-speed induction motor, built in a two-digit frame number series in accordance with NEMA Standards Publication MG1-1987, including IEC metric equivalent motors; constructed in the NEMA 42, 48, and 56 frame sizes or IEC metric equivalent.

solar energy source: source of thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site.

solar heat gain coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area 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. (See *fenestration area*.)

space: an enclosed space within a building. The classifications of spaces are as follows for the purpose of determining building envelope requirements:

conditioned space: a cooled space, heated space, or indirectly conditioned space defined as follows:

a. ***cooled space:*** an enclosed space within a building that is cooled by a cooling system whose sensible output capacity exceeds 5 Btu/h·ft^2 of floor area.
b. ***heated space:*** an enclosed space within a building that is heated by a heating system whose output capacity relative to the floor area is greater than or equal to the criteria in Table 3.2.
c. ***indirectly conditioned space:*** an enclosed space within a building that is not a heated space or a cooled space, which is heated or cooled indirectly by being connected to adjacent space(s) provided:
    1. the product of the U-factor(s) and surface area(s) of the space adjacent to connected space(s) exceeds the combined sum of the product of the U-factor(s) and surface area(s) of the space adjoining the outdoors, unconditioned spaces, and to or from semiheated spaces (e.g., corridors) or
    2. that air from heated or cooled spaces is intentionally transferred (naturally or mechanically) into the space at a rate exceeding 3 ach (e.g., atria).

semiheated space: an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft^2 of floor area but is not a conditioned space.

unconditioned space: an enclosed space within a building that is not a conditioned space or a semiheated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces.

space-conditioning category:

a. nonresidential conditioned space (See *nonresidential*.)
b. residential conditioned space (See *residential*.)
c. nonresidential and residential semiheated space (See *space*.)

steel-framed wall: see *wall*.

steel-joist floor: see *floor*.

TABLE 3.2 Heated Space Criteria

Heating Output, Btu/h·ft^2	Climate Zone
5	1 and 2
10	3
15	4 and 5
20	6 and 7
25	8

story: portion of a building that is between one finished floor level and the next higher finished floor level or the roof, provided, however, that a basement or cellar shall not be considered a story.

substantial contact: a condition where adjacent building materials are placed so that proximal surfaces are contiguous, being installed and supported so they eliminate voids between materials without compressing or degrading the thermal performance of either product.

swinging door: see *door*.

system(s): a combination of equipment and auxiliary devices (e.g., controls, accessories, interconnecting means, and terminal elements) by which energy is transformed so it performs a specific function, such as HVAC, service water heating, or lighting.

task lighting: lighting directed to a specific surface or area that provides illumination for visual tasks.

temperature control throttling range: the number of degrees that room temperature must change in order to go from full heating to no heating or from full cooling to no cooling.

terminal: a device by which energy from a system is finally delivered, e.g., registers, diffusers, lighting fixtures, faucets, etc.

thermal barrier: the boundary between conditioned and unconditioned space which does not contain thermal bridges.

thermal block: a collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block.

thermal bridge: part of a building's conditioned envelope which spans between the conditioned and unconditioned space, has an R-value of 1.5 per inch or less, and is not otherwise insulated along the one-dimensional conductive heat transfer pathway of less than R-3/inch for 1 inch. For the purposes of this definition, fenestration is not counted as a thermal bridge.

thermal conductance (C-factor): time rate of steady-state heat flow through unit area of a material or construction, induced by a unit temperature difference between the body surfaces (Btu/h·ft^2·°F). Note that the C-factor does not include soil or air films.

thermal resistance (R-value): the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions ($h \cdot ft^2 \cdot °F/Btu$).

thermal transmittance (U-factor): heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side ($Btu/h \cdot ft^2 \cdot °F$).

thermally effective panel surface: any exterior surface of a panel that is intended to transfer heat between the panel and the occupants and/or the indoor space.

thermally ineffective panel surface: any exterior surface of a panel, which is not intended to transfer heat between the panel and the occupants and/or the indoor space.

thermostat: an automatic control device used to maintain temperature at a fixed or adjustable setpoint.

thermostatic control: an automatic control device or system used to maintain temperature at a fixed or adjustable setpoint.

tinted: (as applied to fenestration) bronze, green, blue, or gray coloring that is integral with the glazing material. Tinting does not include surface-applied films such as reflective coatings, applied either in the field or during the manufacturing process.

transfer air: air transferred from one room to another through openings in the room envelope, whether it is transferred intentionally or not. The driving force for transfer air is generally a small pressure differential between the rooms, although one or more fans may be used.

transformer: a piece of electrical equipment used to convert electric power from one voltage to another voltage.

> ***dry-type transformer:*** a transformer in which the core and coils are in a gaseous or dry compound.
>
> ***liquid-immersed transformer:*** a transformer in which the core and coils are immersed in an insulating liquid.

toplighting: lighting building interiors with daylight admitted through fenestration, such as skylights and roof monitors, located on the roof.

U-factor: see *thermal transmittance*.

unconditioned space: see *space*.

unenclosed space: a space that is not an enclosed space.

unitary cooling equipment: one or more factory-made assemblies that normally include an evaporator or cooling coil and a compressor and condenser combination. Units that perform a heating function are also included.

unitary heat pump: one or more factory-made assemblies that normally include an indoor conditioning coil, compressor(s), and an outdoor refrigerant-to-air coil or refrigerant-to-water heat exchanger. These units provide both heating and cooling functions.

unmet load hour: an hour in which one or more zones is outside of the thermostat setpoint plus or minus one half of the temperature control throttling range. Any hour with one or more zones with an unmet cooling load or unmet heating load is defined as an unmet load hour.

variable-air-volume (VAV) system: HVAC system that controls the dry-bulb temperature within a space by varying the volumetric flow of heated or cooled supply air to the space.

variable-refrigerant-flow (VRF) system: an engineered direct expansion (DX) multisplit system incorporating at least one variable capacity compressor distributing refrigerant through a piping network to multiple indoor fan-coil units, each capable of individual zone temperature control, through integral zone temperature control devices and common communications network. Variable refrigerant flow utilizes three or more steps of control on common, interconnecting piping.

vegetative roof system: vegetation, growth media, drainage system, and waterproofing over a roof deck.

vent damper: a device intended for installation in the venting system of an individual, automatically operated, fossil-fuel-fired appliance in the outlet or downstream of the appliance draft control device, which is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in a standby or shutdown condition.

ventilation: the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned.

ventilation system motor nameplate horsepower (hp): the sum of the motor nameplate horsepower of all fans that are required to operate as part of the system.

verification: the process by which specific documents, components, equipment, assemblies, systems, and interfaces among systems are confirmed to comply with the criteria described in the *owner's project requirements*. (See *owner's project requirements*.)

vertical fenestration: all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 12 in. of a mass wall, are considered walls, not fenestration. For the purposes of determining building envelope requirements, the vertical fenestration classifications are defined as follows:

> ***metal framing:*** products with metal framing with or without thermal break.
>
> ***metal framing, entrance door:*** any doorway, set of doors, turnstile, vestibule, or other form of portal that is ordinarily used to gain access by its users and occupants to the building or to individual tenant spaces accessed from the exterior. (See *building entrance* and *door*.)
>
> metal framing, fixed: all types of vertical fenestration, other than entrance door and operable, including, but not limited to, curtain walls, window walls, fixed windows, picture windows, glass block walls, nonopenable clere-

story windows, and nonopenable sidelights and transoms.

metal framing, operable: all vertical fenestration that opens, except entrance doors, including, but not limited to, casement windows, projecting windows, pivoting windows, horizontal sliding windows, vertical sliding windows, openable clerestory windows, openable sidelights and transoms, sliding glass doors, and doors that are not entrance doors.

nonmetal framing: all products with framing materials other than metal with or without metal reinforcing or cladding.

visible transmittance (VT): the ratio of visible radiation entering the space through the fenestration product to the incident visible radiation, determined as the spectral transmittance of the total fenestration system, weighted by the photopic response of the eye and integrated into a single dimensionless value.

voltage drop: a decrease in voltage caused by losses in the lines connecting the power source to the load.

VT: see *visible transmittance*.

walk-in cooler: an enclosed storage space of <3000 ft^2 that can be walked into and that is designed to maintain a space temperature of >32°F and ≤55°F.

walk-in freezer: an enclosed storage space of <3000 ft^2 that can be walked into that is designed to maintain a space temperature of ≤32°F.

wall: that portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60 degrees from horizontal or greater. This includes above- and below-grade walls, between floor spandrels, peripheral edges of floors, and foundation walls. For the purposes of determining building envelope requirements, the classifications are defined as follows:

above-grade wall: a wall that is not a below-grade wall.

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

mass wall: a wall with a heat capacity exceeding (1) 7 Btu/ft^2·°F or (2) 5 Btu/ft^2·°F, provided that the wall has a material unit weight not greater than 120 lb/ft^3.

metal building wall: a wall whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain wall systems).

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

wood-framed and other walls: all other wall types, including wood stud walls.

wall area, gross: the area of the wall measured on the exterior face from the top of the floor to the bottom of the roof.

warm-up: increase in space temperature to occupied setpoint after a period of shutdown or setback.

water economizer: see *economizer, water*.

water factor (WF):

a. ***clothes washer (residential* and *commercial):*** the quantity of water, in gallons (liters), used to wash each cubic foot (cubic meter) of machine capacity.
b. ***residential dishwasher:*** the quantity of water use, in gallons (liters), per full machine wash and rinse cycle.

water heater: vessel in which water is heated and is withdrawn for use external to the system.

wood-framed and other walls: see *wall*.

wood-framed and other floors: see *floor*.

3.1 Abbreviations and Acronyms

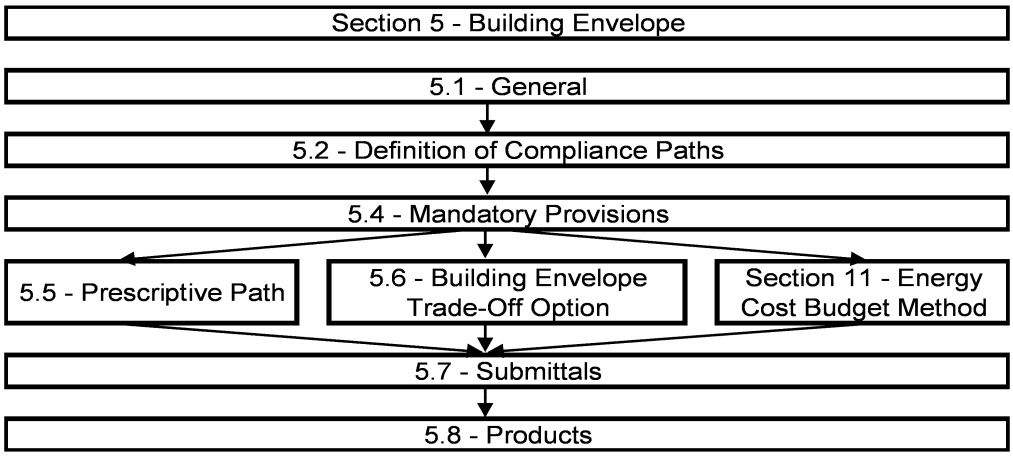
ac	**alternating current**
ach	**air changes per hour**
AFUE	**annual fuel utilization efficiency**
AHAM	**Association of Home Appliance Manufacturers**
AHJ	**authority having jurisdiction**
ANSI	**American National Standards Institute**
AHRI	**Air-Conditioning, Heating and Refrigeration Institute**
ASTM	**ASTM International**
bhp	**brake horsepower**
BSR	**Board of Standards Review**
Btu	**British thermal unit**
Btu/h	**British thermal unit per hour**
Btu/ft^2·°F	**British thermal unit per square foot per degree Fahrenheit**
Btu/h·ft^2	**British thermal unit per hour per square foot**
Btu/h·ft·°F	**British thermal unit per hour per linear foot per degree Fahrenheit**
Btu/h·ft^2·°F	**British thermal unit per hour per square foot per degree Fahrenheit**
CDD	**cooling degree-day**
CDD50	**cooling degree-days base 50°F**
cfm	**cubic feet per minute**
c.i.	**continuous insulation**

COP	**coefficient of performance**
CTI	**Cooling Technology Institute**
CxA	***commissioning authority***
DCV	**demand control ventilation**
DDC	**direct digital control**
DOE	**U.S. Department of Energy**
E_c	**combustion efficiency**
EER	**energy efficiency ratio**
EF	**energy factor**
E_t	**thermal efficiency**
F	**Fahrenheit**
FC	**filled cavity**
ft	**foot**
gr	**grains of moisture per pound of dry air**
h	**hour**
HC	**heat capacity**
HDD	**heating degree-day**
HDD65	**heating degree-days base 65°F**
h·ft^2·°F/Btu	**hour per square foot per degree Fahrenheit per British thermal unit**
HID	**high-intensity discharge**
hp	**horsepower**
HSPF	**heating seasonal performance factor**
HVAC	**heating, ventilating, and air conditioning**
HVACR	**heating, ventilating, air conditioning, and refrigeration**
IEC	**International Electrotechnical Commission**
IES	**Illuminating Engineering Society of North America**
in.	**inch**
I-P	**inch-pound**
IPLV	**integrated part-load value**
J	**joule**
K	**kelvin**
kJ	**kilojoule**
kVA	**kilovolt-ampere**
lin	**linear**
lin ft	**linear foot**
LPD	**lighting power density**
Ls	**liner system**
LSG	**light-to-solar-gain ratio**
m	**metre**
m^2·K/W	**square metre per kelvin per watt**
MICA	**Midwest Insulation Contractors Association**
MSH	**monitor seal height**
NAECA	**U.S. National Appliance Energy Conservation Act**
NFPA	**National Fire Protection Association**
NFRC	**National Fenestration Rating Council**
NPLV	**nonstandard part-load value**
PF	**projection factor**
PTAC	**packaged terminal air conditioner**
PTHP	**packaged terminal heat pump**
R	**R-value (thermal resistance)**
R_c	**thermal resistance of a material or construction from surface to surface**
RCR	**room cavity ratio**
R_u	total thermal resistance of a material or construction including air film resistances
rpm	**revolutions per minute**
SC	**shading coefficient**
SEER	**seasonal energy efficiency ratio**
SHGC	**solar heat gain coefficient**
SL	**standby loss**
SMACNA	**Sheet Metal and Air Conditioning Contractors' National Association**
T_{db}	**dry-bulb temperature**
T_{wb}	**wet-bulb temperature**
UL	**Underwriters Laboratories Inc.**

VAV	**variable-air-volume**
VT	**visible transmittance (also known as visible light transmittance [VLT])**
W	**watt**
W/ft^2	**watts per square foot**
WF	**well factor**
Wh	**watt-hour**

4. ADMINISTRATION AND ENFORCEMENT

4.1 Administration and Enforcement. Administration and enforcement of the *Energy Conservation Code—Commercial Provisions* shall be governed by Chapter 1, Title 12-A DCMR.



5. BUILDING ENVELOPE

5.1 General

5.1.1 Scope. Section 5 specifies requirements for the building envelope.

5.1.2 Space-Conditioning Categories

5.1.2.1 Separate exterior building envelope requirements are specified for each of three categories of conditioned space: (a) nonresidential conditioned space, (b) residential conditioned space, and (c) semiheated space.

5.1.2.2 The minimum skylight area requirements in Section 5.5.4.2.3 are also specified for unconditioned spaces.

5.1.2.3 Spaces shall be assumed to be conditioned spaces and shall comply with the requirements for conditioned spaces at the time of construction, regardless of whether mechanical or electrical equipment is included in the building permit application or installed at that time.

5.1.2.4 In Climate Zones 3 through 8, a space may be designated as either a semiheated space or an unconditioned space only if approved by the building official.

5.1.3 Envelope Alterations. Alterations to the building envelope shall comply with the requirements of Section 5 for insulation, air leakage, and fenestration applicable to those specific portions of the building that are being altered.

Exceptions: The following alterations need not comply with these requirements, provided such alterations will not increase the energy usage of the building:

1. Installation of storm windows or glazing panels over existing glazing, provided the storm window or glazing panel contains a low-emissivity coating. However, a low-emissivity coating is not required where the existing glazing already has a low-emissivity coating. Installation is permitted to be either on the inside or outside of the existing glazing.
2. Replacement of glazing in existing sash and frame due to individual broken panes and considered repair only, provided the U-factor and SHGC will be equal to or lower than before the glass replacement.
3. Alterations to roof/ceiling, wall, or floor cavities that are insulated to full depth with insulation having a minimum nominal value of R-3.0/in.
4. Alterations to walls and floors, where the existing structure is without framing cavities and no new framing cavities are created.
5. *Roof recovering*.
6. Replacement of existing doors that separate a conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided that an existing vestibule that separates a conditioned space from the exterior shall not be removed.

5.1.4 Climate. Determine the climate zone for the location. For U.S. locations, follow the procedure in Section 5.1.4.1. For international locations, follow the procedure in Section 5.1.4.2.

5.1.4.1 United States Locations. Use Figure B1-1 or Table B1-1 in Appendix B to determine the required climate zone.

Exception: If there are recorded historical climatic data available for a construction site, they may be used to determine compliance if approved by the building official.

5.1.4.2 [Reserved]

5.2 Compliance Paths

5.2.1 Compliance. For the appropriate climate, space-conditioning category, and class of construction, the building envelope shall comply with Section 5.1, "General"; Section 5.4, "Mandatory Provisions"; Section 5.7, "Submittals"; Section 5.8, "Product Information and Installation Requirements"; and either

a. Section 5.5, "Prescriptive Building Envelope Option," provided that the fenestration area does not exceed the maximum allowed by Section 5.5.4.2, or
b. Section 5.6, "Building Envelope Trade-Off Option."

5.2.2 Projects using the Performance Method (see Appendix G) shall comply with Section 5.4, the mandatory provisions of this section, as a portion of that compliance path.

5.3 Simplified Building (Not Used)

5.4 Mandatory Provisions

5.4.1 Insulation. Where insulation is required in Section 5.5 or 5.6, it shall comply with the requirements found in Sections 5.8.1.1 through 5.8.1.10.

5.4.1.1 Accounting for Thermal Conduction Components. Where a component of the building envelope assembly reduces the overall U-value of the rest of the assembly, that component shall be thermally represented and integrated into the area-weighted U-value as described by the following default methodology. This default methodology shall be used in all energy compliance pathways including: Prescriptive U-value compliance, Section 5.6 Trade-off, and Appendix G energy model. Prescriptive R-value compliance with Table 5.5 and the energy model baseline shall assume Default Cladding Attachment Coefficients = 1 from Table 5.4.1.1.(1) and no Linear Anomalies as described in Table 5.4.1.1(2). Tables 5.4.1.1(1) and 5.4.1.1(2) shall be used in conjunction with Equation 5.4.1.1 and associated default calculation methodology to account for common thermal conduction situations not currently described in Appendix A. In lieu of the equation and methodology, the project team may demonstrate to the authority having jurisdiction two dimensional heat flow modeling, three dimensional heat flow modeling, linear transmission calculations per ASHRAE D RP-1365, or hot box-testing results showing the resultant area-weighted U-value as acceptable to the authority having jurisdiction. If using this alternative methodology, all thermal bridges described by ASHRAE D RP-1365 shall be represented.

Exceptions:

1. Electrical wiring used for transmission of energy.
2. Plumbing penetrations complying with prescriptive insulation requirements of Section 7.
3. Mechanical penetrations complying with prescriptive insulation requirements of Section 6.
4. Non-metal flashing for moisture management.

Equation 5.4.1.1:

$$\text{U-value}_{\text{(Overall including Thermal Bridges)}} = \frac{1}{\left(\frac{1}{Ubw} + Re \cdot Cac\right) \cdot Wac}$$

Where:

Ubw = "Overall U-Factor for Entire Base Wall Assembly" (such as from Normative Appendix A, Sections A3.3 and A3.4. Insulation in stud cavity, plus gypsum, thermal boundary layers)

Re = Nominal Exterior insulation R-value (From Project Design)

Cac = Cladding Attachment Coefficient [from Table 5.4.1.1(1)]

Wac = Wall Anomaly Coefficient [from Table 5.4.1.1(2)]

Default Methodologies:

Option A – Specification Approach:

1) If complying with the Prescriptive R-value requirements per Table 5.5, the project must have:
   a. No Linear Anomalies for Vertical Assemblies as described in Table 5.4.1.1(2).
   b. For projects using exterior insulation "Materials and/or Orientations" identified in Table 5.4.1.1(1) with Cladding Attachment Coefficients (Cac) of 1 shall be explicitly specified in the drawings and/or specifications.

Option B – Simplified Approach:

1) Find the lowest Default Linear Anomaly for Vertical Assembly applicable to the proposed design. Use this value to include in Equation 5.4.1.1.
2) Determine the Default Cladding Attachment Coefficient for the proposed design.
3) Use Equation 5.4.1.1 to determine $\text{U-value}_{\text{(Overall including Thermal Bridges)}}$ for vertical walls.
4) Use the calculated $\text{U-value}_{\text{(Overall including Thermal Bridges)}}$ for compliance with prescriptive U-value compliance per Table 5.5, Trade off method Section 5.6 (via COMCheck), or the proposed energy model via Appendix G.
5) Calculations and assumptions shall be presented to the authority having jurisdiction.

Option C – Detailed Approach:

1) Define a new rectangular vertical wall area associated with one Default Linear Anomaly per story, or part of a story (includes stories below grade).
2) If there is more than one Default Linear Anomaly per vertical, rectangular wall section (for example such as a wall with both a concrete balcony and a parapet), select the lowest Default Linear Anomaly Coefficient for Vertical Assembly and use that for Equation 5.4.1.1.
3) Determine the Default Cladding Attachment Coefficient for the proposed design wall section.
4) Use equation 5.4.1.1 to determine $\text{U-value}_{\text{(Overall including Thermal Bridges)}}$.
5) Use the calculated $\text{U-value}_{\text{(Overall including Thermal Bridges)}}$ for compliance with prescriptive U-value compliance per Table 5.5, Trade off method section 5.6 (via COMCheck), or the proposed energy model via Appendix G.
6) Each unique vertical wall assembly shall be evaluated and/or included for the compliance Option C, step 5
7) Calculations and assumptions shall be presented to the authority having jurisdiction.

See following Tables:

Table 5.4.1.1(1) Default Cladding Attachment Coefficient

Attachment type through Rigid Insulation	Material and/or Orientation	Cladding Attachment Coefficient, Cac
Girts	Metal Vertical girt (Detail 1*)	53%
	Horizontal Metal girt (Detail 2*)	62%
	Horizontal Non-Metal girt	100%
Clips	Metal Clips	75%
	Stainless Steel Clips	85%
	Thermal Stop Clips	90%
	Fiberglass Clip	100%
Brick Ties	Steel Brick Ties	78%
	Stainless Steel Brick Ties	90%
	Thermal Break Brick Ties	100%
Long Screws	Galvanized Long Screws	80%
	Stainless Long Screws	100%

*Detail Associated with ASHRAE D RP-1365

5.4.2 Fenestration and Doors. Procedures for determining fenestration and door performance are described in Section 5.8.2. Product samples used for determining fenestration performance shall be production line units or representative of units purchased by the consumer or contractor.

5.4.3 Air Leakage

5.4.3.1 Continuous Air Barrier. The entire building envelope shall be designed and constructed with a continuous air barrier.

Exceptions:

1. Semiheated spaces in Climate Zones 1 through 6.
2. Single wythe concrete masonry buildings in Climate Zone 2B.

5.4.3.1.1 Air Barrier Design. The air barrier shall be designed and noted in the following manner:

a. All air barrier components of each building envelope assembly shall be clearly identified or otherwise noted on construction documents.

Table 5.4.1.1(2) Default Linear Anomaly Coefficient for Vertical Assembly

Construction Type	Wall Linear Anomaly	Insulation Placement	ASHRAE D RP -1365 Detail #	Wall Anomaly Coefficient, Wac
All Wall Façades	Concrete Balcony or Concrete Floor	Uninsulated at top and bottom, exterior and in stud cavity insulation	5	36%
	Concrete Balcony or Concrete Floor	Insulated at top of slab, exterior and in stud cavity insulation	5	39%
	Concrete Balcony or Concrete Floor	Insulated at top and bottom of slab, exterior and in stud cavity insulation	5a	42%
All Façades with Structural Steel	Steel Support for Floor	Interior Insulated Wall	16	64%
	Steel Support for Floor	Exterior and Interior Insulated	17	80%
	Metal or Masonry Parapet	Exterior Rigid and Interior Framed	10	72%
Brick Façade	Concrete Slab with Standard Metal Shelf Angle or Metal Flashing	Exterior Rigid and Interior Framed	14	54%
	Concrete Slab with Reduced-Contact Metal Shelf Angle	Exterior Rigid and Interior Framed	15	65%
	Metal or Masonry Parapet	Both sides insulated with rigid, with Roof insulation	9	100%
	Metal or Masonry Parapet	Interior wall metal framed insulation with roof insulation	20	65%
Spandrel Panels	Slab Intersection	No Stud Insulation and Back Pan Insulation	22	34%
	Slab Intersection	Stud Insulation and Back Pan Insulation	23	44%
	Metal or Masonry Parapet	Stud Insulation and Back Pan Insulation	25	41%
Precast Walls	Slab Intersection	Interior Metal Framed Insulation	29	73%
	Metal or Masonry Parapet	Exterior Metal Framed Insulation	30	76%
	Slab Intersection	Sandwich Panel, at slab intersection	32	63%
	Metal or Masonry Parapet	Sandwich Panel, at roof intersection	33	65%
Concrete Block With Exterior Rigid Insulation	Metal Shelf Angle	Exterior Rigid and Metal Shelf Angle	35	62%
	Reduced Contact Shelf Angle	Exterior Rigid and Reduced Contact Shelf Angle	36	70%
	Metal or Masonry Parapet	Brick Ties at Parapet and Roof	37	69%
No Linear Anomalies as Described Above	All	All	—	100%

b. The joints, interconnections, and penetrations of the air barrier components, including lighting fixtures, shall be detailed or otherwise noted.

c. The continuous air barrier shall extend over all surfaces of the building envelope (at the lowest floor, exterior walls, and ceiling or roof).

d. The continuous air barrier shall be designed to resist positive and negative pressures from wind, stack effect, and mechanical ventilation.

5.4.3.1.2 Air Barrier Installation. The following areas of the continuous air barrier in the building envelope shall be wrapped, sealed, caulked, gasketed, or taped in an approved manner to minimize air leakage:

a. Joints around fenestration and door frames (both manufactured and site-built)

b. Junctions between walls and floors, between walls at building corners, and between walls and roofs or ceilings

c. Penetrations through the air barrier in building envelope roofs, walls, and floors

d. Building assemblies used as ducts or plenums

e. Joints, seams, connections between planes, and other changes in air barrier materials

5.4.3.1.3 Acceptable Materials and Assemblies. Continuous air barrier materials and assemblies for the opaque building envelope shall comply with one of the following requirements:

a. Materials that have an air permeance not exceeding 0.004 cfm/ft^2 under a pressure differential of 0.3 in. H_2O (1.57 psf) when tested in accordance with ASTM E2178. The following materials meet these requirements:

   1. Plywood—minimum $^3/_8$ in.
   2. Oriented strand board—minimum $^3/_8$ in.
   3. Extruded polystyrene insulation board—minimum $^1/_2$ in.
   4. Foil-faced urethane insulation board—minimum $^1/_2$ in.
   5. Exterior gypsum sheathing or interior gypsum board—minimum $^1/_2$ in.
   6. Cement board—minimum $^1/_2$ in.
   7. Built-up roofing membrane
   8. Modified bituminous roof membrane
   9. Fully adhered single-ply roof membrane
   10. A Portland cement/sand parge, stucco, or gypsum plaster—minimum $^1/_2$ in. thick
   11. Cast-in-place and precast concrete
   12. Sheet metal
   13. Closed-cell 2 lb/ft^3 nominal density spray polyurethane foam—minimum 1 in.

b. Assemblies of materials and components (sealants, tapes, etc.) that have an average air leakage not to exceed 0.04 cfm/ft^2 under a pressure differential of 0.3 in. H_2O (1.57 psf) when tested in accordance with ASTM E2357, ASTME 1677, ASTME 1680, or ASTME283. The following assemblies meet these requirements:

   1. Concrete masonry walls that are
      (a) fully grouted, or
      (b) painted to fill the pores.

5.4.3.2 Fenestration and Doors. Air leakage for fenestration and doors shall be determined in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283 as specified below. Air leakage shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the National Fenestration Rating Council, and shall be labeled and certified by the manufacturer. Air leakage shall not exceed

a. 1.0 cfm/ft^2 for glazed swinging entrance doors and revolving doors, tested at a pressure of at least 1.57 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283;

b. 0.06 cfm/ft^2 for curtainwall and storefront glazing, tested at a pressure of at least 1.57 psf or higher in accordance with NFRC 400 or ASTM E283;

c. 0.3 cfm/ft^2 for unit skylights having condensation weepage openings, tested at a pressure of at least 1.57 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400, or 0.5 cfm/ft^2 tested at a pressure of at least 6.24 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440;

d. 1.3 cfm/ft^2 for nonswinging doors intended for vehicular access and material transportation, with a minimum opening rate of 32 in./s, tested at a pressure of at least 1.57 psf or higher in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.

e. 0.4 cfm/ft^2 for other nonswinging opaque doors, glazed sectional garage doors, and upward acting nonswinging glazed doors tested at a pressure of at least 1.57 psf or higher in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283; and

f. 0.2 cfm/ft^2 for all other products tested at a pressure of at least 1.57 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400, or 0.3 cfm/ft^2 tested at a pressure of at least 6.24 psf in accordance with AAMA/WDMA/CSA 101/I.S/A440.

Exceptions:

1. Field-fabricated fenestration and doors
2. [Reserved]
3. Products in buildings that comply with a whole building air leakage rate of 0.4 cfm/ft^2 under a pressure differential of 0.3 in. H_2O, 1.57 psf when tested in accordance with ASTM E779

5.4.3.3 Loading Dock Weatherseals. In Climate Zones 4 through 8, cargo doors and loading dock doors shall be equipped with weatherseals to restrict infiltration when vehicles are parked in the doorway.

5.4.3.4 Vestibules. *Building entrances* that separate conditioned space from the exterior 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. Interior and exterior doors shall have a minimum distance between them of not less than 7 ft when in the closed position. The floor area of each vestibule shall not exceed the greater of 50 ft^2 or 2% of the gross conditioned floor area for that level of the building. The exterior envelope of conditioned vestibules shall comply with the requirements for a conditioned space. The interior and exterior envelope of unconditioned vestibules shall comply with the requirements for a semiheated space.

Exceptions:

1. Revolving doors
2. Doors not intended to be used as a building entrance, including service entrance doors
3. Doors opening directly from a dwelling unit
4. Doors that open directly from a space that is less than 3,000 ft^2 in area
5. Semiheated spaces
6. Enclosed elevator lobbies for building entrances directly from parking garages

5.4.3.4.1 Where vestibules are required under Section 5.4.3.4, for spaces having a gross conditioned floor area for that level of the building of 40,000 ft^2 and greater, and when the doors opening into and out of the vestibule are equipped with automatic, electrically driven, self-closing devices, the interior and exterior doors shall have a minimum distance between them of not less than 16 ft.

5.4.4 *On-Site Renewable Energy Systems*. *Building project* design shall show allocated space and pathways for future installation of *on-site renewable energy systems* and associated infrastructure to cover no less than 25% of horizontal projection of the *gross roof area*.

Exceptions:

1. *Building* projects that have an annual daily average incident solar radiation available to a flat plate collector oriented due south at an angle from horizontal equal to the latitude of the collector location less than 1.2 kBtu/ft^2·day (4.0 kWh/m^2·day), accounting for existing buildings, permanent infrastructure that is not part of the building project, topography, or trees.
2. Building projects that comply with Section 13.1.

5.5 Prescriptive Building Envelope Option

5.5.1 For a conditioned space, the exterior building envelope shall comply with either the nonresidential or residential requirements in Table 5.5.

5.5.2 If a building contains any semiheated space or unconditioned space, then the semi-exterior building envelope shall comply with the requirements for semiheated space in Table 5.5. (See Figure 5.5.2.)

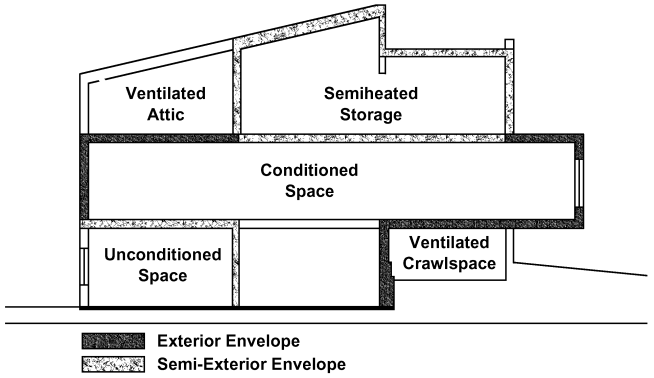


Figure 5.5.2. Exterior and semiexterior building envelope.

5.5.3 Opaque Areas. For all opaque surfaces except doors, compliance shall be demonstrated by one of the following two methods:

a. Minimum rated R-values of insulation for the thermal resistance of the added insulation in framing cavities and continuous insulation only. Specifications listed in Normative Appendix A for each class of construction shall be used to determine compliance.

b. Maximum U-factor, C-factor, or F-factor for the entire assembly. The values for typical construction assemblies listed in Normative Appendix A shall be used to determine compliance.

Exceptions:

1. For assemblies significantly different than those in Appendix A, calculations shall be performed in accordance with the procedures required in Appendix A.
2. For multiple assemblies within a single class of construction for a single space-conditioning category, compliance shall be shown for either (a) the most restrictive requirement or (b) an area-weighted average U-factor, C-factor, or F-factor.

5.5.3.1 Roof Insulation. All roofs shall comply with the insulation values specified in Table 5.5. Sky-light curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5.0, whichever is less.

Table 5.5 Building Envelope Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.028	R-33 c.i.	U-0.028	R-33 c.i.	U-0.093	R-10 c.i.
Metal Building[a]	U-0.033	R-21 + R-12 Ls or R-28 + R-9 Ls	U-0.033	R-21 + R-12 Ls or R-28 + R-9 Ls	U-0.082	R-19
Attic and Other	U-0.0189	R-54	U-0.0189	R-54	U-0.034	R-30
Walls, above Grade						
Mass	U-0.094	R-11 c.i.	U-0.081	R-12.5 c.i.	U-0.580	NR
Metal Building	U-0.054	R-0 + R-17.5 c.i.	U-0.045	R-0 + R-21 c.i.	U-0.162	R-13
Steel Framed	U-0.058	R-15 + R-8 c.i.	U-0.058	R-15 + R-8 c.i.	U-0.124	R-13
Wood Framed and Other	U-0.058	R-15 + R-4.1 c.i.	U-0.058	R-15 + R-4.1 c.i.	U-0.089	R-13
Wall, below Grade						
Below Grade Wall	C-0.119	R-8 c.i.	C-0.092	R-11 c.i.	C-1.140	NR
Floors						
Mass	U-0.051	R-16 c.i.	U-0.046	R-18.4 c.i.	U-0.107	R-6.3 c.i.
Steel Joist	U-0.035	R-33	U-0.034	R-33	U-0.052	R-19
Wood Framed and Other	U-0.030	R-33	U-0.030	R-33	U-0.051	R-19
Slab-on-Grade Floors						
Unheated	F-0.520	R-20 for 24 in.	F-0.520	R-20 for 24 in.	F-0.730	NR
Heated	F-0.843	R-25 for 24 in.	F-0.688	R-25 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.45		U-0.45		U-0.700	
Nonswinging	U-0.45		U-0.45		U-1.450	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/ SHGC
Vertical Fenestration, 0%–40% of Wall		***(for all frame types)***			***(for all frame types)***			***(for all frame types)***	
Nonmetal framing, all	U-0.33	SHGC-0.36	1.10	U-0.33	SHGC-0.36	1.10	U-0.51	NR	NR
Metal framing, fixed	U-0.38			U-0.38			U-0.73		
Metal framing, operable	U-0.45			U-0.45			U-0.81		
Metal framing, entrance door	U-0.69			U-0.61			U-0.77		
Skylight, 0%–3% of Roof									
All types	U-0.45	SHGC-0.36	NR	U-0.45	SHGC-0.36	NR	U-1.15	NR	NR

* The following definitions apply: c.i. = continuous insulation (See Section 3.2), FC = filled cavity (see Section A2.3.2.5), Ls = liner system (see Section A2.3.2.4), NR = no (insulation) requirements.

a. When using the R-value compliance method for metal building roofs, a thermal spacer block is required (see Section A2.3.2).

5.5.3.1.1 Roof Solar Reflectance and Thermal Emittance. Roofs in Climate Zone 4 shall have one of the following:

1. A minimum three-year-aged solar reflectance of 0.55 and a minimum three-year-aged thermal emittance of 0.75 when tested in accordance with CRRC-1 Standard.
2. A minimum initial Solar Reflectance Index of 82 for roofs 2:12 or less and 39 for roofs greater than 2:12 in slope, when determined in accordance with the Solar Reflectance Index method in ASTM E1980 using a convection coefficient of 2.1 Btu/h·ft^2·°F, based on three-year-aged solar reflectance and three-year-aged thermal emittance tested in accordance with CRRC-1 Standard.

Exceptions:

1. Ballasted roofs with a minimum stone ballast of 17 lb/ft^2 or 23 lb/ft^2 pavers.
2. Vegetated roof systems that contain a minimum thickness of 2.5 in. of growing medium and covering a minimum of 75% of the roof area with durable plantings.
3. Roofs where a minimum of 75% of the roof area
   a. is shaded during the peak sun angle on June 21 by permanent components or features of the building; or
   b. is permitted using a combination of 1 and 2 above.
4. Decks constructed using wood or an *approved* bio-based decking material.

The values for three-year-aged solar reflectance and three-year-aged thermal emittance shall be determined by a laboratory accredited by a nationally recognized accreditation organization and shall be labeled and certified by the manufacturer.

5.5.3.2 Above-Grade Wall Insulation. All above-grade walls shall comply with the insulation values specified in Table 5.5.

Exception: Alternatively, for mass walls, where the requirement in Table 5.5 is for a maximum assembly U-0.151 followed by footnote "b," ASTM C90 concrete block walls, ungrouted or partially grouted at 32 in. or less on center vertically and 48 in. or less on center horizontally, shall have ungrouted cores filled with material having a maximum thermal conductivity of 0.44 Btu·in./h·ft^2·°F. Other mass walls with integral insulation shall meet the criteria when their U-factors are equal to or less than those for the appropriate thickness and density in the "Partly Grouted, Cells Insulated" column of Table A3.1-3. When a wall consists of both above-grade and below-grade portions, the entire wall for that story shall be insulated on either the exterior or the interior or be integral.

1. If insulated on the interior, the wall shall be insulated to the above-grade wall requirements.
2. If insulated on the exterior or integral, the below-grade wall portion shall be insulated to the below-grade wall requirements, and the above-grade wall portion shall be insulated to the above-grade wall requirements.

5.5.3.3 Below-Grade Wall Insulation. Below-grade walls shall have a rated R-value of insulation no less than the insulation values specified in Table 5.5.

Exception: Where framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly C-factor.

5.5.3.4 Floor Insulation. All floors shall comply with the insulation values specified in Table 5.5.

5.5.3.5 Slab-on-Grade Floor Insulation. All slab-on-grade floors, including heated slab-on-grade floors and unheated slab-on-grade floors, shall comply with the insulation values specified in Table 5.5.

5.5.3.6 Opaque Doors. All opaque doors shall have a U-factor not greater than that specified in Table 5.5.

5.5.3.7 High-Speed Doors. *High-speed doors* that are intended to operate on average at least 75 cycles per day shall not exceed a maximum U-factor of 1.20 Btu/hr·ft2·°F (6.81 W/m2·K). Opening rate, closing rate, and average cycles per day shall be included in construction drawings. Sections 5.5.3.6 and 5.5.4.3 shall not apply for *high-speed doors* complying with all criteria in this section.

5.5.4 Fenestration

5.5.4.1 General. Compliance with U-factors, SHGC, and VT/SHGC shall be demonstrated for the overall fenestration product. Gross wall areas and gross roof areas shall be calculated separately for each space-conditioning category for the purposes of determining compliance.

Exception: If there are multiple assemblies within a single class of construction for a single space-conditioning category, compliance shall be based on an area-weighted average U-factor, SHGC, VT/SHGC, or LSG. It is not acceptable to do an area-weighted average across multiple classes of construction or multiple space-conditioning categories.

5.5.4.2 Fenestration Area

5.5.4.2.1 Vertical Fenestration Area. The total vertical fenestration area shall not be greater than that specified in Table 5.5.

Exception: Vertical fenestration complying with Exception (3) to Section 5.5.4.4.1.

5.5.4.2.2 Maximum Skylight Fenestration Area. The total skylight area shall not be greater than that specified in Table 5.5.

Exception: The total skylight area is permitted to be increased to no greater than 6% of the gross roof area, provided the skylights meet all of the criteria in Exception (1) to Section 5.5.4.4.2 and the total

daylight area under skylights is a minimum of half the floor area of the space.

5.5.4.2.3 Minimum Skylight Fenestration Area. In any enclosed space in a building that is

a. 2500 ft^2 and greater;

b. directly under a roof with ceiling heights greater than 15 ft; and

c. one of the following space types: office, lobby, atrium, concourse, corridor, storage (including nonrefrigerated warehouse), gymnasium, fitness/exercise area, playing area, gymnasium seating area, convention exhibit/event space, courtroom, automotive service, fire station engine room, manufacturing corridor/transition and bay areas, retail, library reading and stack areas, distribution/sorting area, transportation baggage and seating areas, or workshop,

The total daylight area under skylights shall be a minimum of half the floor area and either

a. provide a minimum skylight area to daylight area under skylights of 3% with a skylight VT of at least 0.40 or
b. provide a minimum skylight effective aperture of at least 1%.

These skylights shall have a glazing material or diffuser with a measured haze value greater than 90% when tested according to ASTM D1003. General lighting in the daylight area shall be controlled as described in Section 9.4.1.1(f).

Exceptions:

1. Enclosed spaces in Climate Zones 6 through 8
2. Enclosed spaces where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
3. Enclosed spaces where the daylight area under roof monitors is greater than 50% of the enclosed space floor area
4. Enclosed spaces where it is documented that 90% of the skylight area is shaded on June 21 in the Northern Hemisphere (December 21 in the Southern Hemisphere) at noon by permanent architectural features of the building
5. Enclosed spaces where the total area minus the primary and secondary sidelighted area(s) is less than 2500 ft^2 and where the lighting is controlled according to sidelighting requirements described in Section 9.4.1.1(e)

5.5.4.3 Fenestration U-Factor. Fenestration shall have a U-factor not greater than that specified in Tables 5.5. However, for locations in Climate Zone 1 with a cooling design temperature of 95°F and greater, the maximum allowed U-factors for vertical fenestration for all conditioned spaces, nonresidential and residential, are U-0.32 for non-metal framing, U-0.50 for fixed metal framing, U-0.65 for operable metal framing, and U-0.83 for entrance door metal framing.

Exception: The U-factor for skylights is permitted to be increased to no greater than 0.90 Btu/h·ft^2·°F in Climate Zones 1 through 3 and 0.75 Btu/h·ft^2·°F in Climate Zones 4 through 8, provided the skylights meet all of the criteria in Exception (1) to Section 5.5.4.4.2.

5.5.4.4 Fenestration Solar Heat Gain Coefficient (SHGC)

5.5.4.4.1 SHGC of Vertical Fenestration. Vertical fenestration shall have an SHGC not greater than that specified in Table 5.5.

Exceptions:

1. For demonstrating compliance for vertical fenestration shaded by opaque permanent projections that will last as long as the building itself, the SHGC in the proposed building shall be reduced by using the multipliers in Table 5.5.4.4.1. Permanent projections consisting of open louvers shall be considered to provide shading, provided that no sun penetrates the louvers during the peak sun angle on June 21.
2. For demonstrating compliance for vertical fenestration shaded by partially opaque permanent projections (e.g., framing with glass or perforated metal) that will last as long as the building itself, the projection factor (PF) shall be reduced by multiplying it by a factor of O_s, which is derived as follows:

$$O_s = (A_i \times O_i) + (A_f \times O_f)$$

where

O_s = percent opacity of the shading device

A_i = percent of the area of the shading device that is a partially opaque infill

O_i = percent opacity of the infill for glass $O_i = (100\% - T_s)$, where T_s is the solar transmittance as determined in accordance with NFRC 300; for perforated or decorative metal panels, O_i = percentage of solid material

A_f = percent of the area of the shading device that represents the framing members

O_f = percent opacity of the framing members; if solid, then 100%

The SHGC in the proposed building then shall be reduced by using the multipliers in Table 5.5.4.4.1 for each fenestration product.

3. Vertical fenestration that is located on the street side of the street-level story only, provided that
   a. the street side of the street-level story does not exceed 20 ft in height,
   b. the fenestration has a continuous overhang with a weighted average PF greater than 0.5, and
   c. the fenestration area for the street side of the street-level story is less than 75% of the gross wall area for the street side of the street-level story.

   When this exception is utilized, separate calculations shall be performed for these sections of the building envelope, and these values shall not be averaged with any others for compliance purposes. No credit shall be given here or elsewhere in the building for not fully utilizing the fenestration area allowed.
4. For dynamic glazing, the minimum SHGC shall be used to demonstrate compliance with this section. Dynamic glazing shall be considered separately from other vertical fenestration, and area-weighted averaging with other vertical fenestration that is not dynamic glazing shall not be permitted.
5. Vertical fenestration that is north-oriented shall be allowed to have a maximum solar heat gain coefficient SHGC-0.05 greater than that specified in Tables 5.5-1 through 5.5-8. When this exception is utilized, separate calculations shall be performed for these sections of the building envelope, and these values shall not be averaged with any others for compliance purposes.

TABLE 5.5.4.4.1 SHGC MULTIPLIERS FOR PERMANENT PROJECTIONS

Projection Factor	SHGC Multiplier (all Other Orientations)	SHGC Multiplier (North-Oriented)
0–0.60	1.00	1.00
>0.60–0.70	0.92	0.96
>0.70–0.80	0.84	0.94
>0.80–0.90	0.77	0.93
>0.90–1.00	0.72	0.90

5.5.4.4.2 SHGC of Skylights. Skylights shall have an SHGC not greater than that specified in Table 5.5.

Exceptions:

1. Skylights are exempt from SHGC requirements provided the following:
   a. They have a glazing material or diffuser with a measured haze value greater than 90% when tested according to ASTM D1003.
   b. They have a skylight VT greater than 0.40.
   c. They have all general lighting in the daylight area under skylights controlled by multilevel photocontrols in accordance with Section 9.4.1.1(f).
2. For dynamic glazing, the minimum SHGC shall be used to demonstrate compliance with this section. Dynamic glazing shall be considered separately from other skylights, and area-weighted averaging with other skylights that is not dynamic glazing shall not be permitted.

5.5.4.5 Fenestration Orientation. The vertical fenestration shall comply with either (a) or (b):

a. $A_W \leq (A_T)/4$ and $A_E \leq (A_T)/4$
b. $A_W \times SHGC_W \leq (A_T \times SHGC_C)/4$ and $A_E \times SHGC_E \leq (A_T \times SHGC_C)/4$

where

A_w = west-oriented vertical fenestration area (oriented within 45 degrees of true west to the south and within 22.5 degrees of true west to the north in the northern hemisphere; oriented within 45 degrees of true west to the north and within 22.5 degrees of true west to the south in the southern hemisphere)

A_e = east-oriented vertical fenestration area (oriented within 45 degrees of true east to the south and within 22.5 degrees of true east to the north in the northern hemisphere; oriented within 45 degrees of true east to the north and within 22.5 degrees of true east to the south in the southern hemisphere)

A_T = total vertical fenestration area

$SHGC_C$ = SHGC criteria in Tables 5.5-1 through 5.5-8 for each climate zone

$SHGC_E$ = SHGC for east-oriented fenestration that complies with Section 5.5.4.4.1

$SHGC_W$ = SHGC for west-oriented fenestration that complies with Section 5.5.4.4.1

Exceptions:

1. Vertical fenestration that complies with Exception (3) Section 5.5.4.4.1.
2. Buildings that have an existing building or existing permanent infrastructure within 20 ft to the south (north in the southern hemisphere) that is at least half as tall as the proposed building
3. Buildings with shade on 75% of the west- and east-oriented vertical fenestration areas from permanent projections, existing buildings, existing permanent infrastructure, or topography at 9 a.m. and 3 p.m. on the summer solstice (June 21 in the northern hemisphere)
4. Alterations and additions with no increase in vertical fenestration area

5. Buildings where the west-oriented and east-oriented vertical fenestration area (as defined in Section 5.5.4.5) does not exceed 20% of the gross wall area for each of those façades, and SHGC on those façades is no greater than 90% of the criteria in Tables 5.5-1 through 5.5-8
6. Buildings in Climate Zone 8

5.5.4.6 Visible Transmittance/SHGC Ratio. Where automatic daylighting controls are required in accordance with Section 9.4.1.1(e) or (f), fenestration shall have a ratio of VT divided by SHGC not less than that specified in Tables 5.5-1 through 5.5-8 for the appropriate fenestration area.

Exceptions:

1. A light-to-solar-gain ratio (LSG) of not less than 1.25 is allowed to be used as an alternative to VT/SHGC. When using this option, the center-of-glass VT and the center-of-glass SHGC shall be determined in accordance with NFRC 300 and NFRC 301, determined by an independent laboratory or included in a database published by a government agency, and certified by the manufacturer.
2. Fenestration not covered in the scope of the NFRC 200
3. Enclosed spaces where the daylight area under rooftop monitors is greater than 50% of the enclosed space floor area
4. Enclosed spaces with skylight(s) that comply with Section 5.5.4.2.3
5. Enclosed spaces where the sidelighting effective aperture is greater than or equal to 0.15
6. For dynamic glazing, the VT/SHGC ratio and the LSG 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.

5.6 Building Envelope Trade-Off Option

5.6.1 The building envelope complies with the standard if

a. the proposed building satisfies the provisions of Sections 5.1, 5.4, 5.7, and 5.8 and
b. the envelope performance factor of the proposed building is less than or equal to the envelope performance factor of the budget building.

5.6.1.1 All components of the building envelope shown on architectural drawings or installed in existing buildings shall be modeled in the proposed building design. The simulation model fenestration and opaque envelope types and area shall be consistent with the design documents. Any envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described, provided it is similar to an assembly being modeled. If not separately described, the area of an envelope assembly shall be added to the area of an assembly of that same type with the same orientation and thermal properties.

5.6.1.2 Trade-Offs Limited to Building Permit. When the building permit being sought applies to less than the whole building, parameters relating to unmodified existing conditions or to future building components shall be identical for both the proposed envelope performance factor and the base envelope performance factor. Future building components shall meet the prescriptive requirements of Section 5.5

5.6.1.3 Envelope performance factor shall be calculated using the procedures of Normative Appendix C.

5.7 Submittals

5.7.1 General. The authority having jurisdiction may require submittal of compliance documentation and supplemental information in accordance with Section 4.2.2 of this standard.

5.7.2 Submittal Document Labeling of Space Conditioning Categories. For buildings that contain spaces that will be only semiheated or unconditioned, and compliance is sought using the semiheated envelope criteria, such spaces shall be clearly indicated on the floor plans that are submitted for review.

5.7.3 Visible Transmittance. Test results required in Section 5.8.2.5 for skylight glazing or diffusers shall be included with construction documents submitted with each application for a permit.

5.7.4 Submittal Documentation of Daylight Areas. Daylighting documentation shall identify daylight areas on floor plans, including the primary sidelighted areas, secondary sidelighted areas, daylight areas under skylights, and daylight areas under roof monitor.

5.8 Product Information and Installation Requirements

5.8.1 Insulation

5.8.1.1 Labeling of Building Envelope Insulation. The rated R-value shall be clearly identified by an identification mark applied by the manufacturer to each piece of building envelope insulation.

Exception: When insulation does not have such an identification mark, the installer of such insulation shall provide a signed and dated certification for the installed insulation listing the type of insulation, the manufacturer, the rated R-value, and, where appropriate, the initial installed thickness, the settled thickness, and the coverage area.

5.8.1.2 Compliance with Manufacturers' Requirements. Insulation materials shall be installed in accordance with manufacturers' recommendations and in such a manner as to achieve rated R-value of insulation.

Exception: Where metal-building roof and metal-building wall insulation is compressed between the roof or wall skin and the structure

5.8.1.3 Loose-Fill Insulation Limitation. Open-blown or poured loose-fill insulation shall not be used in attic roof spaces when the slope of the ceiling is more than three in twelve.

5.8.1.4 Baffles. When eave vents are installed, baffling of the vent openings shall be provided to deflect the incoming air above the surface of the insulation.

5.8.1.5 Substantial Contact. Insulation shall be installed in a permanent manner in substantial contact with the inside surface in accordance with manufacturers' recommendations for the framing system used. Flexible batt insulation installed in floor cavities shall be supported in a permanent manner by supports no greater than 24 in. on center.

Exception: Insulation materials that rely on air spaces adjacent to reflective surfaces for their rated performance.

5.8.1.6 Recessed Equipment. Lighting fixtures; heating, ventilating, and air-conditioning equipment, including wall heaters, ducts, and plenums; and other equipment shall not be recessed in such a manner as to affect the insulation thickness unless

a. the total combined area affected (including necessary clearances) is less than 1% of the opaque area of the assembly,

b. the entire roof, wall, or floor is covered with insulation to the full depth required, or

c. the effects of reduced insulation are included in calculations using an area-weighted-average method and compressed insulation values obtained from Table A9.4-2.

In all cases, air leakage through or around the recessed equipment to the conditioned space shall be limited in accordance with Section 5.4.3.

5.8.1.7 Insulation Protection. Exterior insulation shall be covered with a protective material to prevent damage from sunlight, moisture, landscaping operations, equipment maintenance, and wind.

5.8.1.7.1 In attics and mechanical rooms, a way to access equipment that prevents damaging or compressing the insulation shall be provided.

5.8.1.7.2 Foundation vents shall not interfere with the insulation.

5.8.1.7.3 Insulation materials in ground contact shall have a water absorption rate no greater than 0.3% when tested in accordance with ASTM C272.

5.8.1.8 Location of Roof Insulation. The roof insulation shall not be installed on a suspended ceiling with removable ceiling panels.

5.8.1.9 Extent of Insulation. Insulation shall extend over the full component area to the required rated R-value of insulation, U-factor, C-factor, or F-factor, unless otherwise allowed in Section 5.8.1.

5.8.1.10 Joints in Rigid Insulation. Where two or more layers of rigid insulation board are used in a construction assembly, the edge joints between each layer of boards shall be staggered.

5.8.2 Fenestration and Doors

5.8.2.1 Rating of Fenestration Products. The U-factor, SHGC, VT, and air leakage rate for all manufactured fenestration products shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the National Fenestration Rating Council.

5.8.2.2 Labeling of Fenestration and Door Products. All manufactured and site-built fenestration and door products shall be labeled, or a signed and dated certificate shall be provided, by the manufacturer, listing the U-factor, SHGC, VT, and air leakage rate.

Exception: Doors with less than 25% glazing are not required to list SHGC and VT.

5.8.2.3 U-Factor. U-factors shall be determined in accordance with NFRC 100. U-factors for skylights shall be determined for a slope of 20 degrees above the horizontal.

Exceptions:

1. U-factors from Section A8.1 shall be an acceptable alternative for determining compliance with the U-factor criteria for skylights. Where credit is being taken for a low-emissivity coating, the emissivity of the coating shall be determined in accordance with NFRC 300. Emissivity shall be verified and certified by the manufacturer.
2. U-factors from Section A8.2 shall be an acceptable alternative for determining compliance with the U-factor criteria for vertical fenestration.
3. U-factors from Section A7 shall be an acceptable alternative for determining compliance with the U-factor criteria for opaque doors.
4. For garage doors, ANSI/DASMA105 shall be an acceptable alternative for determining U-factors.

5.8.2.4 Solar Heat Gain Coefficient. SHGC for the overall fenestration area shall be determined in accordance with NFRC 200.

Exceptions:

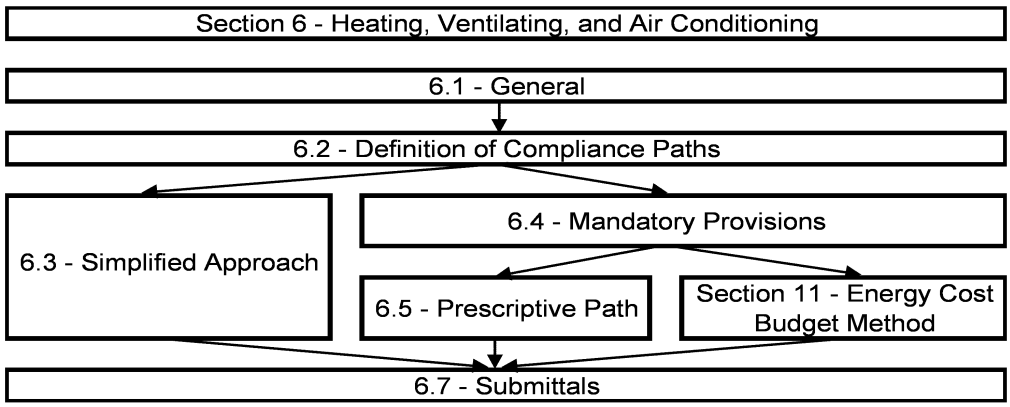
1. Shading coefficient (SC) of the center-of-glass multiplied by 0.86 shall be an acceptable alternative for determining compliance with the SHGC requirements for the overall fenestration area. SC shall be determined using a spectral data file determined in accordance with NFRC 300. SC shall be verified and certified by the manufacturer.
2. SHGC of the center-of-glass shall be an acceptable alternative for determining compliance with

the SHGC requirements for the overall fenestration area. SHGC shall be determined using a spectral data file determined in accordance with NFRC 300. SHGC shall be verified and certified by the manufacturer.

3. SHGC from Section A8.1 shall be an acceptable alternative for determining compliance with the SHGC criteria for skylights. Where credit is being taken for a low-emissivity coating, the emissivity of the coating shall be determined in accordance with NFRC 300. Emissivity shall be verified and certified by the manufacturer.
4. SHGC from Section A8.2 shall be an acceptable alternative for determining compliance with the SHGC criteria for vertical fenestration.

5.8.2.5 Visible Transmittance. VT shall be determined in accordance with NFRC 200. VT shall be verified and certified by the manufacturer.

Exceptions: For skylights whose transmittances are not within the scope of NFRC 200, their transmittance shall be the solar photometric transmittance of the skylight glazing material(s) determined in accordance with ASTM E972.



6. HEATING, VENTILATING, AND AIR CONDITIONING

6.1 General

6.1.1 Scope

6.1.1.1 New Buildings. Mechanical equipment and systems serving the heating, cooling, ventilating, or refrigeration needs of new buildings shall comply with the requirements of this section as described in Section 6.2.

6.1.1.2 Additions to Existing Buildings. Mechanical equipment and systems serving the heating, cooling, ventilating, or refrigeration needs of additions to existing buildings shall comply with the requirements of this section as described in Section 6.2.

Exception: When HVACR to an addition is provided by existing HVACR systems and equipment, such existing systems and equipment shall not be required to comply with this standard. However, any new systems or equipment installed must comply with specific requirements applicable to those systems and equipment.

6.1.1.3 Alterations to Heating, Ventilating, Air Conditioning, and Refrigeration in Existing Buildings

6.1.1.3.1 New HVACR equipment as a direct replacement of existing HVACR equipment shall comply with the specific minimum efficiency requirements applicable to that equipment.

6.1.1.3.2 New cooling systems installed to serve previously uncooled spaces shall comply with this section as described in Section 6.2.

6.1.1.3.3 Alterations to existing cooling systems shall not decrease economizer capability unless the system complies with Section 6.5.1.

6.1.1.3.4 New and replacement ductwork shall comply with Sections 6.4.4.1 and 6.4.4.2.

6.1.1.3.5 New and replacement piping shall comply with Section 6.4.4.1.

Exceptions: Compliance shall not be required

1. for equipment that is being modified or repaired but not replaced, provided that such modifications and/or repairs will not result in an increase in the annual energy consumption of the equipment using the same energy type;
2. where a replacement or alteration of equipment requires extensive revisions to other systems, equipment, or elements of a building, and such replaced or altered equipment is a like-for-like replacement;
3. for a refrigerant change of existing equipment;
4. for the relocation of existing equipment; or
5. for ducts and piping where there is insufficient space or access to meet these requirements.

6.2 Compliance Paths

6.2.1 Compliance. Compliance with Section 6 shall be achieved by meeting all requirements for Sections 6.1, "General"; Section 6.7, "Submittals"; Section 6.8, "Minimum Equipment Efficiency Tables"; and one of the following:

a. Section 6.3, "Simplified Approach Option for HVAC Systems"

b. Sections 6.4, "Mandatory Provisions" and 6.5, "Prescriptive Path"

c. Sections 6.4, "Mandatory Provisions" and 6.6, "Alternative Compliance Path"

6.2.2 Projects using the Energy Cost Budget Method (see Section 11 of this standard) must comply with Section 6.4, the mandatory provisions of this section, as a portion of that compliance path.

6.3 Simplified Approach Option for HVAC Systems

6.3.1 Scope. The simplified approach is an optional path for compliance when the following conditions are met:

a. The building is two stories or fewer in height.

b. Gross floor area is less than 25,000 ft^2.

c. Each HVAC system in the building complies with the requirements listed in Section 6.3.2.

6.3.2 Criteria. The HVAC system shall meet all of the following criteria:

a. The system serves a single HVAC zone.

b. The equipment must meet the variable flow requirements of Section 6.5.3.2.1.

c. Cooling (if any) shall be provided by a unitary packaged or split-system air conditioner that is either air cooled or evaporatively cooled, with efficiency meeting the requirements shown in Table 6.8.1-1 (air conditioners), Table 6.8.1-2 (heat pumps), or Table 6.8.1-4 (packaged terminal and room air conditioners and heat pumps) for the applicable equipment category. All building projects complying with the Alternate Renewables Approach in Section 13.1.1.2 shall comply with the equipment efficiency requirements in Section 13.1.1.2 in place of Tables 6.8.1-1 through 6.8.1-11 and shall comply with the applicable ENERGY STAR heating and cooling requirements in Section 10.11.2.

d. The system shall have an air economizer meeting the requirements of Section 6.5.1.

e. Heating (if any) shall be provided by a unitary packaged or split-system heat pump that meets the applicable efficiency requirements shown in Table 6.8.1-2 (heat pumps) or Table 6.8.1-4 (packaged terminal and room air conditioners and heat pumps), a fuel-fired furnace that meets the applicable efficiency requirements shown in Table 6.8.1-5 (furnaces, duct furnaces, and unit heaters), an electric resistance heater, or a baseboard system connected to a boiler that meets the applicable efficiency requirements shown in Table 6.8.1-6 (boilers).

f. The system shall meet the exhaust air energy recovery requirements of Section 6.5.6.1.

g. The system shall be controlled by a manual changeover or dual setpoint thermostat.

h. If a heat pump equipped with auxiliary internal electric resistance heaters is installed, controls shall be provided that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles. The heat pump must be controlled by either (1) a digital or electronic thermostat designed for heat-pump use that energizes auxiliary heat only when the heat pump has insufficient capacity to maintain setpoint or to warm up the space at a sufficient rate or (2) a multistage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last stage of the space thermostat and when outdoor air temperature is less than 40°F.

Exception: Heat pumps that comply with the following:

1. Have a minimum efficiency regulated by NAECA
2. Meet the requirements in Table 6.8.1-2
3. Include all usage of internal electric resistance heating

i. The system controls shall not permit reheat or any other form of simultaneous heating and cooling for humidity control.

j. Systems serving spaces other than hotel/motel guest rooms, and other than those requiring continuous operation, which have both a cooling or heating capacity greater than 15,000 Btu/h and a supply fan motor power greater than 0.75 hp, shall be provided with a time clock that (1) can start and stop the system under different schedules for seven different day types per week, (2) is capable of retaining programming and time setting during a loss of power for a period of at least ten hours, (3) includes an accessible manual override that allows temporary operation of the system for up to two hours, (4) is capable of temperature setback down to 55°F during off hours, and (5) is capable of temperature setup to 90°F during off hours.

k. Except for piping within manufacturers' units, HVAC piping shall be insulated in accordance with Tables 6.8.3-1 and 6.8.3-2. Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation.

l. Ductwork and plenums shall be insulated in accordance with Tables 6.8.2-1 and 6.8.2-2 and shall be sealed in accordance with Section 6.4.4.2.1.

m. Construction documents shall require a ducted system to be air balanced in accordance with industry accepted procedures.

n. Outdoor air intake and exhaust systems shall meet the requirements of Section 6.4.3.4.

o. Where separate heating and cooling equipment serves the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling.

p. Systems with a design supply air capacity greater than 10,000 cfm shall have optimum start controls.

q. The system shall comply with the demand control ventilation requirements in Section 6.4.3.8.

r. The system complies with the door switch requirements in Section 6.5.10.

6.4 Mandatory Provisions

6.4.1 Equipment Efficiencies, Verification, and Labeling Requirements

6.4.1.1 Minimum Equipment Efficiencies—Listed Equipment—Standard Rating and Operating Conditions. Equipment shown in Tables 6.8.1-1 through 6.8.1-13 shall have a minimum performance at the specified rating conditions when tested in accordance with the specified test procedure. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements unless otherwise exempted by footnotes in the table. Equipment covered under the Federal Energy Policy Act of 1992 (EPACT) shall have no minimum efficiency requirements for operation at minimum capacity or other than standard rating conditions. Equipment used to provide water heating functions as part of a combination system shall satisfy all stated requirements for the appropriate space heating or cooling category.

Tables are as follows:

a. Table 6.8.1-1—Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

b. Table 6.8.1-2—Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements

c. Table 6.8.1-3—Water-Chilling Packages—Efficiency Requirements (see Section 6.4.1.2 for water-cooled centrifugal water-chilling packages that are designed to operate at nonstandard conditions.)

d. Table 6.8.1-4—Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single-Package Vertical Heat Pumps, Room Air Conditioners, and Room Air Conditioner Heat Pumps—Minimum Efficiency Requirements

e. Table 6.8.1-5—Warm-Air Furnaces, Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters

f. Table 6.8.1-6—Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements

g. Table 6.8.1-7—Performance Requirements for Heat Rejection Equipment

h. Table 6.8.1-8—Heat Transfer Equipment

i. Table 6.8.1-9—Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements

j. Table 6.8.1-10—Electrically Operated Variable-Refrigerant-Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements

k. Table 6.8.1-11—Air Conditioners and Condensing Units Serving Computer Rooms

l. Table 6.8.1-12—Commercial Refrigerators and Freezers

m. Table 6.8.1-13—Commercial Refrigeration

All furnaces with input ratings of ≥225,000 Btu/h, including electric furnaces, that are not located within the conditioned space shall have jacket losses not exceeding 0.75% of the input rating. Air conditioners primarily serving computer rooms and covered by ASHRAE Standard 127 shall meet the requirements in Table 6.8.1-11. All other air conditioners shall meet the requirements in Table 6.8.1-1.

6.4.1.1.1 Higher-Efficiency Requirements. All *building projects* complying with the Alternate Renewables Approach in Section 13.1.1.2 shall comply with the equipment efficiency requirements in Section 13.1.1.2 in place of Tables 6.8.1-1 through 6.8.1-11 and shall comply with the applicable ENERGY STAR heating and cooling requirements in Section 10.11.2.

6.4.1.1.2 Heat Pump Requirement. For spaces which are both heated and cooled using unitary systems per Tables 6.8.1-1 through 6.8.1-2, and Table 6.8.1-4, heating shall also include use of a heat pump for primary heating. Packaged systems shall not include electric resistance heating unless used as back-up heat and controlled per Section 6.4.3.5.

Exceptions:

a. Water cooled systems in Tables 6.8.1-1 and 6.8.1-2 where no additional water heating is provided during the heating season.

b. In retrofit applications and additions, where the use of a central heating system is already being used such as hydronic heating or central forced air furnace.

6.4.1.2 Minimum Equipment Efficiencies—Listed Equipment—Nonstandard Conditions

6.4.1.2.1 Water-Cooled Centrifugal Chilling Packages. Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44°F leaving chilled-fluid temperature and 2.4 gpm/ton evaporator fluid flow and 85°F entering condenser-fluid temperature with 3.0 gpm/ton condenser-fluid flow shall have maximum full-load kW/ton (FL) and part-load rating requirements adjusted using the following equations:

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

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

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

where

FL = full-load kW/ton value from Table 6.8.1-3

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

IPLV = IPLV value from Table 6.8.1-3

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

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

B = $0.0015 \times \text{LvgEvap} + 0.934$

LIFT = LvgCond – LvgEvap

LvgCond = full-load condenser leaving fluid temperature (°F)

LvgEvap = full-load evaporator leaving temperature (°F)

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

- Minimum Evaporator Leaving Temperature: 36°F
- Maximum Condenser Leaving Temperature:115°F
- 20°F ≤ LIFT ≤ 80°F

Manufacturers shall calculate the FL_{adj} and PLV_{adj} before determining whether to label the chiller per Section 6.4.1.5. Compliance with 90.1-2007, 2010, 2013, or combinations thereof, shall be labeled on chillers within the scope of the standard.

Centrifugal chillers designed to operate outside of these ranges are not covered by this standard.

Example: Path A 600 ton centrifugal chiller Table 6.8.1-3 efficiencies effective 1/1/2015:

FL = 0.560 kW/ton

IPLV = 0.500 kW/ton

LvgCond = 91.16°F

LvgEvap = 42.00°F

LIFT = 91.16 – 42 = 49.16°F

K_{adj} = $A \times B$

A = $0.00000014592 \times (49.16)^4 - 0.0000346496 \times (49.16)^3 + 0.00314196 \text{ x } (49.16)^2 - 0.147199 \times (49.16) + 3.9302 = 1.0228$

B = $0.0015 \times 42 + 0.934 = 0.9970$

FL_{adj} = $0.560/(1.0228 \times 0.9970) = 0.549$ kW/ton

PLV_{adj} = $0.500/(1.0228 \times 0.9970) = 0.490$ kW/ton

6.4.1.2.2 Positive Displacement (Air- and Water-Cooled) Chilling Packages. Equipment with an evaporator leaving fluid temperature higher than 32°F and water-cooled positive displacement chilling packages with a condenser leaving fluid temperature below 115°F shall show compliance with Table 6.8.1-3 when tested or certified with water at standard rating conditions, per the referenced test procedure.

6.4.1.3 Equipment Not Listed. Equipment not listed in the tables referenced in Sections 6.4.1.1 and 6.4.1.2 may be used.

6.4.1.4 Verification of Equipment Efficiencies. Equipment efficiency information supplied by manufacturers shall be verified by one of the following:

a. Equipment covered under EPACT shall comply with U.S. Department of Energy certification requirements.

b. 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.

c. 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.

d. If no certification program exists for a covered product, the equipment efficiency ratings shall be supported by data furnished by the manufacturer.

e. Where components such as indoor or outdoor coils from different manufacturers are used, the system designer shall specify component efficiencies whose combined efficiency meets the minimum equipment efficiency requirements in Section 6.4.1.

f. Requirements for plate-type liquid-to-liquid heat exchangers are listed in Table 6.8.1-8.

6.4.1.5 Labeling

6.4.1.5.1 Mechanical Equipment. Mechanical equipment that is not covered by the U.S. National Appliance Energy Conservation Act (NAECA) of 1987 shall carry a permanent label installed by the manufacturer stating that the equipment complies with the requirements of Standard 90.1.

6.4.1.5.2 Packaged Terminal Air Conditioners. Nonstandard-size packaged terminal air conditioners and heat pumps with existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 $in.^2$ shall be factory labeled as follows: *Manufactured for nonstandard-size applications only: Not to be installed in new construction projects.*

6.4.2 Calculations

6.4.2.1 Load Calculations. Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with ANSI/ASHRAE/ACCA Standard 183.

6.4.2.2 Pump Head. Pump differential pressure (head) for the purpose of sizing pumps shall be determined in accordance with generally accepted engineering standards and handbooks acceptable to the adopting authority. The pressure drop through each device and pipe segment in the critical circuit at design conditions shall be calculated.

6.4.3 Controls

6.4.3.1 Zone Thermostatic Controls

6.4.3.1.1 General. The supply of heating and cooling energy to each zone shall be individually controlled by thermostatic controls responding to temperature within the zone. For the purposes of this section, a dwelling unit shall be permitted to be considered a single zone.

Exceptions: Independent perimeter systems that are designed to offset only building envelope loads shall be permitted to serve one or more zones also served by an interior system, provided that

1. the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for 50 contiguous feet or more and
2. the perimeter system heating and cooling supply is controlled by a thermostatic control(s) located within the zones(s) served by the system.

Exterior walls are considered to have different orientations if the directions they face differ by more than 45 degrees.

6.4.3.1.2 Dead Band. Where used to control both heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or dead band of at least 5°F within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

Exceptions:

1. Thermostats that require manual changeover between heating and cooling modes
2. Special occupancy or special applications where wide temperature ranges are not acceptable (such as retirement homes, process applications, museums, some areas of hospitals) and are approved by the authority having jurisdiction

6.4.3.2 Setpoint Overlap Restriction. Where heating and cooling to a zone are controlled by separate zone thermostatic controls located within the zone, means (such as limit switches; mechanical stops; or, for DDC systems, software programming) shall be provided to prevent the heating setpoint from exceeding the cooling setpoint minus any applicable proportional band.

6.4.3.3 Off-Hour Controls. HVAC systems shall have the off-hour controls required by Sections 6.4.3.3.1 through 6.4.3.3.4.

Exceptions:

1. HVAC systems intended to operate continuously
2. HVAC systems having a design heating capacity and cooling capacity less than 15,000 Btu/h that are equipped with readily accessible manual on/off controls

6.4.3.3.1 Automatic Shutdown. HVAC systems shall be equipped with at least one of the following:

a. Controls that can start and stop the system under different time schedules for seven different day types per week, are capable of retaining programming and time setting during loss of power for a period of at least ten hours, and include an accessible manual override, or equivalent function, that allows temporary operation of the system for up to two hours

b. An occupant sensor that is capable of shutting the system off when no occupant is sensed for a period of up to 30 minutes

c. A manually operated timer capable of being adjusted to operate the system for up to two hours

d. An interlock to a security system that shuts the system off when the security system is activated

Exception: Residential occupancies may use controls that can start and stop the system under two different time schedules per week.

6.4.3.3.2 Setback Controls. Heating systems shall be equipped with controls configured to automatically restart and temporarily operate the system as required to maintain zone temperatures above an adjustable heating setpoint at least 10°F below the occupied heating setpoint. Cooling systems shall be equipped with controls configured to automatically restart and temporarily operate the mechanical cooling system as required to maintain zone temperatures below an adjustable cooling setpoint at least 5°F above the occupied cooling setpoint or to prevent high space humidity levels.

Exception: Radiant heating systems configured with a setback heating setpoint at least 4°F below the occupied heating setpoint

6.4.3.3.3 Optimum Start Controls. Individual heating and cooling systems with setback controls and DDC shall have optimum start controls. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied setpoint, the outdoor temperature, and the amount of time prior to scheduled occupancy. Mass radiant floor slab systems shall incorporate floor temperature into the optimum start algorithm.

6.4.3.3.4 Zone Isolation. HVAC systems serving zones that are intended to operate or be occupied nonsimultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 25,000 ft^2 of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outdoor air to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting the requirements of Section 6.4.3.3.1.

For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

Exceptions: Isolation devices and controls are not required for

1. exhaust air and outdoor air connections to isolation zones when the fan system to which they connect is 5000 cfm and smaller;
2. exhaust airflow from a single isolation zone of less than 10% of the design airflow of the exhaust system to which it connects; or
3. zones intended to operate continuously or intended to be inoperative only when all other zones are inoperative.

6.4.3.4 Ventilation System Controls

6.4.3.4.1 Stair and Shaft Vents. Stair and elevator shaft vents shall be equipped with motorized dampers that are capable of being automatically closed during normal building operation and are interlocked to open as required by fire and smoke detection systems.

6.4.3.4.2 Shutoff Damper Controls. All outdoor air intake and exhaust systems shall be equipped with motorized dampers that will automatically shut when the systems or spaces served are not in use. Ventilation outdoor air and exhaust/relief dampers shall be capable of automatically shutting off during preoccupancy building warm-up, cooldown, and setback, except when ventilation reduces energy costs or when ventilation must be supplied to meet code requirements.

Exceptions:

1. Back draft gravity (nonmotorized) dampers are acceptable for exhaust and relief in buildings less than three stories in height and for ventilation air intakes and exhaust and relief dampers in buildings of any height located in Climate Zones 1, 2, and 3. Back draft dampers for ventilation air intakes must be protected from direct exposure to wind.
2. Back draft gravity (nonmotorized) dampers are acceptable in systems with a design outdoor air intake or exhaust capacity of 300 cfm or less.
3. Dampers are not required in ventilation or exhaust systems serving unconditioned spaces.
4. Dampers are not required in exhaust systems serving Type 1 kitchen exhaust hoods.

6.4.3.4.3 Damper Leakage. Where outdoor air supply and exhaust/relief dampers are required by Section 6.4.3.4.1, they shall have a maximum leakage rate as indicated in Table 6.4.3.4.3 when tested in accordance with AMCA Standard 500.

TABLE 6.4.3.4.3 Maximum Damper Leakage, cfm per ft^2 at 1.0 in. wc

Climate Zone	Ventilation Air Intake		Exhaust/Relief	
	Nonmotorized[a]	Motorized	Nonmotorized[a]	Motorized
1, 2	—	—	—	—
Any height	20	4	20	4
3	—	—	—	—
Any height	20	10	20	10
4, 5b, 5c	—	—	—	—
Fewer than three stories	NA	10	20	10
Three or more stories	NA	10	NA	10
5a, 6, 7, 8	—	—	—	—
Fewer than three stories	NA	4	20	4
Three or more stories	NA	4	NA	4

a. Dampers smaller than 24 in. in either dimension may have leakage of 40 cfm/ft^2.
NA = Not allowed

6.4.3.4.4 Ventilation Fan Controls. Fans with motors greater than 0.75 hp shall have automatic controls complying with Section 6.4.3.3.1 that are capable of shutting off fans when not required.

Exception: HVAC systems intended to operate continuously.

6.4.3.4.5 Enclosed Parking Garage Ventilation. Enclosed parking garage ventilation systems shall automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of design capacity, provided acceptable contaminant levels are maintained.

Exceptions:

1. Garages less than 30,000 ft^2 with ventilation systems that do not utilize mechanical cooling or mechanical heating
2. Garages that have a garage area to ventilation system motor nameplate hp ratio that exceeds 1500 ft^2/hp and do not utilize mechanical cooling or mechanical heating.
3. Where not permitted by the authority having jurisdiction.

6.4.3.5 Heat Pump Auxiliary Heat Control. Heat pumps equipped with internal electric resistance heaters shall have controls that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles.

Exception: Heat pumps whose minimum efficiency is regulated by NAECA and whose ratings meet the requirements shown in Table 6.8.1-2 and include all usage of internal electric resistance heating.

6.4.3.6 Humidification and Dehumidification. Humidity control shall prevent the use of fossil fuel or electricity to produce RH above 30% in the warmest zone served by the humidification system and to reduce RH below 60% in the coldest zone served by the dehumidification system. Where a zone is served by a system or systems with both humidification and dehumidification capability, means (such as limit switches, mechanical stops, or, for DDC systems, software programming) shall be provided capable of preventing simultaneous operation of humidification and dehumidification equipment.

Exceptions:

1. Zones served by desiccant systems, used with direct evaporative cooling in series
2. Systems serving zones where specific humidity levels are required, such as museums and hospitals, and approved by the authority having jurisdiction or required by accreditation standards and humidity controls are configured to maintain a deadband of at least 10% RH where no active humidification or dehumidification takes place
3. Systems serving zones where humidity levels are required to be maintained with precision of not more than ±5% RH to comply with applicable codes or accreditation standards or as approved by the authority having jurisdiction

6.4.3.7 Freeze Protection and Snow/Ice Melting Systems. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls capable of shutting off the systems when outdoor air temperatures are above 40°F or when the conditions of the protected fluid will prevent freezing. Snow- and ice-melting systems shall include automatic controls capable of shutting off the systems 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 so that the potential for snow or ice accumulation is negligible.

6.4.3.8 Ventilation Controls for High-Occupancy Areas. *Demand control ventilation (DCV)* shall be provided for *densely occupied spaces* served by systems with one or more of the following:

a. Air-side economizer.

b. Automatic modulating control of outdoor air dampers.

c. Design outdoor airflow greater than 1000 cfm.

Exceptions:

1. Systems with the exhaust air energy recovery complying with Section 6.5.6.1.
2. Systems with a design outdoor airflow less than 750 cfm (375 L/s).
3. *Spaces* where more than 75% of the *space* design *outdoor airflow* is utilized as *makeup air* or *transfer air* to provide *makeup air* for other *space(s).*
4. *Spaces* with one of the following occupancy categories as defined in ASHRAE Standard 62.1: cells in correctional facilities; daycare sickrooms; science laboratories; barbers; beauty and nail salons; and bowling alleys.

6.4.3.8.1 Design of DCV System. The DCV system shall be designed to be in compliance with Section 6.2.7 of ANSI/ASHRAE Standard 62.1-2013. Occupancy assumptions shall be shown in the design documents for spaces provided with DCV. All CO_2 sensors used as part of a DCV system or any other system that dynamically controls outdoor air shall meet the following requirements:

a. Spaces with CO_2 sensors or air-sampling probes leading to a central CO_2 monitoring station shall be provided with at least one sensor or probe for each 10,000 ft^2

(1000 m^2) of floor space. Sensors or probes shall be installed between 3 and 6 ft (1 and 2 m) above the floor.

b. CO_2 sensors shall be accurate to ±50 ppm at 1000 ppm.

c. *Outdoor air* CO_2 concentrations shall be determined one of the following:

   1. *Outdoor air* CO_2 concentrations shall be dynamically measured using a CO_2 sensor.

   2. When documented statistical data are available on the local ambient CO_2 concentrations, a fixed value typical of the location where the building is located shall be allowed in lieu of an outdoor sensor.

d. Occupant CO_2 generation rate assumptions shall be shown in the design documents.

6.4.3.9 Heating in Vestibules. Heating for vestibules, in accordance with Section 5.4.3.4, and air curtains shall include automatic controls configured to shut off the heating system when outdoor air temperatures are above 45°F. Vestibule heating systems shall also be controlled by a thermostat in the vestibule with a setpoint limited to a maximum of 60°F.

Exception: Vestibules with no heating system or that are tempered with transfer air that would otherwise be exhausted.

6.4.3.10 Direct Digital Control (DDC) Requirements. Direct digital control shall be required as follows.

6.4.3.10.1 DDC Applications. DDC shall be provided in the applications and qualifications listed in Table 6.4.3.10.1.

Exception: DDC is not required for systems using the simplified approach to compliance in accordance with Section 6.3.

6.4.3.10.2 DDC Controls. Where DDC is required by Section 6.4.3.10.1, the DDC system shall be capable of all of the following, as required, to provide the control logic required in Section 6.5:

a. Monitoring zone and system demand for fan pressure, pump pressure, heating, and cooling

b. Transferring zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers

c. Automatically detecting those zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator

d. Readily allowing operator removal of zone(s) from the reset algorithm

6.4.3.10.3 DDC Display. Where DDC is required by Section 6.4.3.10.1 for new buildings, the DDC system shall be capable of trending and graphically displaying input and output points.

TABLE 6.4.3.10.1 DDC Applications and Qualifications

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

6.4.4 HVAC System Construction and Insulation

6.4.4.1 Insulation

6.4.4.1.1 General. Insulation required by this section shall be installed in accordance with industry-accepted standards (see Informative Appendix E). These requirements do not apply to HVAC equipment. Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance and wind, but not limited to the following:

a. Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.
b. Insulation covering chilled-water piping, refrigerant suction piping, or cooling ducts located outside the conditioned space shall include a vapor retardant located outside the insulation (unless the insulation is inherently vapor retardant), all penetrations and joints of which shall be sealed.

6.4.4.1.2 Duct and Plenum Insulation. All supply and return ducts and plenums installed as part of an HVAC air distribution system shall be thermally insulated in accordance with Tables 6.8.2-1 and 6.8.2-2. Projects complying with Chapter 13 shall instead reference Tables A-2 and A-3 in Normative Appendix A, ASHRAE 189.1.

Exceptions:

1. Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with Section 6.4.1.
2. Ducts or plenums located in conditioned spaces.
3. For runouts less than 10 ft. in length to air terminals or air outlets, the rated R-value of insulation need not exceed R-3.5.
4. Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas exceeding 5 ft^2 need not exceed R-2; those 5 ft^2 or smaller need not be insulated.

6.4.4.1.3 Piping Insulation. Piping, including but not limited to, all branch piping and piping components, shall be thermally insulated in accordance with Tables 6.8.3-1 and 6.8.3-2.

Exceptions:

1. Factory-installed piping within HVAC equipment tested and rated in accordance with Section 6.4.1.
2. Piping that conveys fluids having a design operating temperature range between 60°F and 105°F, inclusive.
3. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electricity (such as roof and condensate drains, domestic cold-water supply, natural-gas piping).
4. Where heat gain or heat loss will not increase energy usage (such as liquid refrigerant piping).
5. In piping 1 inch (2.54 cm) or less, insulation is not required for strainers, control valves, and balancing valves.

6.4.4.1.4 Sensible Heating Panel Insulation. All thermally ineffective panel surfaces of sensible heating panels, including U-bends and headers, shall be insulated with a minimum of R-3.5. Adjacent envelope insulation counts toward this requirement.

6.4.4.1.5 Radiant Floor Heating. The bottom surfaces of floor structures incorporating radiant heating shall be insulated with a minimum of R-3.5. Adjacent envelope insulation counts toward this requirement.

Exception: Requirements for heated slab-on-grade floors incorporating radiant heating are in Chapter 5.

6.4.4.2 Ductwork and Plenum Leakage

6.4.4.2.1 Duct Sealing. Ductwork and all plenums with pressure class ratings shall be constructed to Seal Class A, as required to meet the requirements of Section 6.4.4.2.2, and with standard industry practice (see Informative Appendix E). Openings for rotating shafts shall be sealed with bushings or other devices that seal off air leakage. Pressure-sensitive tape shall not be used as the primary sealant unless it has been certified to comply with UL-181A or UL-181B by an independent testing laboratory and the tape is used in accordance with that certification. All connections shall be sealed, including but not limited to spin-ins, taps, other branch connections, access doors, access panels, and duct connections to equipment. Sealing that would void product listings is not required. Spiral lock seams need not be sealed. All duct pressure class ratings shall be designated in the design documents.

6.4.4.2.2 Duct Leakage Tests. Ductwork that is designed to operate at static pressures in excess of 3 in. wc and all ductwork located outdoors shall be leak-tested according to industry-accepted test procedures (see Informative Appendix E). Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. All sections shall be selected by the building owner or the designated representative of the build-

ing owner. Positive pressure leakage testing is acceptable for negative pressure ductwork.The maximum permitted duct leakage shall be

$$L_{max} = C_L P^{0.65}$$

where

L_{max} = maximum permitted leakage, cfm/100 ft^2 duct surface area

C_L = 4, duct leakage class, cfm/100 ft^2 duct surface area at 1 in. wc

P = test pressure, which shall be equal to the design duct pressure class rating, in. wc

6.4.5 Walk-In Coolers and Freezers. Site-assembled or site-constructed walk-in coolers and freezers shall conform to the following requirements:

a. Shall be equipped with automatic door closers that firmly close walk-in doors that have been closed to within 1 in. of full closure.

Exception: Doors wider than 3 ft 9 in. or taller than 7 ft

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

c. Walk-in coolers shall contain wall, ceiling, and door insulation of at least R-25 and walk-in freezers at least R-32.

Exception: Glazed portions of doors or structural members

d. Walk-in freezers shall contain floor insulation of at least R-28.

e. Evaporator fan motors that are less than 1 hp and less than 460 V shall use electronically commutated motors (brushless direct-current motors) or three-phase motors.

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

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

h. Transparent reach-in doors for walk-in coolers, and windows in walk-in cooler doors, shall be double-pane glass with heat-reflective treated glass and gas filled, or they shall be triple-pane glass, either filled with inert gas or with heat-reflective treated glass.

i. Antisweat heaters without antisweat heater controls shall have a total door rail, glass, and frame heater power draw of ≤7.1 W/ft^2 of door opening for walk-in freezers and 3.0 W/ft^2 of door opening for walk-in coolers.

j. Antisweat heater controls shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.

k. Condenser fan motors that are less than 1 hp shall use electronically commutated motors, permanent split capacitor-type motors, or three-phase motors.

l. All walk-in freezers shall incorporate temperature-based defrost termination control with a time limit default. The defrost cycle shall terminate first on an upper temperature limit breach and second upon a time limit breach.

Exception: Walk-in coolers and walk-in freezers combined in a single enclosure greater than 3000 ft^2

6.4.6 Refrigerated Display Case

a. All refrigerated display cases shall conform to Section 6.4.1.1 and Tables 6.8.1-1 through 6.8.1-13.

b. Lighting in refrigerated display cases and glass doors installed on walk-in coolers and freezers shall be controlled by one of the following:

1. Automatic time-switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases or walk-in coolers and freezers may be used to turn the lights on for up to one hour and shall automatically time out to turn the lights off.

2. Motion sensor controls on each display case or walk-in door section that reduce lighting power by at least 50% within three minutes after the area within the sensor range is vacated.

c. All low-temperature display cases shall incorporate temperature-based defrost termination control with a time-limit default. The defrost cycle shall terminate first on an upper temperature limit breach and second upon a time limit breach.

d. Antisweat heater controls shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.

6.5 Prescriptive Path

6.5.1 Economizers. Each cooling system that has a fan shall include either an air or water economizer meeting the requirements of Sections 6.5.1.1 through 6.5.1.5.

a. The minimum size requirements for economizers for comfort cooling and for computer rooms are defined in Table 6.5.1-1.

b. Air-cooled packaged units with a capacity of less than 54,000 Btu/h (16 kW) shall have two stages of capacity control, with the first stage controlling the economizer and the second stage controlling mechanical cooling. Units with a capacity equal to or greater than 54,000 Btu/h (16 kW) shall comply with the staging requirements defined in Section 6.5.3.1

c. For systems that control to a fixed leaving air temperature (i.e., variable-air-volume [VAV] systems), the system shall be capable of resetting the supply air temperature up at least 5°F (3°C) during economizer operation.

Exceptions: Economizers are not required for the following systems:

1. Individual fan-cooling units with a supply capacity less than the minimum listed in Table 6.5.1-1 for comfort cooling applications and Table 6.5.1-2 for computer room applications.
2. Systems that include nonparticulate air treatment as required by Section 6.2.1 in Standard 62.1.
3. In hospitals and ambulatory surgery centers, where more than 75% of the air designed to be supplied by the system is to spaces that are required to be humidified above 35°F dew-point temperature to comply with applicable codes or accreditation standards; in all other buildings, where more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F dew-point temperature to satisfy process needs. This exception does not apply to computer rooms.
4. Systems that include a condenser heat recovery system with a minimum capacity as defined in Section 6.5.6.2.2.
5. Systems that serve residential spaces where the system capacity is less than five times the requirement listed in Table 6.5.1-1.
6. Systems that serve spaces whose sensible cooling load at design conditions, excluding transmission and infiltration loads, is less than or equal to transmission and infiltration losses at an outdoor temperature of 60°F.
7. Systems expected to operate less than 20 hours per week.
8. Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems.
9. For comfort cooling where the cooling efficiency meets or exceeds the efficiency improvement requirements in Table 6.5.1-3.
    a. Where the reduced renewable approach defined in Section 13.1.1.2 is used, Exception (9) shall be permitted to eliminate the economizer requirement, provided the requirements in Table 6.5.1-3 are applied to the efficiency requirements required by Section 13.1.1.2. If the standard renewable approach is chosen as defined in Section 13.1.1.1 then the requirements in Table 6.5.1-3 shall be applied to the efficiency requirements in Tables 6.8.1-1 through 6.8.1-11.
10. Systems primarily serving computer rooms where:
    a. The total design cooling load of all computer rooms in the building is less than 3,000,000 Btu/h and the building in which they are located is not served by a centralized chilled water plant;
    b. The room total design cooling load is less than 600,000 Btu/h and the building in which they are located is served by a centralized chilled water plant;
    c. The local water authority does not allow cooling towers; or
    d. Less than 600,000 Btu/h of computer-room cooling equipment capacity is being added to an existing building
11. For water-cooled units with a capacity less than 54,000 Btu/h (16 kW) that are used in systems where heating and cooling loads are transferred within the building (i.e., water-source heat pump systems), the requirement for an air or water economizer can be eliminated if the condenser-water temperature controls are capable of being set to maintain full-load heat rejection capacity down to a 55°F (12°C) condenser-water supply temperature, and the HVAC equipment is capable of operating with a 55°F (12°C) condenser-water supply temperature.
12. Variable refrigerant volume with energy recovery or variable refrigerant flow with energy recovery systems. (VRV/VRF).

TABLE 6.5.1-1 Minimum Fan-Cooling Unit Size for which an Economizer is Required for Comfort Cooling

Climate Zones	Cooling Capacity for Which an Economizer is Required
1a, 1b	No economizer requirement
2a, 2b, 3a, 3b, 3c, 4a, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	≥33,000 Btu/h[a]

a. Where economizers are required, the total capacity of all systems without economizers shall not exceed 480,000 Btu/h (140 kW) per building or 10% of the building's installed cooling capacity, whichever is greater.

6.5.1.1 Air Economizers

6.5.1.1.1 Design Capacity. Air economizer systems shall be capable of modulating outdoor air and return air dampers to provide up to 100% of the design supply air quantity as outdoor air for cooling.

TABLE 6.5.1-3 Eliminate Required Economizer for Comfort Cooling by Increasing Cooling Efficiency

Climate Zone	Efficiency Improvement[a]
2a	17%
2b	21%
3a	27%
3b	32%
3c	65%
4a	42%
4b	49%
4c	64%
5a	49%
5b	59%
5c	74%
6a	56%
6b	65%
7	72%
8	77%

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

6.5.1.1.2 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).

6.5.1.1.3 High-Limit Shutoff. All 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 and associated setpoints for specific climate zones shall be chosen from Table 6.5.1.1.3.

6.5.1.1.4 Dampers. Return, exhaust/relief, and outdoor air dampers shall meet the requirements of Section 6.4.3.4.3.

6.5.1.1.5 Relief of Excess Outdoor Air. Systems shall provide a means to relieve excess outdoor air during air economizer operation to prevent overpressurizing the building. The relief air outlet shall be located so as to avoid recirculation into the building.

6.5.1.1.6 Sensor Accuracy. Outdoor air, return air, mixed air, and supply air sensors shall be calibrated within the following accuracies:

a. Dry-bulb and wet-bulb temperatures shall be accurate to ±2°F over the range of 40°F to 80°F.

b. Enthalpy and the value of a differential enthalpy sensor shall be accurate to ±3 Btu/lb over the range of 20 to 36 Btu/lb.

c. Relative humidity shall be accurate to ±5% over the range of 20% to 80% RH.

6.5.1.2 Water Economizers

6.5.1.2.1 Design Capacity. Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100% of the expected system cooling load at outdoor air temperatures of 50°F dry bulb/45°F wet bulb and below.

Exceptions:

1. Systems primarily serving computer rooms in which 100% of the expected system cooling load at the dry-bulb and wet-bulb temperatures

TABLE 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers[b]

Control Type	Allowed Only in Climate Zone at Listed Setpoint	Required High-Limit Setpoints (Economizer Off When):	
		Equation	Description
Fixed dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	T_{OA} > 75°F	Outdoor air temperature exceeds 75°F
	5a, 6a	T_{OA} > 70°F	Outdoor air temperature exceeds 70°F
	1a, 2a, 3a, 4a,	T_{OA} > 65°F	Outdoor air temperature exceeds 65°F
Differential dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperature	All	h_{OA} > 28 Btu/lb[a] or T_{OA} > 75°F	Outdoor air enthalpy exceeds 28 Btu/lb[a] of dry air[a] or outdoor air temperature exceeds 75°F
Differential enthalpy with fixed dry-bulb temperature	All	$h_{OA} > h_{RA}$ or T_{OA} > 75°F	Outdoor air enthalpy exceeds return air enthalpy or outdoor air temperature exceeds 75°F

a. At altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 75°F and 50% RH. As an example, at approximately 6000 ft elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

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

listed in Table 6.5.1.2.1 is met with evaporative water economizers

2. Systems primarily serving computer rooms in which 100% of the expected system cooling load at the dry-bulb temperatures listed in Table 6.5.1.2.1 is met with dry cooler water economizers
3. Systems where dehumidification requirements cannot be met using outdoor air temperatures of 50°F dry-bulb/45°F wet-bulb and where 100% of the expected system cooling load at 45°F dry-bulb/40°F wet-bulb is met with evaporative water economizers

TABLE 6.5.1.2.1 Water Economizer Sizing Dry-Bulb and Wet-Bulb Requirements for Computer Rooms

Zone		Evaporative Water Economizer		Dry Cooler Water Economizer
		Dry Bulb, °F	Wet Bulb, °F	Dry Bulb, °F
1	A		NR	NR
1	B		NR	NR
2	A	40.0	35.0	30.0
2	B	35.0	30.0	30.0
3	A	40.0	35.0	25.0
3	B	30.0	25.0	25.0
3	C	30.0	25.0	30.0
4	A	40.0	35.0	25.0
4	B	30.0	25.0	25.0
4	C	30.0	25.0	25.0
5	A	40.0	35.0	20.0
5	B	30.0	25.0	20.0
5	C	30.0	25.0	25.0
6	A	35.0	30.0	20.0
6	B	30.0	25.0	20.0
7		30.0	25.0	20.0
8		30.0	25.0	20.0

NR—Not required

6.5.1.2.2 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 ft 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.

6.5.1.3 Integrated Economizer Control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load. Controls shall not false load the mechanical cooling systems by limiting or disabling the economizer or by any other means, such as hot gas bypass, except at the lowest stage of mechanical cooling.

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

a. Unit controls shall have the mechanical cooling capacity control interlocked with the air economizer controls such that the outdoor air damper is at the 100% open position when mechanical cooling is on, and the outdoor air damper does not begin to close to prevent coil freezing due to minimum compressor run time until the leaving air temperature is less than 45°F.
b. DX units that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of two stages of mechanical cooling capacity per the following effective dates:

   ≥75,000 Btu/h Rated Capacity—Effective 1/1/2014

   ≥65,000 Btu/h Rated Capacity—Effective 1/1/2016

c. Effective 1/1/2014, all other DX units, including those that control space temperature by modulating the airflow to the space, shall comply with the requirements of Table 6.5.1.3.

6.5.1.4 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.

Exceptions: Economizers on VAV systems that cause zone-level heating to increase due to a reduction in supply air temperature

6.5.1.5 Economizer Humidification System Impact. Systems with hydronic cooling and humidification systems designed to maintain inside humidity at a dew-point temperature greater than 35°F shall use a water economizer if an economizer is required by Section 6.5.1.

TABLE 6.5.1.4 DX Cooling Stage Requirements for Modulating Airflow Units

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

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

6.5.2 Simultaneous Heating and Cooling Limitation

6.5.2.1 Zone Controls. Zone thermostatic controls shall prevent:

a. Reheating;

b. Recooling;

c. Mixing or simultaneously supplying air that has been previously mechanically heated and air that has been previously cooled, either by mechanical cooling or by economizer systems; and

d. Other simultaneous operation of heating and cooling systems to the same zone.

Exceptions:

1. Commercial kitchens.
2. Zones with DDC that comply with all of the following:
   a. The airflow rate in dead band between heating and cooling does not exceed the larger of the following:
      (i) 20% of the zone design peak supply rate.
      (ii) The design outdoor airflow rate for the zone.
      (iii) Any higher rate that can be demonstrated, to the satisfaction of the authority having jurisdiction, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake.
      (iv) The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.
   b. The airflow rate that is reheated, recooled, or mixed shall be less than 50% of the zone design peak supply rate.
   c. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint while the airflow is maintained at the dead band flow rate.
   d. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate.
3. Laboratory exhaust systems that comply with Section 6.5.7.2
4. Zones where at least 75% of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered (including condenser heat) or site-solar energy source.

6.5.2.1.1 Supply Air Temperature Reheat Limit. Where reheating is permitted by other parts of this standard, zones that have both supply and return/exhaust air openings greater than 6 ft above floor shall not supply heating air more than 20°F above the space temperature setpoint.

Exceptions:

1. Laboratory exhaust systems that comply with Section 6.5.7.2.
2. During preoccupancy building warm-up and setback

6.5.2.2 Hydronic System Controls. The heating of fluids in hydronic systems that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections 6.5.2.2.1 through 6.5.2.2.3.

6.5.2.2.1 Three-Pipe System. Hydronic systems that use a common return system for both hot water and chilled water shall not be used.

6.5.2.2.2 Two-Pipe Changeover System. Systems that use a common distribution system to supply both heated and chilled water are acceptable provided all of the following are met:

a. The system is designed to allow a dead band between changeover from one mode to the other of at least 15°F outdoor air temperature.

b. The system is designed to operate and is provided with controls that will allow operation in one mode for at least four hours before changing over to the other mode.

c. Reset controls are provided that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F apart.

6.5.2.2.3 Hydronic (Water Loop) Heat Pump Systems. Hydronic heat pumps connected to a common heat-pump water loop with central devices for heat rejection (e.g., cooling tower) and heat addition (e.g., boiler) shall have the following:

a. Controls that are capable of providing a heat-pump water supply temperature dead band of at least 20°F between initiation of heat rejection and heat addition by the central devices (e.g., tower and boiler).

b. For Climate Zones 3 through 8, if a closed-circuit tower (fluid cooler) is used, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers shall be provided. If an open-circuit tower is used directly in the heat-pump loop, an automatic valve shall be installed to bypass all heat-pump water flow around the tower. If an open-circuit tower is

used in conjunction with a separate heat exchanger to isolate the tower from the heat-pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

Exception: Where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20°F shall be allowed.

6.5.2.3 Dehumidification. Where humidity controls are provided, such controls shall prevent reheating, mixing of hot and cold airstreams, or other means of simultaneous heating and cooling of the same airstream.

Exceptions:

1. The system is configured to reduce supply air volume to 50% or less of the design airflow rate or the minimum outdoor air ventilation rate specified in ASHRAE Standard 62.1 or other applicable federal, state, or local code or recognized standard, whichever is larger, before simultaneous heating and cooling takes place.
2. The individual fan cooling unit has a design cooling capacity of 65,000 Btu/h or less and is capable of unloading to 50% capacity before simultaneous heating and cooling takes place.
3. The individual mechanical cooling unit has a design cooling capacity of 40,000 Btu/h or less. An individual mechanical cooling unit is a single system composed of a fan or fans and a cooling coil capable of providing mechanical cooling.
4. Systems serving spaces where specific humidity levels are required to satisfy process needs, such as vivariums, museums, surgical suites, pharmacies, and buildings with refrigerating systems, such as supermarkets, refrigerated warehouses, and ice arenas, and the building includes site-recovered or site solar energy source that provide energy equal to at least 75% of the annual energy for reheating or for providing warm air in mixing systems. This exception does not apply to computer rooms.
5. At least 90% of the annual energy for reheating or for providing warm air in mixing systems is provided from a site-recovered (including condenser heat) or site-solar energy source.
6. Systems where the heat added to the airstream is the result of the use of a desiccant system and 75% of the heat added by the desiccant system is removed by a heat exchanger, either before or after the desiccant system with energy recovery.

6.5.2.4 Humidification

6.5.2.4.1 Humidifiers with preheating jackets mounted in the airstream shall be provided with an automatic valve to shut off preheat when humidification is not required.

6.5.2.4.2 Humidification system dispersion tube hot surfaces in the airstreams of ducts or air-handling units shall be insulated with a product with an insulating value of at least R-0.5.

Exception: Systems where mechanical cooling, including economizer operation, does not occur simultaneously with humidification

6.5.2.5 Preheat Coils. Preheat coils shall have controls that stop their heat output whenever mechanical cooling, including economizer operation, is occurring.

6.5.3 Air System Design and Control. Each HVAC system having a total fan system motor nameplate hp exceeding 5 hp shall meet the provisions of Sections 6.5.3.1 through 6.5.3.5. Hotels and motels with more than 50 guest rooms shall comply with Section 6.5.12.

6.5.3.1 Fan System Power and Efficiency

6.5.3.1.1 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 6.5.3.1-1. This includes supply fans, return/relief fans, exhaust fans, and fan-powered terminal units associated with systems providing heating or cooling capability. Single-zone variable-air-volume systems shall comply with the constant-volume fan power limitation.

Exceptions:

1. Hospital, vivarium, and laboratory systems that utilize flow control devices on exhaust and/or

TABLE 6.5.3.1-1 FAN POWER LIMITATION[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan system motor nameplate hp	Allowable nameplate motor hp	$hp \le cfm_S \cdot 0.00099$	$hp \le cfm_S \cdot 0.00135$
Option 2: Fan system bhp	Allowable fan system bhp	$bhp \le cfm_S \cdot 0.00084 + A$	$bhp \le cfm_S \cdot 0.00117 + A$

a. where
cfm_S=maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp=maximum combined motor nameplate horsepower
hp= maximum combined fanbrake horsepower
A=sum of (PD × cfm_D/4131)
where
PD=each applicable pressure drop adjustment from Table 6.5.3.1-2 in in. wc
cfm_D=the design airflow through each applicable device from Table 6.5.3.1-2 in cubic feet per minute

return to maintain space pressure relationships necessary for occupant health and safety or environmental control may use variable-volume fan power limitation.

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

6.5.3.1.2 Motor Nameplate Horsepower. For each fan, the selected fan motor shall be no larger than the first available motor size greater than the bhp. The fan bhp must be indicated on the design documents to allow for compliance verification by the code official.

Exceptions:

1. For fans less than 6 bhp, where the first available motor larger than the bhp has a nameplate rating within 50% of the bhp, the next larger nameplate motor size may be selected.
2. For fans 6 bhp and larger, where the first available motor larger than the bhp has a nameplate rating within 30% of the bhp, the next larger nameplate motor size may be selected.
3. Systems complying with Section 6.5.3.1.1, Option 1.

6.5.3.1.3 Fan Efficiency. Fans shall have a fan efficiency grade (FEG) of 67 or higher based on manufacturers' certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 10 percentage points of the maximum total efficiency of the fan.

Exceptions:

1. Single fans with a motor nameplate kilowatts of 5 hp or less.
2. Multiple fans in series or parallel (e.g., fan arrays) that have a combined motor nameplate kilowatts of 5 hp or less and are operated as the functional equivalent of a single fan.
3. Fans that are part of equipment listed under Section 6.4.1.1.
4. Fans included in equipment bearing a third-party-certified seal for air or energy performance of the equipment package.
5. Powered wall/roof ventilators (PRV).
6. Fans outside the scope of AMCA 205.
7. Fans that are intended to only operate during emergency conditions.

TABLE 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment

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

6.5.3.2 Fan Control

6.5.3.2.1 Fan Airflow Control Each cooling system listed in Table 6.5.3.2.1 shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

a. DX and chilled-water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have a minimum of two stages of fan control. Low or minimum speed shall not exceed 66% of full speed. At low or minimum speed, the fan system shall draw no more than 40% of the fan power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

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

c. Units that include an air-side economizer to meet the requirements of Section 6.5.1 shall have a minimum of two speeds of fan control during economizer operation.

Exceptions:

1. Modulating fan control is not required for chilled-water and evaporative cooling units with <1 hp fan motors if the units are not used to provide ventilation air and the indoor fan cycles with the load.
2. If the volume of outdoor air required to meet the ventilation requirements of Standard 62.1 at low speed exceeds the air that would be delivered at the speed defined in Section 6.5.3.2.1(a) or 6.5.3.2.1(b) then the minimum speed shall be selected to provide the required ventilation air.

TABLE 6.5.3.2.1 Effective Dates for Fan Control

Cooling System Type	Fan Motor Size, hp	Mechanical Cooling Capacity, Btu/h	Effective Date
DX cooling	Any	≥110,000	
		≥75,000	1/1/2014
		≥65,000	1/1/2016
Chilled-water and evaporative cooling	≥5	Any	
	≥1/4	Any	1/1/2014

6.5.3.2.2 VAV Static Pressure Sensor Location. Static pressure sensors used to control VAV fans shall be located such that the controller setpoint is no greater than 1.2 in. wc. If this results in the sensor being located downstream of major duct splits, sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.

Exception: Systems complying with Section 6.5.3.2.3

6.5.3.2.3 VAV Setpoint Reset. For systems with DDC of individual zones reporting to the central control panel, 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. Controls shall provide the following:

a. Monitor zone damper positions or other indicator of need for static pressure

b. Automatically detect those zones that may be excessively driving the reset logic and generate an alarm to the system operator

c. Readily allow operator removal of zone(s) from the reset algorithm

6.5.3.3 Multiple-Zone VAV System Ventilation Optimization Control. Multiple-zone VAV systems with DDC of individual zone boxes reporting to a central control panel shall include means to automatically reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency as defined by Appendix A of ASHRAE Standard 62.1.

Exceptions:

1. VAV systems with zonal transfer fans that recirculate air from other zones without directly mixing it with outdoor air, dual-duct dual-fan VAV systems, and VAV systems with fan-powered terminal units
2. Systems required to have the exhaust air energy recovery complying with Section 6.5.6.1
3. Systems where total design exhaust airflow is more than 70% of total design outdoor air intake flow requirements

6.5.3.4 Supply Air Temperature Reset Controls. Multiple zone HVAC systems must include controls that automatically reset the supply air temperature in response to representative building loads, or to outdoor air temperature. The controls shall reset the supply air temperature at least 25% of the difference between the design supply air temperature and the design room air temperature. Controls that adjust the reset based on zone humidity are allowed. Zones that are expected to experience relatively constant loads, such as electronic equipment rooms, shall be designed for the fully reset supply temperature.

Exceptions:

1. Climate Zones 1a, 2a, and 3a

2. Systems that prevent reheating, recooling, or mixing of heated and cooled supply ai.
3. Systems in which at least 75% of the energy for reheating (on an annual basis) is from site recovered or site solar energy sources

6.5.3.5 Fractional Horsepower Fan Motors. Motors for fans that are 1/12 hp or greater and less than 1 hp shall be electronically-commutated motors or shall have a minimum motor efficiency of 70% when rated in accordance with DOE 10 CFR 431. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

Exceptions:

1. Motors in the airstream within fan-coils and terminal units that operate only when providing heating to the space served
2. Motors installed in space conditioning equipment certified under Section 6.4.1
3. Motors covered by Table 10.8-4 or 10.8-5

6.5.4 Hydronic System Design and Control

6.5.4.1 Boiler Turndown. Boiler systems with design input of at least 1,000,000 Btu/h shall comply with the turndown ratio specified in Table 6.5.4.1.

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

All boilers shall meet the minimum efficiency requirements in Table 6.8.1-6.

TABLE 6.5.4.1 Boiler Turndown

Boiler System Design Input, Btu/h	Minimum Turndown Ratio
≥1,000,000 and ≤5,000,000	3 to 1
>5,000,000 and ≤10,000,000	4 to 1
>10,000,000	5 to 1

6.5.4.2 Hydronic Variable Flow Systems. HVAC pumping systems having a total pump system power exceeding 10 hp that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual chilled-water pumps serving variable-flow systems having motors exceeding 5 hp shall have controls and/or devices (such as variable-speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure. The differential pressure setpoint shall be no more than 110% of that required to achieve design flow through the heat exchanger. Where differential pressure control is used to comply with this section and DDC systems are used, the setpoint shall be reset downward based on valve positions until one valve is nearly wide open.

Exceptions:

1. Systems where the minimum flow is less than the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system, such as chillers, and where total pump system power is 75 hp or less
2. Systems that include no more than three control valves

6.5.4.3 Chiller and Boiler Isolation

6.5.4.3.1 When a chilled-water plant includes more than one chiller, provisions shall be made so that all fluid flow through the chiller is automatically shut off when the chiller is shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller. Where constant-speed chilled-water or condenser water pumps are used to serve multiple chillers, the number of pumps shall be no less than the number of chillers and staged on and off with the chillers.

6.5.4.3.2 When a boiler plant includes more than one boiler, provisions shall be made so that the flow through the boiler is automatically shut off when the boiler is shut down. Where constant-speed hot-water pumps are used to serve multiple boilers, the number of pumps shall be no less than the number of boilers and staged on and off with the boilers.

6.5.4.4 Chilled- and Hot-Water Temperature Reset Controls. Chilled- and hot-water systems with a design capacity exceeding 300,000 Btu/h supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature.

Exceptions:

1. Where the supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidifying, or dehumidifying systems
2. Hydronic systems, such as those required by Section 6.5.4.1, that use variable flow to reduce pumping energy

6.5.4.5 Hydronic (Water Loop) Heat Pumps and Water-Cooled Unitary Air-Conditioners

6.5.4.5.1 Each hydronic heat pump and water-cooled unitary air-conditioner shall have a two-position automatic

valve interlocked to shut off water flow when the compressor is off.

Exception: Units employing water economizer

6.5.4.5.2 Hydronic heat pumps and water-cooled unitary air-conditioners having a total pump system power exceeding 5 hp shall have controls and/or devices (such as variable-speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

6.5.4.6 Pipe Sizing. All chilled-water and condenser-water piping shall be designed such that the design flow rate in each piping segment shall not exceed the values listed in Table 6.5.4.6 for the appropriate total annual hours of operation. Piping size selections for systems that operate under variable flow conditions (e.g., modulating two-way control valves at coils) and that contain variable-speed pump motors are allowed to be made from the "Variable Flow/Variable Speed" columns. All others shall be made from the "Other" columns.

Exceptions:

1. Design flow rates exceeding the values in Table 6.5.4.6 are allowed in specific sections of piping if the piping in question is not in the critical circuit at design conditions and is not predicted to be in the critical circuit during more than 30% of operating hours.
2. Piping systems that have equivalent or lower total pressure drop than the same system constructed with standard weight steel pipe with piping and fittings sized per Table 6.5.4.6

6.5.5 Heat Rejection Equipment

6.5.5.1 General. Section 6.5.5 applies to heat rejection equipment used in comfort cooling systems, such as air-cooled condensers, dry coolers, open-circuit cooling towers, closed-circuit cooling towers, and evaporative condensers.

Exception: Heat rejection devices whose energy usage is included in the equipment efficiency ratings listed in Tables 6.8.1-1 through 6.8.1-4

6.5.5.2 Fan Speed Control

6.5.5.2.1 Each fan powered by a motor of 7.5 hp or larger shall have the capability to operate at two-thirds 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.

Exceptions:

1. Condenser fans serving multiple refrigerant circuits
2. Condenser fans serving flooded condensers
3. Installations located in Climate Zones 1 and 2

6.5.5.2.2 Multicell heat rejection equipment with variable-speed fan drives shall

a. operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components and
b. control all fans to the same fan speed required for the instantaneous cooling duty, as opposed to staged (on/off) operation. Minimum fan speed shall comply with the minimum allowable speed of the fan drive system per the manufacturer's recommendations.

6.5.5.3 Limitation on Centrifugal Fan Open-Circuit Cooling Towers. Centrifugal fan open-circuit cooling towers with a combined rated capacity of 1100 gpm or greater at 95°F condenser water return, 85°F condenser water supply, and 75°F outdoor air wet-bulb temperature shall meet the

TABLE 6.5.4.6 Piping System Design Maximum Flow Rate in GPM

Operating Hours/Year	≤2000 Hours/Year		>2000 and ≤4400 Hours/Year		>4400 Hours/Year	
Nominal Pipe Size, in.	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
2 1/2	120	180	85	130	68	110
3	180	270	140	210	110	170
4	350	530	260	400	210	320
5	410	620	310	470	250	370
6	740	1100	570	860	440	680
8	1200	1800	900	1400	700	1100
10	1800	2700	1300	2000	1000	1600
12	2500	3800	1900	2900	1500	2300
Maximum velocity for pipes over 14–24 in. in size	8.5 ft/s	13.0 ft/s	6.5 ft/s	9.5 ft/s	5.0 ft/s	7.5 ft/s

energy efficiency requirement for axial fan open-circuit cooling towers listed in Table 6.8.1-7.

Exception: Centrifugal open-circuit cooling towers that are ducted (inlet or discharge) or require external sound attenuation.

6.5.5.4 Tower Flow Turndown. Open-circuit cooling towers used on water-cooled chiller systems that are configured with multiple- or variable-speed condenser water pumps shall be designed so that all open-circuit cooling tower cells can be run in parallel with the larger of

a. the flow that is produced by the smallest pump at its minimum expected flow rate or
b. 50% of the design flow for the cell.

6.5.6 Energy Recovery

6.5.6.1 Exhaust Air Energy Recovery. Each fan system shall have an energy recovery system when the system's supply airflow rate exceeds the value listed in Tables 6.5.6.1-1 and 6.5.6.1-2, based on the climate zone and percentage of outdoor airflow rate at design conditions. Table 6.5.6.1-1 shall be used for all ventilation systems that operate less than 8,000 hours per year, and Table 6.5.6.1-2 shall be used for all ventilation systems that operate 8,000 or more hours per year.

Energy recovery systems required by this section shall have at least 60% energy recovery effectiveness. Sixty percent energy recovery effectiveness shall mean a change in the enthalpy of the outdoor air supply equal to 60% of the difference between the outdoor air and return air enthalpies at design conditions. Provision shall be made to bypass or control the energy recovery system to permit air economizer operation as required by Section 6.5.1.1.

Exceptions:

1. Laboratory systems meeting Section 6.5.7.2
2. Systems serving spaces that are not cooled and that are heated to less than 60°F.
3. Systems exhausting toxic, flammable, paint, or corrosive fumes or dust.
4. Commercial kitchen hoods used for collecting and removing grease vapors and smoke.
5. Where more than 60% of the outdoor air heating energy is provided from site-recovered or site solar energy.
6. Where the largest source of air exhausted at a single location at the building exterior is less than 75% of the design outdoor airflow rate.
7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.
8. Systems expected to operate less than 20 hours per week at the outdoor air percentage covered by Table 6.5.6.1-1.

6.5.6.2 Heat Recovery for Service Water Heating

6.5.6.2.1 Condenser heat recovery systems shall be installed for heating or preheating of service hot water provided all of the following are true:

a. The facility operates 24 hours a day.
b. The total installed heat rejection capacity of the water-cooled systems exceeds 6,000,000 Btu/h of heat rejection.
c. The design service water heating load exceeds 1,000,000 Btu/h.

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

a. 60% of the peak heat rejection load at design conditions or
b. preheat of the peak service hot-water draw to 85°F.

Exceptions:

1. Facilities that employ condenser heat recovery for space heating with a heat recovery design

TABLE 6.5.6.1-1 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Less than 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 5C	NR	NR	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥28,000	≥26,500	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥26,000	≥16,000	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7, 8	≥4500	≥4000	≥2500	≥1000	>0	>0	>0	>0

NR—Not required

TABLE 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3C	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	>0
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0

NR—Not required

exceeding 30% of the peak water-cooled condenser load at design conditions

2. Facilities that provide 60% of their service water heating from site-solar or site-recovered energy or from other sources

6.5.6.3 Supermarket Heat Recovery. Supermarkets with a floor area of 25,000 ft^2 (2500 m2) or greater shall recover waste heat from the condenser heat rejection on *permanently installed* refrigeration and/or HVAC equipment meeting one of the following criteria:

a. 25% of the refrigeration system full-load total heat rejection.
b. 80% of the space heat, service water heating, and dehumidification reheat.

If a recovery system is used that is installed in the refrigeration system, the system shall not increase the saturated condensing temperature at design conditions by more than 5°F (3°C) and shall not impair other head pressure control/energy reduction strategies.

6.5.7 Exhaust Systems

6.5.7.1 Kitchen Exhaust Systems

6.5.7.1.1 Replacement air introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10% of the hood exhaust airflow rate.

6.5.7.1.2 Conditioned supply air delivered to any space with a kitchen hood shall not exceed the greater of

a. the supply flow required to meet the space heating or cooling load or
b. the hood exhaust flow minus the available transfer air from adjacent spaces. Available transfer air is that portion of outdoor ventilation air not required to satisfy other exhaust needs, such as restrooms, and not required to maintain pressurization of adjacent spaces

6.5.7.1.3 For kitchen/dining facilities with total kitchen hood exhaust airflow rate greater than 2,000 cfm, the maximum exhaust flow rate for each hood shall be determined in accordance with Table 6.5.7.1.3. For single hoods, or hood sections installed over appliances with different duty ratings, the maximum allowable exhaust flow rate for the hood or hood section shall be determined in accordance with Table 6.5.7.1.3 for the highest appliance duty rating under the hood or hood section. Refer to ASHRAE Standard 154 for definitions of hood type, appliance duty, and net exhaust flow rate.

Exception: When at least 75% of all the replacement air is *transfer air* that would otherwise be exhausted.

6.5.7.1.4 Kitchen/dining facilities with total kitchen hood exhaust airflow rate greater than 2,000 cfm shall comply with at least one of the following:

a. At least 50% of all replacement air shall be *transfer air* that would otherwise be exhausted.
b. At least 75% of kitchen hood exhaust air shall be controlled by a demand ventilation system(s), which shall:
    1. be capable of reducing exhaust and replacement air system airflow rates by no more than the larger of:
        i. 50% of total design exhaust and replacement air system airflow rate, or
        ii. the outdoor airflow and exhaust rates required to meet the ventilation and exhaust requirements of Sections 6.2 and 6.5 of ANSI/ASHRAE Standard 62.1 for the zone.
    2. include controls to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent, and combustion products during cooking and idle;
    3. include controls that result in full flow when the demand ventilation system(s) fail to modulate airflow in response to appliance operation; and
    4. allow occupants to temporarily override the system(s) to full flow.

TABLE 6.5.7.1.3 Maximum Net Exhaust Flow Rate, cfm per Linear Foot of Hood Length

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

NA = not allowed

6.5.7.1.5 Performance Testing. An approved field test method shall be used to evaluate design airflow rates and demonstrate proper capture and containment performance of installed commercial kitchen exhaust systems. Where demand ventilation systems are utilized to meet Section 6.5.7.1.4, additional performance testing shall be required to demonstrate proper capture and containment at minimum airflow.

6.5.7.2 Laboratory Exhaust Systems. Buildings with laboratory exhaust systems having a total exhaust rate greater than 5000 cfm shall include at least one of the following features:

a. VAV laboratory exhaust and room supply system capable of reducing exhaust and makeup airflow rates and/or incorporate a heat recovery system to precondition makeup air from laboratory exhaust that shall meet the following:

$$A + B \times (E/M) \geq 50\%$$

where

A = percentage that the exhaust and makeup airflow rates can be reduced from design conditions

B = percentage sensible recovery effectiveness

E = exhaust airflow rate through the heat recovery device at design conditions

M = makeup airflow rate of the system at design conditions.

b. VAV laboratory exhaust and room supply systems that are required to have minimum circulation rates to comply with code or accreditation standards shall be capable of reducing zone exhaust and makeup airflow rates to the regulated minimum circulation values or the minimum required to maintain pressurization relationship requirements. Nonregulated zones shall be capable of reducing exhaust and makeup airflow rates to 50% of the zone design values or the minimum required to maintain pressurization relationship requirements.

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

6.5.8 Radiant Heating Systems

6.5.8.1 Heating Unenclosed Spaces. Radiant heating shall be used when heating is required for unenclosed spaces.

Exception: Loading docks equipped with air curtains

6.5.8.2 Heating Enclosed Spaces. Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the standard, including, but not limited to, the following:

a. Radiant hydronic ceiling or floor panels (used for heating or cooling)

b. Combination or hybrid systems incorporating radiant heating (or cooling) panels

c. Radiant heating (or cooling) panels used in conjunction with other systems such as VAV or thermal storage systems

6.5.9 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 6.5.9 for VAV units and single-zone VAV units. Hot gas bypass shall not be used on constant-volume units.

TABLE 6.5.9 Hot-Gas Bypass Limitation

Rated Capacity	Maximum Hot-Gas Bypass, % of Total Capacity
≤240,000 Btu/h	15%
>240,000 Btu/h	10%

6.5.10 Door Switches. Any conditioned space with a door, including doors with more than one-half glass, opening to the outdoors shall be provided with controls that, when any such door is open,

a. disable mechanical heating or reset the heating setpoint to 55°F or lower within five minutes of the door opening and

b. disable mechanical cooling or reset the cooling setpoint to 90°F or greater within five minutes of the door open-

ing. Mechanical cooling may remain enabled if outdoor air temperature is below space temperature.

Exceptions:

1. Building entries with automatic closing devices
2. Any space without a thermostat
3. Alterations to existing buildings
4. Loading docks

6.5.11 Refrigeration Systems. Refrigeration systems that are comprised of refrigerated display cases, walk-in coolers, or walk-in freezers connected to remote compressors, remote condensers, or remote condensing units shall meet the requirements of Sections 6.5.11.1 through 6.5.11.2.

Exception: Systems utilizing transcritical refrigeration cycle or ammonia refrigerant

6.5.11.1 Condensers Serving Refrigeration Systems. Fan-powered condensers shall conform to the following requirements:

a. Design saturated condensing temperatures for air-cooled condensers shall be less than or equal to the design dry-bulb temperature plus 10°F for low-temperature refrigeration systems and less than or equal to the design dry-bulb temperature plus 15°F for medium-temperature refrigeration systems.
   1. Saturated condensing temperature for blend refrigerants shall be determined using the average of liquid and vapor temperatures as converted from the condenser drain pressure.

b. Condenser fan motors that are less than 1 hp shall use electronically commutated motors, permanent split capacitor-type motors, or three-phase motors.

c. All condenser fans for air-cooled condensers, evaporatively cooled condensers, and air- or water-cooled fluid coolers or cooling towers shall incorporate one of the following continuous variable-speed fan-control approaches and shall reduce fan motor demand to no more than 30% of design wattage at 50% of design air volume:
   1. Refrigeration system condenser control for air-cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature.
   2. Refrigeration system condenser control for evaporatively cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient wet-bulb temperature.

d. Multiple fan condensers shall be controlled in unison.

e. The minimum condensing temperature setpoint shall be no greater than 70°F.

6.5.11.2 Compressor Systems. Refrigeration compressor systems shall conform to the following requirements:

a. Compressors and multiple-compressor systems suction groups shall include control systems that use floating suction pressure control logic to reset the target suction pressure temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Exceptions:

1. Single-compressor systems that do not have variable capacity capability
2. Suction groups that have a design saturated suction temperature equal to or greater than 30°F, suction groups that comprise the high stage of a two-stage or cascade system, or suction groups that primarily serve chillers for secondary cooling fluids.

b. Liquid subcooling shall be provided for all low-temperature compressor systems with a design cooling capacity equal to or greater than 100,000 Btu/h with a design saturated suction temperature equal to or less than –10°F. The subcooled liquid temperature shall be controlled at a maximum temperature setpoint of 50°F at the exit of the subcooler using either compressor economizer (interstage) ports or a separate compressor suction group operating at a saturated suction temperature equal to or greater than 18°F.
   1. Subcooled liquid lines are subject to the insulation requirements of Table 6.8.3-2.

c. All compressors that incorporate internal or external crankcase heaters shall provide a means to cycle the heaters off during compressor operation.

6.5.12 Automatic Control of HVAC in Hotel/Motel Guest Rooms. In hotels and motels with more than 50 guest rooms, *automatic* controls of HVAC equipment serving each guest room shall be configured according to the following requirements.

6.5.12.1 HVAC Setpoint Control. Within 30 minutes of all occupants leaving the guest room, HVAC setpoints shall be automatically raised by at least 5°F (3°C) from the occupant setpoint in the cooling mode and automatically lowered by at least 5°F (3°C) from the occupant setpoint in the heating mode. When the guest room is unrented and unoccupied, HVAC setpoints shall be automatically reset to 80°F (27°C) or higher in the cooling mode and to 60°F (16°C) or lower in the heating mode. Unrented and unoccupied guest rooms shall be determined by either of the following criteria:

a. The guest room has been continuously unoccupied for up to 16 hours.

b. A *networked guest-room control system* indicates the guest room is unrented and the guest room is unoccupied for no more than 30 minutes.

Exceptions:

1. A *networked guest-room control system* may return the thermostat setpoints to their default setpoints 60 minutes prior to the time the room is scheduled to be occupied.
2. Cooling for humidity control shall be permitted during unoccupied periods.

6.5.12.2 Ventilation Control. Within 30 minutes of all occupants leaving the guest room, ventilation and exhaust fans shall be automatically turned off, or *isolation devices* serving each guest room shall automatically shut off the supply of *outdoor air* to the room and shut off exhaust air from the guest room.

Exception: Exception: Central exhaust systems for bathrooms.

6.6 Alternative Compliance Path

6.6.1 Computer Rooms Systems. HVAC systems serving the heating, cooling, or ventilating needs of a computer room shall comply with Sections 6.1, 6.4, 6.6.1.1 or 6.6.1.2, 6.6.1.3, 6.7, and 6.8.

6.6.1.1 The computer room PUE_1 shall be less than or equal to the values listed in Table 6.6.1. Hourly simulation of the proposed design, for purposes of calculating PUE_1, shall be based on the ASHRAE Standard 90.1 Appendix G simulation methodology.

Exceptions: This compliance path is not allowed for a proposed computer room design utilizing a combined heat and power system.

TABLE 6.6.1 Power Usage Effectiveness (PUE) Maximum

Climate Zone	PUE[a]
1A	1.61
2A	1.49
3A	1.41
4A	1.36
5A	1.36
6A	1.34
1B	1.53
2B	1.45
3B	1.42
4B	1.38
5B	1.33
6B	1.33
3C	1.39
4C	1.38
5C	1.36
7	1.32
8	1.30

a. PUE_0 and PUE_1 shall not include energy for battery charging.

6.6.1.2 The computer room PUE_0 is less than or equal to the values listed in Table 6.6.1, shall be the highest value determined at outdoor cooling design temperatures, and shall be limited to systems only utilizing electricity for an energy source. PUE_0 shall be calculated for two conditions: 100% design IT equipment energy and 50% design IT equipment energy.

6.6.1.3 Documentation shall be provided, including a breakdown of energy consumption or demand by at least the following components: IT equipment, power distribution losses external to the IT equipment, HVAC systems, and lighting.

6.7 Submittals

6.7.1 General. The authority having jurisdiction may require submittal of compliance documentation and supplemental information in accordance with Section 4.2.2 of this standard.

6.7.2 Completion Requirements. The following requirements are mandatory provisions and are necessary for compliance with the standard.

6.7.2.1 Drawings. Construction documents shall require that, within 90 days after the date of system acceptance, record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include, as a minimum, the location and performance data on each piece of equipment; general configuration of the duct and pipe distribution system, including sizes; and the terminal air or water design flow rates.

6.7.2.2 Manuals. Construction documents shall require that an operating manual and a maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of system acceptance. These manuals shall be in accordance with industry-accepted standards (see Informative Appendix E) and shall include, at a minimum, the following:

a. Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.

b. Operation manuals and maintenance manuals for each piece of equipment and system requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

c. Names and addresses of at least one service agency.

d. HVAC controls system maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field-determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, in programming comments.

e. A complete narrative of how each system is intended to operate, including suggested setpoints.

6.7.2.3 System Balancing

6.7.2.3.1 General. Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards (see Informative Appendix E). Construction documents shall require that a written balance report be provided to the building owner or the designated representative of the building owner for HVAC systems serving zones with a total conditioned area exceeding 5000 ft^2.

6.7.2.3.2 Air System Balancing. Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with fan system power greater than 1 hp, fan speed shall be adjusted to meet design flow conditions.

6.7.2.3.3 Hydronic System Balancing. 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.

Exceptions: Impellers need not be trimmed nor pump speed adjusted

1. for pumps with pump motors of 10 hp or less or
2. when throttling results in no greater than 5% of the nameplate horsepower draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed.

6.7.2.4 System Commissioning. HVAC control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition. For projects larger than 50,000 ft^2 conditioned area, except warehouses and semiheated spaces, detailed instructions for commissioning HVAC systems (see Informative Appendix E) shall be provided by the designer in plans and specifications.

6.8 Minimum Equipment Efficiency Tables

6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions

6.8.2 Duct Insulation Tables

6.8.3 Pipe Insulation Tables

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

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	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
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	
Air conditioners, water cooled	<65,000 Btu/h	All	Split system and single package	12.1 EER 12.3 IEER	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	12.1 EER 13.9 IEER	AHRI 340/360
		All other	Split system and single package	11.9 EER 13.7 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	12.5 EER 13.9 IEER	
		All other	Split system and single package	12.3 EER 13.7 IEER	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	12.4 EER 13.6 IEER	AHRI 340/360
		All other	Split system and single package	12.2 EER 13.4 IEER	
	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	12.2 EER 13.5 IEER	AHRI 340/360
		All other	Split system and single package	12.0 EER 13.3 IEER	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements *(Continued)*

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 IERR	
		All other	Split system and single package	11.8 EER 12.0 IEER	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.9 EER 12.1 IEER	
		All other	Split system and single package	11.7 EER 11.9 IEER	
	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.7 EER 11.9 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 11.8 IEER	AHRI 365
Condensing units, water cooled	≥135,000 Btu/h			13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥135,000 Btu/h			13.5 EER 14.0 IEER	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-2 Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air cooled (cooling mode)	<65,000 Btu/h[b]	Heat pump with electric backup, Gas	Split system	14 SEER	AHRI 210/240
			Single package	14 SEER	
Through the wall, air cooled (cooling mode)	≤30,000 Btu/h[b]	Heat pump with electric backup, Gas	Split system	12.0 SEER	
			Single package	12.0 SEER	
Small duct high velocity, air cooled	<65,000 Btu/h[b]	Heat pump with electric backup, Gas	Split System	11.0 SEER	
Air cooled (cooling mode)	≥65,000 Btu/h and <135,000 Btu/h	None	Split system and single package	11.0 EER 12.2 IEER	AHRI 340/360
		Heat pump with electric backup, Gas	Split system and single package	10.8 EER 12.0 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	None	Split system and single package	10.6 EER 11.6 IEER	
		Heat pump with electric backup, Gas	Split system and single package	10.4 EER 11.4 IEER	
	≥240,000 Btu/h	None	Split system and single package	9.5 EER 10.6 IEER	
		Heat pump with electric backup, Gas	Split system and single package	9.3 EER 10.4 IEER	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-3 Water-Chilling Packages—Efficiency Requirements[a,b,e]

Equipment Type	Size Category	Units	Effective 1/1/2010		Effective 1/1/2015		Test Procedure[c]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	<150 tons	EER (Btu/Wh)	≥9.562 FL	NA[d]	≥10.100 FL	≥9.700 FL	AHRI 550/590
			≥12.500 IPLV		≥13.700 IPLV	≥15.800 IPLV	
	≥150 tons		≥9.562 FL	NA[d]	≥10.100 FL	≥9.700 FL	
			≥12.750 IPLV		≥14.000 IPLV	≥16.100 IPLV	
Air-cooled without condenser, electrically operated	All capacities	EER (Btu/Wh)	Air-cooled chillers without condenser must be rated with matching condensers and comply with air-cooled chiller efficiency requirements				
Water-cooled, electrically operated positive displacement	<75 tons	kW/ton	≤0.780 FL	≤0.800 FL	≤0.750 FL	≤0.780 FL	
			≤0.630 IPLV	≤0.600 IPLV	≤0.600 IPLV	≤0.500 IPLV	
	≥75 tons and <150 tons		≤0.775 FL	≤0.790 FL	≤0.720 FL	≤0.750 FL	
			≤0.615 IPLV	≤0.586 IPLV	≤0.560 IPLV	≤0.490 IPLV	
	≥150 tons and < 300 tons		≤0.680 FL	≤0.718 FL	≤0.660 FL	≤0.680 FL	
			≤0.580 IPLV	≤0.540 IPLV	≤0.540 IPLV	≤0.440 IPLV	
	≥300 tons and < 600 tons		≤0.620 FL	≤0.639 FL	≤0.610 FL	≤0.625 FL	
			≤0.540 IPLV	≤0.490 IPLV	≤0.520 IPLV	≤0.410 IPLV	
	≥600 tons		≤0.620 FL	≤0.639 FL	≤0.560 FL	≤0.585 FL	
			≤0.540 IPLV	≤0.490 IPLV	≤0.500 IPLV	≤0.380 IPLV	
Water cooled, electrically operated centrifugal	<150 tons	kW/ton	≤0.634 FL	≤0.639 FL	≤0.610 FL	≤0.695 FL	
			≤0.596 IPLV	≤0.450 IPLV	≤0.550 IPLV	≤0.440 IPLV	
	≥150 tons and <300 tons		≤0.634 FL	≤0.639 FL	≤0.610 FL	≤0.635 FL	
			≤0.596 IPLV	≤0.450 IPLV	≤0.550 IPLV	≤0.400 IPLV	
	≥300 tons and <400 tons		≤0.576 FL	≤0.600 FL	≤0.560 FL	≤0.595 FL	
			≤0.549 IPLV	≤0.400 IPLV	≤0.520 IPLV	≤0.390 IPLV	
	≥400 tons and <600 tons		≤0.576 FL	≤0.600 FL	≤0.560 FL	≤0.585 FL	
			≤0.549 IPLV	≤0.400 IPLV	≤0.500 IPLV	≤0.380 IPLV	
	≥600 tons		≤0.570 FL	≤0.590 FL	≤0.560 FL	≤0.585 FL	
			≤0.539 IPLV	≤0.400 IPLV	≤0.500 IPLV	≤0.380 IPLV	
Air-cooled absorption, single effect	All capacities	COP (W/W)	≥0.600 FL	NA[d]	≥0.600 FL	NA[d]	AHRI 560
Water-cooled absorption, single effect	All capacities	COP (W/W)	≥0.700 FL	NA[d]	≥0.700 FL	NA[d]	
Absorption double effect, indirect fired	All capacities	COP (W/W)	≥1.000 FL	NA[d]	≥1.000 FL	NA[d]	
			≥1.050 IPLV		≥1.050 IPLV		
Absorption double effect, direct fired	All capacities	COP (W/W)	≥1.000 FL	NA[d]	≥1.000 FL	NA[d]	
			≥1.000 IPLV		≥1.000 IPLV		

a. The requirements for centrifugal chillers shall be adjusted for nonstandard rating conditions per Section 6.4.1.2.1 and are only applicable for the range of conditions listed there. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements must be met or exceeded to comply with this standard. When there is a Path B, compliance can be with either Path A or Path B for any application.

c. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

d. NA means the requirements are not applicable for Path B, and only Path A can be used for compliance.

e. FL is the full-load performance requirements, and IPLV is for the part-load performance requirements.

TABLE 6.8.1-4 Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single-Package Vertical Heat Pumps, Room Air Conditioners, and Room Air-Conditioner Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
PTAC (cooling mode) standard size	All capacities	95°F db outdoor air	13.8 – (0.300 × Cap/1000)[c] (before 1/1/2015) 14.0 – (0.300 × Cap/1000)[c] (as of 1/1/2015)	AHRI 310/380
PTAC (cooling mode) nonstandard size[a]	All capacities	95°F db outdoor air	10.9 – (0.213 × Cap/1000)[c] EER	
PTHP (cooling mode) standard size	All capacities	95°F db outdoor air	14.0 – (0.300 × Cap/1000)[c]	
PTHP (cooling mode) nonstandard size[b]	All capacities	95°F db outdoor air	10.8 – (0.213 × Cap/1000)[c] EER	
PTHP (heating mode) standard size	All capacities	—	3.7 – (0.052 × Cap/1000)[c] COP_H	
PTHP (heating mode) nonstandard size[b]	All capacities	—	2.9 – (0.026 × Cap/1000)[c] COP_H	
SPVAC (cooling mode)	<65,000 Btu/h	95°F db/75°F wb outdoor air	10.0 EER	AHRI 390
	≥65,000 Btu/h and <135,000 Btu/h	95°F db/75°F wb outdoor air	10.0 EER	
	≥135,000 Btu/h and <240,000 Btu/h	95°F db/75°F wb outdoor air	10.0 EER	
SPVHP (cooling mode)	<65,000 Btu/h	95°F db/75°F wb outdoor air	10.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	95°F db/75°F wb outdoor air	10.0 EER	
	≥135,000 Btu/h and <240,000 Btu/h	95°F db/75°F wb outdoor air	10.0 EER	
SPVHP (heating mode)	<65,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP_H	
	≥65,000 Btu/h and <135,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP_H	
	≥135,000 Btu/h and <240,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP_H	
Room air conditioners with louvered sides	<6000 Btu/h	—	9.7 SEER	ANSI/AHAM RAC-1
	≥6000 Btu/h and <8000 Btu/h		9.7 SEER	
	≥8000 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	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS." Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 $in.^2$.

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

TABLE 6.8.1-4 Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single-Package Vertical Heat Pumps, Room Air Conditioners, and Room Air-Conditioner Heat Pumps—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
SPVAC (cooling mode), nonweatherized space constrained	≤30,000 Btu/h	95°F db/75°F wb outdoor air	9.2 EER	AHRI 390
	>30,000 Btu/h and ≤36,000 Btu/h	95°F db/75°F wb outdoor air	9.0 EER	
SPVHP (cooling mode), nonweatherized space constrained	≤30,000 Btu/h	95°F db/75°F wb outdoor air	9.2 EER	
	>30,000 Btu/h and ≤36,000 Btu/h	95°F db/75°F wb outdoor air	9.0 EER	
SPVHP (heating mode), nonweatherized space constrained	≤30,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP_H	
	>30,000 Btu/h and ≤36,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP_H	
Room air conditioners without louvered sides	<8000 Btu/h	—	9.0 EER	ANSI/AHAM RAC-1
	≥8000 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	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS." Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 $in.^2$.

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

TABLE 6.8.1-5 Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Warm-air furnace, gas fired	<225,000 Btu/h	Maximum capacity[c]	78% AFUE or 80% E_t [b,d]	DOE 10 CFR Part 430 or Section 2.39, Thermal Efficiency, ANSI Z21.47
	≥225,000 Btu/h	Maximum capacity[c]	80% E_t[d]	Section 2.39, Thermal Efficiency, ANSI Z21.47
Warm-air furnace, oil fired	<225,000 Btu/h	Maximum capacity[c]	78% AFUE or 80% E_t[b,d]	DOE 10 CFR Part 430 or Section 42, Combustion, UL 727
	≥225,000 Btu/h	Maximum capacity[c]	81% E_t[d]	Section 42, Combustion, UL 727
Warm-air duct furnaces, gas fired	All capacities	Maximum capacity[c]	80% E_c[e]	Section 2.10, Efficiency, ANSI Z83.8
Warm-air unit heaters, gas fired	All capacities	Maximum capacity[c]	80% E_c[e,f]	Section 2.10, Efficiency, ANSI Z83.8
Warm-air unit heaters, oil fired	All capacities	Maximum capacity[c]	80% E_c[e,f]	Section 40, Combustion, UL 731

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Combination units not covered by NAECA (three-phase power or cooling capacity greater than or equal to 65,000 Btu/h) may comply with either rating.
c. Compliance of multiple firing rate units shall be at the maximum firing rate.
d. E_t = thermal efficiency. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
e. E_c = combustion efficiency (100% less flue losses). See test procedure for detailed discussion.
f. As of August 8, 2008, according to the Energy Policy Act of 2005, units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an automatic flue damper.

TABLE 6.8.1-6 Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements

Equipment Type[a]	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency	Efficiency as of 3/2/2020	Test Procedure
Boilers, hot water	Gas fired	<300,000 Btu/h[f,g]	82% AFUE	82% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	80% E_t	80% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	82% E_c	82% E_c	
	Oil fired[e]	<300,000 Btu/h[g]	84% AFUE	84% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	82% E_t	82% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	84% E_c	84% E_c	
Boilers, steam	Gas fired	<300,000 Btu/h[f]	80% AFUE	80% AFUE	10 CFR Part 430
	Gas fired—all, except natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	79% E_t	79% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	79% E_t	79% E_t	
	Gas fired—natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	77% E_t	79% E_t	
		>2,500,000 Btu/h[a]	77% E_t	79% E_t	
	Oil fired[e]	<300,000 Btu/h	82% AFUE	82% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	81% E_t	81% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	81% E_t	81% E_t	

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. E_c = combustion efficiency (100% less flue losses). See reference document for detailed information.
c. E_t = thermal efficiency. See reference document for detailed information.
d. Maximum capacity—minimum and maximum ratings as provided for and allowed by the unit's controls.
e. Includes oil-fired (residual).
f. Boilers shall not be equipped with a constant burning pilot light.
g. A boiler not equipped with a tankless domestic water heating coil shall be equipped with an automatic means for adjusting the temperature of the water such that an incremental change in inferred heat load produces a corresponding incremental change in the temperature of the water supplied.

TABLE 6.8.1-7 Performance Requirements for Heat Rejection Equipment

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition[h]	Performance Required[a,b,c,d,f,g]	Test Procedure[e]
Propeller or axial fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥40.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Propeller or axial fan evaporative condensers	All	R-507A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥157,000 Btu/h·hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥134,000 Btu/h·hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-507A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥135,000 Btu/h·hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥110,000 Btu/h·hp	CTI ATC-106
Air cooled condensers	All	125°F condensing temperature 190°F entering gas temperature 15°F subcooling 95°F entering db	≥176,000 Btu/h·hp	AHRI 460

a. 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 6.8.1-7 divided by the fan motor nameplate power.

b. For purposes of this table, closed-circuit cooling tower performance is defined as the process water flow rating of the tower at the thermal rating condition listed in Table 6.8.1-7 divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.

c. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan motor nameplate power.

d. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

e. The efficiencies and test procedures for both open- and closed-circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of separate wet and dry heat exchange sections. The certification requirements do not apply to field-erected cooling towers.

f. All cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.

g. For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table, divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.

h. Requirements for evaporative condensers are listed with ammonia (R-717) and R-507A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-507A must meet the minimum efficiency requirements listed above with R-507A as the test fluid.

TABLE 6.8.1-8 Heat Transfer Equipment

Equipment Type	Subcategory	Minimum Efficiency[a]	Test Procedure[b]
Liquid-to-liquid heat exchangers	Plate type	NR	AHRI 400

a. NR = No requirement
b. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1-9 Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF air conditioners, air cooled	<65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.2 EER 13.1 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 12.9 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.0 EER 11.6 IEER	

TABLE 6.8.1-10 Electrically Operated Variable-Refrigerant-Flow and Applied Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF air cooled (cooling mode)	<65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 12.9 IEER	
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	10.8 EER 12.7 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.6 EER 12.3 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	10.4 EER 12.1 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	9.5 EER 11.0 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	9.3 EER 10.8 IEER	
VRF water source (cooling mode)	<65,000 Btu/h	All	VRF multisplit systems 86°F entering water	12.0 EER	AHRI 1230
	<65,000 Btu/h	All	VRF multisplit systems with heat recovery 86°F entering water	11.8 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF multisplit system 86°F entering water	12.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF multisplit system with heat recovery 86°F entering water	11.8 EER	
	≥135,000 Btu/h	All	VRF multisplit system 86°F entering water	10.0 EER	
	≥135,000 Btu/h	All	VRF multisplit system with heat recovery 86°F entering water	9.8 EER	
VRF groundwater source (cooling mode)	<135,000 Btu/h	All	VRF multisplit system 59°F entering water	16.2 EER	AHRI 1230
	<135,000 Btu/h	All	VRF multisplit system with heat recovery 59°F entering water	16.0 EER	
	≥135,000 Btu/h	All	VRF multisplit system 59°F entering water	13.8 EER	
	≥135,000 Btu/h	All	VRF multisplit system with heat recovery 59°F entering water	13.6 EER	

TABLE 6.8.1-10 Electrically Operated Variable-Refrigerant-Flow and Applied Heat Pumps—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF ground source (cooling mode)	<135,000 Btu/h	All	VRF multisplit system 77°F entering water	13.4 EER	AHRI 1230
	<135,000 Btu/h	All	VRF multisplit system with heat recovery 77°F entering water	13.2 EER	
	≥135,000 Btu/h	All	VRF multisplit system 77°F entering water	11.0 EER	
	≥135,000 Btu/h	All	VRF multisplit system with heat recovery 77°F entering water	10.8 EER	
VRF air cooled (heating mode)	<65,000 Btu/h (cooling capacity)	—	VRF multisplit system	7.7 HSPF	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h (cooling capacity)	—	VRF multisplit system 47°F db/43°F wb outdoor air	3.3 COP_H	
			17°F db/15°F wb outdoor air	2.25 COP_H	
	≥135,000 Btu/h (cooling capacity)	—	VRF multisplit system 47°F db/43°F wb outdoor air	3.2 COP_H	
			17°F db/15°F wb outdoor air	2.05 COP_H	
VRF water source (heating mode)	<135,000 Btu/h (cooling capacity)	—	VRF multisplit system 68°F entering water	4.2 COP_H	AHRI 1230
	≥135,000 Btu/h (cooling capacity)	—	VRF multisplit system 68°F entering water	3.9 COP_H	
VRF groundwater source (heating mode)	<135,000 Btu/h (cooling capacity)	—	VRF multisplit system 50°F entering water	3.6 COP_H	AHRI 1230
	≥135,000 Btu/h (cooling capacity)	—	VRF multisplit system 50°F entering water	3.3 COP_H	
VRF ground source (heating mode)	<135,000 Btu/h (cooling capacity)	—	VRF multisplit system 32°F entering water	3.1 COP_H	AHRI 1230
	≥135,000 Btu/h (cooling capacity)	—	VRF multisplit system 32°F entering water	2.8 COP_H	

TABLE 6.8.1-11 Air Conditioners and Condensing Units Serving Computer Rooms

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

a. Net sensible cooling capacity: The total gross cooling capacity less the latent cooling less the energy to the air movement system. (Total Gross – Latent – Fan Power)

b. Sensible coefficient of performance (SCOP-127): A ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding reheaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity is the gross sensible capacity minus the energy dissipated into the cooled space by the fan system.

TABLE 6.8.1-12 Commercial Refrigerator and Freezers

Equipment Type	Application	Energy Use Limits, kWh/day	Test Procedure
Refrigerator with solid doors	Holding temperature	$0.10 \times V + 2.04$	AHRI 1200
Refrigerator with transparent doors		$0.12 \times V + 3.34$	
Freezers with solid doors		$0.40 \times V + 1.38$	
Freezers with transparent doors		$0.75 \times V + 4.10$	
Refrigerators/freezers with solid doors		the greater of $0.12 \times V + 3.34$ or 0.70	
Commercial refrigerators	Pulldown	$0.126 \times V + 3.51$	

V = the chiller or frozen compartment volume (ft^3) as defined in Association of Home Appliance Manufacturers Standard HRF-1.

TABLE 6.8.1-13 Commercial Refrigeration—Minimum Efficiency Requirements

Equipment Type				Energy Use Limits as of 1/1/2012,[b,c] kWh/day	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical open	Remote condensing	Medium temperature	0.82 × TDA + 4.07	AHRI 1200
SVO.RC.M	Semivertical open	Remote condensing	Medium temperature	0.83 × TDA + 3.18	
HZO.RC.M	Horizontal open	Remote condensing	Medium temperature	0.35 × TDA + 2.88	
VOP.RC.L	Vertical open	Remote condensing	Low temperature	2.27 × TDA + 6.85	
HZO.RC.L	Horizontal open	Remote condensing	Low temperature	0.57 × TDA + 6.88	
VCT.RC.M	Vertical transparent door	Remote condensing	Medium temperature	0.22 × TDA + 1.95	
VCT.RC.L	Vertical transparent door	Remote condensing	Low temperature	0.56 × TDA + 2.61	
SOC.RC.M	Service over counter	Remote condensing	Medium temperature	0.51 × TDA + 0.11	
VOP.SC.M	Vertical open	Self contained	Medium temperature	1.74 × TDA + 4.71	
SVO.SC.M	Semivertical open	Self contained	Medium temperature	1.73 × TDA + 4.59	
HZO.SC.M	Horizontal open	Self contained	Medium temperature	0.77 × TDA + 5.55	
HZO.SC.L	Horizontal open	Self contained	Low temperature	1.92 × TDA + 7.08	
VCT.SC.I	Vertical transparent door	Self contained	Ice cream	0.67 × TDA + 3.29	
VCS.SC.I	Vertical solid door	Self contained	Ice cream	0.38 × V + 0.88	
HCT.SC.I	Horizontal transparent door	Self contained	Ice cream	0.56 × TDA + 0.43	
SVO.RC.L	Semivertical open	Remote condensing	Low temperature	2.27 × TDA + 6.85	
VOP.RC.I	Vertical open	Remote condensing	Ice cream	2.89 × TDA + 8.7	
SVO.RC.I	Semivertical open	Remote condensing	Ice cream	2.89 × TDA + 8.7	
HZO.RC.I	Horizontal open	Remote condensing	Ice cream	0.72 × TDA + 8.74	
VCT.RC.I	Vertical transparent door	Remote condensing	Ice cream	0.66 × TDA + 3.05	

a. Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of the following:
(AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical transparent doors, VCS = vertical solid doors, HCT = horizontal transparent doors, HCS = horizontal solid doors, and SOC = service over counter); (BB)—An operating mode code (RC = remote condensing and SC = self contained); and (C)—A rating temperature code (M = medium temperature [38°F], L = low temperature [0°F], or I = ice cream temperature [15°F]). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.

b. V is the volume of the case (ft) as measured in AHRI Standard 1200, Appendix C.

c. TDA is the total display area of the case (ft) as measured in AHRI Standard 1200, Appendix D.

TABLE 6.8.1-13 Commercial Refrigeration—Minimum Efficiency Requirements *(Continued)*

Equipment Type				Energy Use Limits as of 1/1/2012,[b,c] kWh/day	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
HCT.RC.M	Horizontal transparent door	Remote condensing	Medium temperature	0.16 × TDA + 0.13	
HCT.RC.L	Horizontal transparent door	Remote condensing	Low temperature	0.34 × TDA + 0.26	
HCT.RC.I	Horizontal transparent door	Remote condensing	Ice cream	0.4 × TDA + 0.31	
VCS.RC.M	Vertical solid door	Remote condensing	Medium temperature	0.11 × *V* + 0.26	
VCS.RC.L	Vertical solid door	Remote condensing	Low temperature	0.23 × *V* + 0.54	
VCS.RC.I	Vertical solid door	Remote condensing	Ice cream	0.27 × *V* + 0.63	
HCS.RC.M	Horizontal solid door	Remote condensing	Medium temperature	0.11 × *V* + 0.26	
HCS.RC.L	Horizontal solid door	Remote condensing	Low temperature	0.23 × *V* + 0.54	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	0.27 × *V* + 0.63	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	0.27 × *V* + 0.63	AHRI 1200
SOC.RC.L	Service over counter	Remote condensing	Low temperature	1.08 × TDA + 0.22	
SOC.RC.I	Service over counter	Remote condensing	Ice cream	1.26 × TDA + 0.26	
VOP.SC.L	Vertical open	Self contained	Low temperature	4.37 × TDA + 11.82	
VOP.SC.I	Vertical open	Self contained	Ice cream	5.55 × TDA + 15.02	
SVO.SC.L	Semivertical open	Self contained	Low temperature	4.34 × TDA + 11.51	
SVO.SC.I	Semivertical open	Self contained	Ice cream	5.52 × TDA + 14.63	
HZO.SC.I	Horizontal open	Self contained	Ice cream	2.44 × TDA + 9.0	
SOC.SC.I	Service over counter	Self contained	Ice cream	1.76 × TDA + 0.36	
HCS.SC.I	Horizontal solid door	Self contained	Ice cream	0.38 × *V* + 0.88	

a. Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of the following:
(AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical transparent doors, VCS = vertical solid doors, HCT = horizontal transparent doors, HCS = horizontal solid doors, and SOC = service over counter); (BB)—An operating mode code (RC = remote condensing and SC = self contained); and (C)—A rating temperature code (M = medium temperature [38°F], L = low temperature [0°F], or I = ice cream temperature [15°F]). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.

b. *V* is the volume of the case (ft) as measured in AHRI Standard 1200, Appendix C.

c. TDA is the total display area of the case (ft) as measured in AHRI Standard 1200, Appendix D.

TABLE 6.8.2-1 Minimum Duct Insulation R-Value,[a] Cooling- and Heating-Only Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Heating-Only Ducts							
1, 2	None	None	None	None	None	None	None
3	R-3.5	None	None	None	None	None	None
4	R-3.5	None	None	None	None	None	None
5	R-6	R-3.5	None	None	None	None	R-3.5
6	R-6	R-6	R-3.5	None	None	None	R-3.5
7	R-8	R-6	R-6	None	R-3.5	None	R-3.5
8	R-8	R-8	R-6	None	R-6	None	R-6
Cooling-Only Ducts							
1	R-6	R-6	R-8	R-3.5	R-3.5	None	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
3	R-6	R-6	R-6	R-3.5	R-1.9	None	None
4	R-3.5	R-3.5	R-6	R-1.9	R-1.9	None	None
5, 6	R-3.5	R-1.9	R-3.5	R-1.9	R-1.9	None	None
7, 8	R-1.9	R-1.9	R-1.9	R-1.9	R-1.9	None	None
Return Ducts							
1 to 8	**R-3.5**	**R-3.5**	**R-3.5**	**None**	**None**	**None**	**None**

a. Insulation R-values, measured in $(h \cdot ft^2 \cdot °F)/Btu$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.

b. Includes crawlspaces, both ventilated and nonventilated.

c. Includes return air plenums with or without exposed roofs above.

TABLE 6.8.2-2 Minimum Duct Insulation R-Value,[a] Combined Heating and Cooling Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Supply Ducts							
1	R-6	R-6	R-8	R-3.5	R-3.5	None	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
3	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
4	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
5	R-6	R-6	R-6	R-1.9	R-3.5	None	R-3.5
6	R-8	R-6	R-6	R-1.9	R-3.5	None	R-3.5
7	R-8	R-6	R-6	R-1.9	R-3.5	None	R-3.5
8	R-8	R-8	R-8	R-1.9	R-6	None	R-6
Return Ducts							
1 to 8	R-3.5	R-3.5	R-3.5	None	None	None	None

a. Insulation R-values, measured in $(h \cdot ft^2 \cdot °F)/Btu$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.

b. Includes crawlspaces, both ventilated and nonventilated.

c. Includes return air plenums with or without exposed roofs above.

TABLE 6.8.3-1 Minimum Piping Insulation Thickness Heating and Hot Water Systems[a,b,c,d,e] (Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)

Fluid Operating Temperature Range(°F) and Usage	Insulation Conductivity		≥Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in./(h·ft²·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
>350°F	0.32–0.34	250	4.5	5.0	5.0	5.0	5.0
251°F–350°F	0.29–0.32	200	3.0	4.0	4.5	4.5	4.5
201°F–250°F	0.27–0.30	150	2.5	2.5	2.5	3.0	3.0
141°F–200°F	0.25–0.29	125	1.5	1.5	2.0	2.0	2.0
105°F–140°F	0.22–0.28	100	1.0	1.0	1.5	1.5	1.5

a. 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 (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this 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 this table for the applicable fluid temperature.

b. These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

c. For piping smaller than 1.5 in. and located in partitions within conditioned spaces, reduction of these thicknesses by 1 in. shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 1 in.

d. For direct-buried heating and hot-water system piping, reduction of these thicknesses by 1.5 in. shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 1 in.

e. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per metre than a steel pipe of the same size with the insulation thickness shown in the table.

TABLE 6.8.3-2 Minimum Piping Insulation Thickness Cooling Systems (Chilled Water, Brine, and Refrigerant)[a,b,c,d]

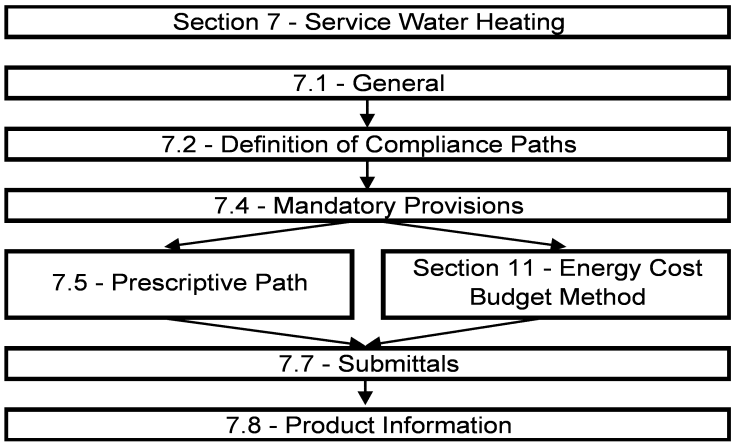
Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in./(h·ft²·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
40°F–60°F	0.21–0.27	75	0.5	0.5	1.0	1.0	1.0
<40°F	0.20–0.26	50	0.5	1.0	1.0	1.0	1.5

a. 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 (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this 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 this table for the applicable fluid temperature.

b. These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

c. For direct-buried cooling system piping, insulation is not required.

d. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.



7. SERVICE WATER HEATING

7.1 General

7.1.1 Service Water Heating Scope

7.1.1.1 New Buildings. Service water heating systems and equipment shall comply with the requirements of this section as described in Section 7.2.

7.1.1.2 Additions to Existing Buildings. Service water heating systems and equipment shall comply with the requirements of this section.

Exception: When the service water heating to an addition is provided by existing service water heating systems and equipment, such systems and equipment shall not be required to comply with this standard. However, any new systems or equipment installed must comply with specific requirements applicable to those systems and equipment.

7.1.1.3 Alterations to Existing Buildings. Building service water heating equipment installed as a direct replacement for existing building service water heating equipment shall comply with the requirements of Section 7 applicable to the equipment being replaced. New and replacement piping shall comply with Section 7.4.3.

Exception: Compliance shall not be required where there is insufficient space or access to meet these requirements.

7.2 Compliance Paths

7.2.1 Compliance. Compliance shall be achieved by meeting the requirements of Section 7.1, "General"; Section 7.4, "Mandatory Provisions"; Section 7.5, "Prescriptive Path"; Section 7.7, "Submittals"; and Section 7.8, "Product Information."

7.2.2 Projects using the Energy Cost Budget Method (Section 11) for demonstrating compliance with the standard shall meet the requirements of Section 7.4, "Mandatory Provisions," in conjunction with Section 11, "Energy Cost Budget Method."

7.3 Simplified/Small Building Option (Not Used)

7.4 Mandatory Provisions

7.4.1 Load Calculations. Service water heating system design loads for the purpose of sizing systems and equipment shall be determined in accordance with manufacturers' published sizing guidelines or generally accepted engineering standards and handbooks acceptable to the adopting authority (e.g., *ASHRAE Handbook—HVAC Applications*).

7.4.2 Equipment Efficiency. All water heating equipment, hot-water supply boilers used solely for heating potable water, pool heaters, and hot-water storage tanks shall meet the criteria listed in Table 7.8, except for projects complying with the Alternate Renewables Approach in Section 13.1.1.2, which shall comply with Table 13-9 and the ENERGY STAR requirements in Section 10.11.2. Where multiple criteria are listed, all criteria shall be met. Omission of minimum performance requirements for certain classes of equipment does not preclude use of such equipment where appropriate. Equipment not listed in Table 7.8 has no minimum performance requirements.

Exceptions: All water heaters and hot-water supply boilers having more than 140 gal of storage capacity are not required to meet the standby loss (SL) requirements of Table 7.8 when:

a. the tank surface is thermally insulated to R-12.5,

b. a standing pilot light is not installed, and

c. gas- or oil-fired storage water heaters have a flue damper or fan-assisted combustion.

7.4.3 Service Hot-Water Piping Insulation. The following piping shall be insulated to levels shown in Section 6, Table 6.8.3-1:

a. Recirculating system piping, including the supply and return piping of a circulating tank type water heater

b. The first 8 ft of outlet piping for a constant temperature nonrecirculating storage system

c. The inlet piping between the storage tank and a heat trap in a nonrecirculating storage system

d. Piping that is externally heated (such as heat trace or impedance heating)

7.4.4 Service Water Heating System Controls

7.4.4.1 Temperature Controls. Temperature controls shall be provided that allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use.

Exception: When the manufacturers' installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion.

7.4.4.2 Temperature Maintenance Controls. Systems designed to maintain usage temperatures in hot-water pipes, such as recirculating hot-water systems or heat trace, shall be equipped with automatic time switches or other controls that can be set to switch off the usage temperature maintenance system during extended periods when hot water is not required.

7.4.4.3 Outlet Temperature Controls. Temperature controlling means shall be provided to limit the maximum temperature of water delivered from lavatory faucets in public facility restrooms to 110°F.

7.4.4.4 Circulating Pump Controls. When used to maintain storage tank water temperature, recirculating pumps shall be equipped with controls limiting operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle.

7.4.5 Pools

7.4.5.1 Pool Heaters. Pool heaters shall be equipped with a readily accessible "on/off" switch to allow shutting off the heater without adjusting the thermostat setting. Pool heaters fired by natural gas shall not have continuously burning pilot lights.

7.4.5.2 Pool Covers. Heated pools shall be equipped with a vapor retardant pool cover on or at the water surface. Pools heated to more than 90°F shall have a pool cover with a minimum insulation value of R-12.

Exception: Pools deriving over 60% of the energy for heating from site-recovered energy or solar energy source.

7.4.5.2.1 Insulation for Spas and Pools. Spas and pools heated to more than 90°F (32°C) shall also have side and bottom surfaces insulated on the exterior with a minimum insulation value of R-12.

7.4.5.3 Time Switches. Time switches shall be installed on swimming pool heaters and pumps.

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

7.4.6 Heat Traps. Vertical pipe risers serving storage water heaters and storage tanks not having integral heat traps and serving a nonrecirculating system shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank. A heat trap is a means to counteract the natural convection of heated water in a vertical pipe run. The means is either a device specifically designed for the purpose or an arrangement of tubing that forms a loop of 360 degrees or piping that from the point of connection to the water heater (inlet or outlet) includes a length of piping directed downward before connection to the vertical piping of the supply water or hot-water distribution system, as applicable.

7.5 Prescriptive Path

7.5.1 Space Heating and Water Heating. The use of a gas-fired or oil-fired space-heating boiler system otherwise complying with Section 6 to provide the total space heating and water heating for a building is allowed when one of the following conditions is met:

a. The single space-heating boiler, or the component of a modular or multiple boiler system that is heating the service water, has a standby loss in Btu/h not exceeding

$$(13.3 \times \text{pmd} + 400)/n$$

where pmd is the probable maximum demand in gal/h determined in accordance with the procedures described in generally accepted engineering standards and handbooks, and n is the fraction of the year when the outdoor daily mean temperature is greater than 64.9°F.

The standby loss is to be determined for a test period of 24 hours duration while maintaining a boiler water temperature of at least 90°F above ambient, with an ambient temperature between 60°F and 90°F. For a boiler with a modulating burner, this test shall be conducted at the lowest input.

b. It is demonstrated to the satisfaction of the authority having jurisdiction that the use of a single heat source will consume less energy than separate units.

c. The energy input of the combined boiler and water heater system is less than 150,000 Btu/h.

7.5.2 Service Water Heating Equipment. Service water heating equipment used to provide the additional function of space heating as part of a combination (integrated) system shall satisfy all stated requirements for the service water heating equipment.

7.5.3 Buildings with High-Capacity Service Water Heating Systems. New buildings with gas service hot-water systems with a total installed gas water-heating input capacity of 1,000,000 Btu/h or greater, shall have gas service water-heating equipment with a minimum thermal efficiency (E_t) of 90%. Multiple units of gas water-heating equipment are

allowed to meet this requirement if the water-heating input provided by equipment with thermal efficiency (E_t) above and below 90% provides an input capacity-weighted average thermal efficiency of at least 90%.

The requirements of Section 7.5.3 are effective on July 30, 2015.

Exceptions:

1. Where 25% of the annual service water-heating requirement is provided by site-solar or site-recovered energy.
2. Water heaters installed in individual dwelling units.
3. Individual gas water heaters with input capacity not greater than 100,000 Btu/h.

7.6 Alternative Compliance Path (Not Used)

7.7 Submittals

7.7.1 General. The authority having jurisdiction may require submittal of compliance documentation and supplemental information, in accord with Section 4.2.2 of this standard.

7.8 Product Information

TABLE 7.8 Performance Requirements for Water-Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure[b,c]
Electric table-top water heaters	≤12 kW	Resistance ≥20 gal	0.93–0.00035V EF	DOE 10 CFR Part 430
Electric water heaters	≤12 kW[e]	Resistance ≥20 gal	0.97–0.00035V EF	DOE 10 CFR Part 430
	>12 kW	Resistance ≥20 gal	5.9 + 5.3/Vm%/h	Section G.2 of ANSI Z21.10.3
	≤24 Amps and ≤250 Volts	Heat Pump	0.93–0.00035V EF	DOE 10 CFR Part 430
Gas storage water heaters	≤75,000 Btu/h	≥20 gal	0.67–0.0005V EF	DOE 10 CFR Part 430
	>75,000 Btu/h	<4000 (Btu/h)/gal	80% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	Sections G.1 and G.2 of ANSI Z21.10.3
Gas instantaneous water heaters	>50,000 Btu/h and <200,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.62–0.0005V EF	DOE 10 CFR Part 430
	≥200,000 Btu/h[d,]	≥4000 (Btu/h)/gal and <10 gal	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
	≥200,000 Btu/h	≥4000 (Btu/h)/gal and ≥10 gal	80% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Oil storage water heaters	≤105,000 Btu/h	≥20 gal	0.59–0.0005V EF	DOE 10 CFR Part 430
	>105,000 Btu/h	<4000 (Btu/h)/gal	80% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	Sections G.1 and G.2 of ANSI Z21.10.3
Oil instantaneous water heaters	≤210,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.59–0.0005V EF	DOE 10 CFR Part 430
	>210,000 Btu/h	≥4000 (Btu/h)/gal and <10 gal	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
	>210,000 Btu/h	≥4000 (Btu/h)/gal and ≥10 gal	78% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Hot-water supply boilers, gas and oil[f]	≥300,000 Btu/h and <12,500,000 Btu/h	≥4000 (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[f]		≥4000 (Btu/h)/gal and ≥10 gal	80% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Hot-water supply boilers, oil		≥4000 (Btu/h)/gal and ≥10 gal	78% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Pool heaters, oil and gas	All		78% E_t	ASHRAE 146
Heat-pump pool heaters	All		4.0 COP	ASHRAE 146
Unfired storage tanks	All		R-12.5	(none)

a. Energy factor (EF) and thermal efficiency (E_t) are minimum requirements, while standby loss (SL) is maximum Btu/h based on a 70°F temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in gallons. 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

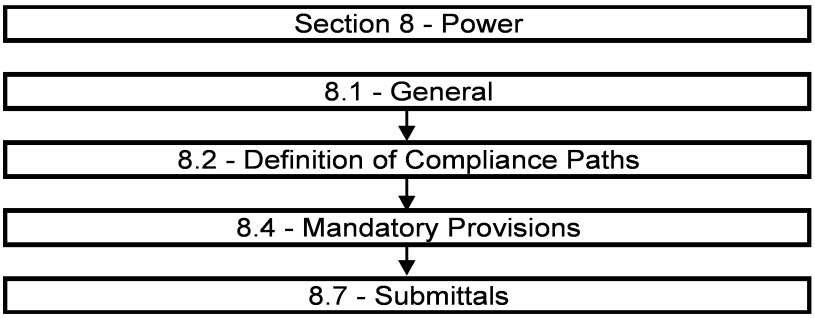
b. Section 12 contains a complete specification, including the year version, of the referenced test procedure.

c. Section G.1 is titled "Test Method for Measuring Thermal Efficiency" and Section G.2 is titled "Test Method for Measuring Standby Loss."

d. 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.

e. 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.

f. Refer to Section 7.5.3 for additional requirements for gas storage and instantaneous water heaters and gas hot-water supply boilers.



8. POWER

8.1 General

8.1.1 Scope. This section applies to all building power distribution systems and only to equipment described below.

8.1.2 New Buildings. Equipment installed in new buildings shall comply with the requirements of this section.

8.1.3 Addition to Existing Buildings. Equipment installed in addition to existing buildings shall comply with the requirements of this section.

8.1.4 Alterations to Existing Buildings

Exception: Compliance shall not be required for the relocation or reuse of existing equipment at the same site.

8.1.4.1 Alterations to building service equipment or systems shall comply with the requirements of this section applicable to those specific portions of the building and its systems that are being altered.

8.1.4.2 Any new equipment subject to the requirements of this section that is installed in conjunction with the alterations as a direct replacement of existing equipment shall comply with the specific requirements applicable to that equipment.

8.1.5 Establishing an Open and Interoperable Automated Demand Response (Auto-DR) Infrastructure. Buildings that contain heating, ventilation, or air conditioning (HVAC) systems shall comply with Sections 8.1.5.1 through 8.1.5.3. Actual participation in demand response programs is not required.

Exceptions: Auto-DR infrastructure is not required for the following:

1. Buildings located where the electric utility or regional Independent System Operator (ISO) or Regional Transmission Operator (RTO) does not offer a demand response program to buildings regulated by this code.
2. Buildings with a peak electric demand not greater than 0.75 times that of the standard reference design.
3. Buildings that have incorporated on-site renewable energy generation to provide 20 percent or more of the building's energy demand.

8.1.5.1 Software Clients. Demand response automation software clients shall be capable of communicating with a demand response automation server via the Internet or other communication relay.

8.1.5.2 Heating, Ventilating and Air-Conditioning (HVAC) Systems. The Auto-DR strategy for HVAC systems shall be capable of reducing the building peak cooling or heating HVAC demand by not less than 10 percent when signaled from the electric utility, regional independent system operator (ISO) or regional transmission operator (RTO), through any combination of the strategies and systemic adjustments, including, but not limited to the following:

Exceptions: The Auto-DR strategy is not required to include the following buildings and systems:

1. Hospitals and critical emergency response facilities.
2. Ventilation and exhaust systems required by Chapter 5 of the *Mechanical Code* for the control or removal of dust, particles, odors, fumes, spray, gas, smoke or other hazardous materials, considered to be irritating or injurious to health or safety, and produced by or involved in operations or processes, including hazardous materials storage.
3. Manufacturing process systems.
4. Group R occupancies.

8.1.5.2.1 Rebound Avoidance. The Auto-DR strategy shall include logic to prevent a rebound peak. When the signal for Auto-DR is ended, a gradual return to normal heating, ventilation and air-conditioning (HVAC) equipment operations shall be part of the Auto-DR strategy, through any combination of the strategies and systemic adjustments, including, but not limited to the following:

1. Where close to the unoccupied period, the Auto-DR period shall be extended using rebound avoidance, extended Auto-DR control strategy until the initiation of the unoccupied period.
2. Rebound avoidance, slow recovery control strategies, gradually increasing or decreasing space temperature setpoints or a variance in the timing by cooling or heating zone.

3. Rebound avoidance, slow recovery control strategies, gradually increasing or decreasing zone supply air temperatures.
4. Rebound avoidance, slow recovery control strategies, gradually increasing or decreasing chilled water temperatures or decreasing hot water temperatures.
5. Rebound avoidance, sequential equipment recovery strategies, gradually restoring demand limited equipment capacity.
6. Rebound avoidance, sequential equipment recovery strategies, gradually restoring equipment that was turned off during the Auto-DR period.
7. Rebound avoidance, slow recovery control strategies, gradually increasing capacity for air moving and pumping systems.
8. Rebound avoidance, sequential equipment recovery or rebound avoidance, slow recovery control where chilled water or hot water and other capacity control valves are sequentially or gradually allowed to return to normal operation, respectively.

8.2 Compliance Paths

8.2.1 Compliance. Power distribution systems in all projects shall comply with the requirements of Section 8.1, "General"; Section 8.4, "Mandatory Provisions"; and Section 8.7, "Submittals."

8.3 Simplified/Small Building Option (Not Used)

8.4 Mandatory Provisions

8.4.1 Voltage Drop

Exception: Feeder conductors and branch circuits that are dedicated to emergency services

8.4.1.1 Feeders. Feeder conductors shall be sized for a maximum voltage drop of 2% at design load.

8.4.1.2 Branch Circuits. Branch circuit conductors shall be sized for a maximum voltage drop of 3% at design load.

8.4.2 Automatic Receptacle Control. The following shall be automatically controlled:

1. One (1) 125-volt 15- and 20-amp duplex receptacles in each private office, and individual workstation to be located at the desk area and 50% of 125-volt 15- and 20-amp duplex receptacles in conference rooms, rooms used primarily for printing and/or copying functions, break rooms, and classrooms.
2. Twenty-five percent (25%) of the circuits feeding each base feed point of modular furniture or a minimum of one (1) circuit.

This control shall function on

a. A scheduled basis using a time-of-day operated control device that turns receptacles off at specific programmed times—an independent program schedule shall be provided for controlled areas of no more than 5000 ft^2 and not more than one floor (the occupant shall be able to manually override the control device for up to two hours),
b. An occupant sensor that shall turn receptacles off within 20 minutes of all occupants leaving a space, or
c. An automated signal from another control or alarm system that shall turn receptacles off within 20 minutes after determining that the area is unoccupied.

All controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles and are to be uniformly distributed throughout the space.

Plug-in devices shall not be used to comply with Section 8.4.2.

Exceptions: Receptacles for the following shall not require an automatic control device:

1. Receptacles specifically designated for equipment requiring continuous operation (24 hours/day, 365 days/year).
2. Spaces where an automatic control would endanger the safety or security of the room or building occupant(s).

8.4.3 Energy Metering, Monitoring and Reporting. The provisions of Section 8.4.3 shall only apply to new construction and projects that are undertaking a complete electrical system replacement. Section 8.4.3 shall not apply to Group R occupancies, other than Group R-1 occupancies.

8.4.3.1 Purpose. The purpose of this section is to provide requirements that will ensure that projects are constructed or altered in a way that will provide the capability for their energy use, production and reclamation to be measured, monitored and reported. This includes the design of energy distribution systems so as to isolate load types, the installation of or ability to install in the future meters, devices and a data acquisition system, and the installation of, or the ability to provide, energy displays and other appropriate reporting mechanisms in the future.

All forms of energy delivered to the building and building site, produced on the building site or in the building, and reclaimed at the building site or in the building shall be metered and all energy load types measured in accordance with this section.

8.4.3.1.1 Buildings with Tenants within the Scope of Section 8.4.3. The metering required by Section 8.4.3 shall be collected for the entire building and for each floor in the building. Tenants within the scope of Section 8.4.3 shall have access to all data collected for the floors in which they have occupancy. Means of access shall be left to the discretion of the owner.

8.4.3.2 Energy Distribution Design Requirements and Load Type Isolation in Buildings. Energy distribution systems within, on or adjacent to and serving a building shall be designed such that each primary circuit, panel, feeder, piping system or supply mechanism supplies only one energy use type as defined in Sections 8.4.3.2.1 through 8.4.3.2.5. The

energy use type served by each distribution system shall be clearly designated on the energy distribution system with the use served, and adequate space shall be provided for installation of metering equipment or other data collection devices, temporary or permanent, to measure their energy use. The energy distribution system shall be designed to facilitate the collection of data for each of the building energy use categories in Section 8.4.3.4 and for each of the end use categories listed in Sections 8.4.3.2.1 through 8.4.3.2.5. Where there are multiple buildings on a building site, each building shall comply separately with the provisions of Section 8.4.3.

Exceptions: Buildings designed and constructed such that the total usage of each of the load types described in Sections 8.4.3.2.1 through 8.4.3.2.5 shall be permitted to be measured through the use of installed sub-meters or other equivalent methods as approved.

8.4.3.2.1 HVAC System Total Energy Use. The HVAC system total energy use category shall include all energy used to heat, cool, and provide ventilation to the building including, but not limited to, fans, pumps, boiler energy, chiller energy and hot water.

8.4.3.2.2 Lighting System Total Energy Use. The lighting system total energy use category shall include all interior and exterior lighting used in occupant spaces and common areas.

8.4.3.2.3 Plug Loads. The plug loads energy use category shall include all energy use by devices, appliances and equipment connected to convenience receptacle outlets.

8.4.3.2.4 Process Loads. The process loads energy use category shall include the energy used by any single load associated with activities within the building, such as, but not limited to, data centers, manufacturing equipment and commercial kitchens, that exceeds 5 percent of the peak connected load of the whole building.

8.4.3.2.5 Energy Used for Building Operations Loads and other Miscellaneous Loads. The category of energy used for building operations loads and other miscellaneous loads shall include all vertical transportation systems, automatic doors, motorized shading systems, ornamental fountains and fireplaces, swimming pools, inground spas, snow-melt systems, exterior lighting that is mounted on the building or used to illuminate building façades and the use of any miscellaneous loads in the building not specified in Sections 8.4.3.2.1 through 8.4.3.2.4.

8.4.3.3 Energy-Type Metering. Buildings shall be provided with the capability to determine energy use and peak demand as provided in this section for each of the energy types specified in Sections 8.4.3.3.1 through 8.4.3.3.7. Utility energy meters or supplemental sub-meters are permitted to be used to collect whole building data, and shall be equipped with a local data port connected to a data acquisition system in accordance with Section 8.4.3.5.

8.4.3.3.1 Gaseous Fuels. Gaseous fuels including, but not limited to, natural gas, LP gas, coal gas, hydrogen, landfill gas, digester gas and biogas shall be capable of being metered at the building site to determine the gross consumption and peak demand of each different gaseous fuel by each building on a building site. The installation of gas meters and related piping shall be in accordance with the *Fuel Gas Code*.

8.4.3.3.2 Liquid Fuels. Liquid fuels including, but not limited to, fuel oil, petroleum-based diesel, kerosene, gasoline, bio diesel, methanol, ethanol and butane shall be capable of being metered at the building site to allow a determination of the gross consumption and peak demand of each liquid fuel use by each building on a building site. The installation of meters and related piping shall be in accordance with the *Mechanical Code*.

8.4.3.3.3 Solid Fuels. Solid fuels including, but not limited to, coal, charcoal, peat, wood products, grains, and municipal waste shall be capable of having their use determined at the building site to allow a determination of the gross consumption and peak demand of each solid fuel use by each building on a building site.

8.4.3.3.4 Electric Power. Electric power shall be capable of being metered at the building site to allow a determination of the gross consumption and peak demand by each building on a building site. The installation of electric meters and related wiring shall be in accordance with NFPA 70.

8.4.3.3.5 District Heating and Cooling. Hot water, steam, chilled water, and brine shall be capable of being metered at the building site, or where produced on the building site, to allow a determination of the gross consumption of heating and cooling energy by each building on a building site. Energy use associated with the production of hot water, steam, chilled water or brine shall be determined based on the fuel used.

8.4.3.3.6 Combined Heat and Power. Equipment and systems with a connected load greater than 125,000 Btu/hr (36.63 kW) providing combined heat and power (CHP) shall be capable of being metered to allow a determination of the gross consumption of each form of delivered energy to the equipment. The output of CHP shall be metered in accordance with the applicable portions of Section 8.4.3 based on the forms of output from the CHP.

8.4.3.3.7 Renewable Energy. Equipment and systems providing energy from renewable energy sources which is included in the determination of the building zEPI, shall be capable of being metered to allow a determination of the output of equipment and systems in accordance with Sections 8.4.3.3.7.1 through 8.4.3.3.7.3.

8.4.3.3.7.1 Solar Electric. Equipment and systems providing electric power through conversion of solar energy directly to electric power shall be capable of being metered so that the peak electric power (kW) provided to the building and its systems or to off-site entities can be determined at 15-minute intervals, and the amount of electric power (kWh)

provided to the building and its systems can be determined at intervals of one hour or less.

8.4.3.3.7.2 Wind Power Systems. Equipment and systems providing electric power through conversion of wind energy directly to electric power shall be capable of being metered so that the peak electric power (kW) provided to the building and its systems or to off-site entities can be determined at 15-minute intervals, and the amount of electric power (kWh) provided to the building and its systems can be determined at intervals of one hour or less.

8.4.3.3.7.3 Other Renewable Energy Electric Production Systems. Equipment and systems providing electric power through conversion of other forms of renewable energy directly to electric power shall be capable of being metered so that the peak electric power (kW) provided to the building and its systems or to off-site entities can be determined at 15-minute intervals, and the amount of electric power (kWh) provided to the building and its systems can be determined at intervals of one hour or less.

8.4.3.4 Energy Load-Type Sub-metering. For projects that are 25,000 square feet (2323 m^2) or larger in total floor area, the energy use of the categories specified in Section 8.4.3.2 shall be metered through the use of sub-meters or other approved equivalent methods meeting the capability requirements of Section 8.4.3.3.

8.4.3.4.1 Projects Less Than 25,000 Square Feet. For projects that are less than 25,000 square feet (2323 m^2) in total floor area, and encompass at least one entire floor, the energy distribution system shall be designed and constructed to accommodate the future installation of sub-meters and other approved devices in accordance with Section 8.4.3.4. This includes, but is not limited to, providing access to distribution lines and ensuring adequate space for the installation of submeters and other approved devices.

8.4.3.5 Minimum Energy Measurement And Verification. Meters, sub-meters, and other approved devices installed in compliance with Sections 8.4.3.3 and 8.4.3.4 shall be connected to a data acquisition and management system capable of storing not less than 36 months' worth of data collected by all meters and other approved devices.

8.5 Prescriptive Path

8.5.1 Automatic Control of Equipment in Hotel/Motel Guest Rooms. In hotels and motels with more than 50 guest rooms, *automatic* controls for switched outlets and televisions serving each guest room shall be configured according to the following requirements.

8.5.1.1 Switched Outlet Control. Within 30 minutes of all occupants leaving the guest room, power for lighting and switched outlets shall be automatically turned off.

8.5.1.2 Television Control. Within 30 minutes of all occupants leaving the guest room, televisions shall be automatically turned off or placed in sleep or standby mode.

8.6 Alternative Compliance Path (Not Used)

8.7 Submittals

8.7.1 Drawings. Construction documents shall require that within 30 days after the date of system acceptance, record drawings of the actual installation shall be provided to the building owner, including

a. a single-line diagram of the building electrical distribution system and

b. floor plans indicating location and area served for all distribution.

TABLE 8.4.4 Minimum Nominal Efficiency Levels for 10 CFR 431 Low-Voltage Dry-Type Distribution Transformers[a]

Single-Phase Transformers		Three-Phase Transformers	
kVA[b]	Efficiency, %[c]	kVA[b]	Efficiency, %[c]
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

a. A low-voltage distribution transformer is a transformer that is air-cooled, does not use oil as a coolant, has an input voltage ≤600 V, and is rated for operation at a frequency of 60 Hz.
b. Kilovolt-ampere rating.
c. Nominal efficiencies shall be established in accordance with the 10 CFR 431 test procedure for low-voltage dry-type transformers.

8.7.2 Manuals. Construction documents shall require that an operating manual and maintenance manual be provided to the building owner. The manuals shall include, at a minimum, the following:

a. Submittal data stating equipment rating and selected options for each piece of equipment requiring maintenance.

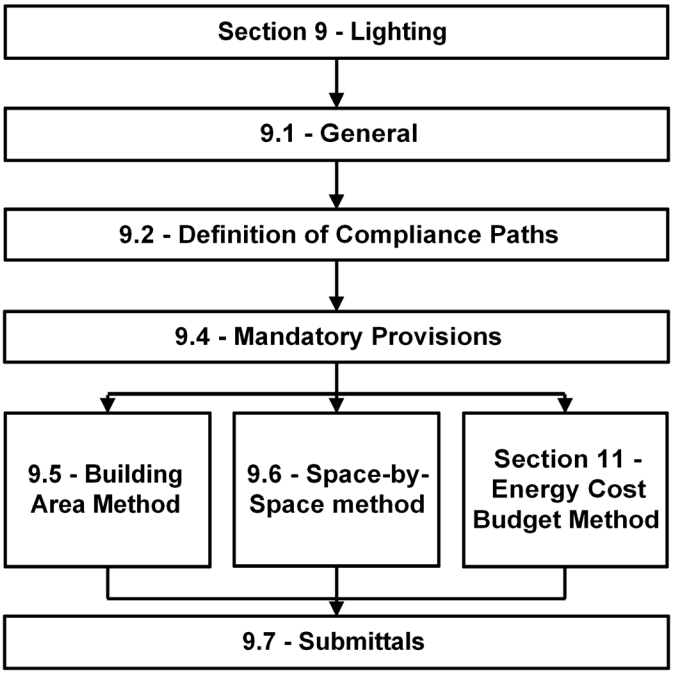
b. Operation manuals and maintenance manuals for each piece of equipment requiring maintenance. Required routine maintenance actions shall be clearly identified.

c. Names and addresses of at least one qualified service agency.

d. A complete narrative of how each system is intended to operate.

(Enforcement agencies should only check to ensure that the construction documents require this information to be transmitted to the owner and should not expect copies of any of the materials.)

8.8 Product Information (Not Used)



9. LIGHTING

9.1 General

9.1.1 Scope. This section shall apply to the following:

a. Interior spaces of buildings

b. Exterior building features, including façades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies.

c. Exterior building grounds lighting provided through the building's electrical service.

Exceptions:

1. Emergency lighting that is automatically off during normal building operation.
2. Lighting within dwelling units provided that 85% of the lamps in permanently installed luminaires are *high efficacy*.
3. Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation.
4. Decorative gas lighting systems

9.1.2 Lighting Alterations. For the alteration of any lighting system in an interior space, that space shall comply with the lighting power density (LPD) requirements of Section 9 applicable to that space and the automatic shutoff requirements of Section 9.4.1.1. For the alteration of any lighting system in an exterior building application, that lighting system shall comply with the lighting power density (LPD) requirements of Section 9 applicable to the area illuminated by that lighting system and the applicable control requirements of Sections 9.4.1.4(a) and 9.4.1.4(b). Such alterations shall include all luminaires that are added, replaced or removed. This requirement shall also be met for alterations that involve only the replacement of lamps plus ballasts. Alterations do not include routine maintenance or repair situations.

Exception: Alterations that involve replacing less than 50% of the connected lighting load in a space or area need not comply with these requirements, provided that such alterations do not increase the installed LPD.

9.1.3 Installed Lighting Power. The luminaire wattage for all interior and exterior applications shall include all power used by the luminaires, including lamps, ballasts, transformers, and control devices, except as specifically exempted in Section 9.1.1, 9.2.2.3, or 9.4.2.

Exception: If two or more independently operating lighting systems in a space are capable of being controlled to prevent simultaneous user operation, the installed interior lighting power or the installed exterior lighting power shall be based solely on the lighting system with the highest wattage.

9.1.4 Interior and Exterior Luminaire Wattage. Luminaire wattage, when used to calculate either installed interior lighting power or installed exterior lighting power, shall be determined in accordance with the following criteria:

a. The wattage of line-voltage luminaires not containing permanently installed ballasts, transformers, or similar devices shall be the manufacturers' labeled maximum wattage of the luminaire.

Exception: Where lighting is connected to a current limiter and containing *high efficacy* lamping shall be designed to use the wattage of the current limiter.

b. The wattage of luminaires with permanently installed or remote ballasts, transformers, or similar devices shall be the operating input wattage of the maximum lamp/auxiliary combination based on values from the auxiliary manufacturers' literature or recognized testing laboratories or shall be the maximum labeled wattage of the luminaire.

Exception: Lighting power calculations for ballasts with adjustable ballast factors shall be based on the ballast factor that will be used in the space, provided that the ballast factor is not user changeable.

c. For line-voltage lighting track and plug-in busway designed to allow the addition and/or relocation of luminaires without altering the wiring of the system, the wattage shall be:

1. the specified wattage of the luminaires included in the system with a minimum of 30 W/lin ft,
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.

d. The wattage of low-voltage lighting track, cable conductor, rail conductor, and other flexible lighting systems that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the specified wattage of the transformer supplying the system.

e. The wattage of all other miscellaneous lighting equipment shall be the specified wattage of the lighting equipment.

9.2 Compliance

9.2.1 Compliance Paths. Lighting systems and equipment shall comply with Section 9.1, "General"; Section 9.4, "Mandatory Provisions"; Section 9.7, "Submittals"; and the prescriptive requirements of either

a. Section 9.5, "Building Area Method Compliance Path" or
b. Section 9.6, "Alternative Compliance Path: Space-by-Space Method."

9.2.2 Prescriptive Requirements

9.2.2.1 Building Area Method. This method for determining the interior lighting power allowance, described in Section 9.5, is a simplified approach for demonstrating compliance.

9.2.2.2 Space-by-Space Method. This method, described in Section 9.6, is an alternative approach that allows greater flexibility.

9.2.2.3 Interior Lighting Power. The interior lighting power allowance for a building or a separately metered or permitted portion of a building shall be determined by either the Building Area Method, described in Section 9.5, or the Space-by-Space Method, described in Section 9.6. Trade-offs of interior lighting power allowance among portions of the building for which a different method of calculation has been used are not permitted. The installed interior lighting power identified in accordance with Section 9.1.3 shall not exceed the interior lighting power allowance developed in accordance with Section 9.5 or 9.6.

Exceptions: The following lighting equipment and applications shall not be considered when determining the interior lighting power allowance developed in accordance with Section 9.5 or 9.6, nor shall the wattage for such lighting be included in the installed interior lighting power identified in accordance with Section 9.1.3. However, any such lighting shall not be exempt unless it is an addition to general lighting and is controlled by an independent control device.

1. Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments
2. Lighting that is integral to equipment or instrumentation and is installed by its manufacturer
3. Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical equipment
4. Lighting integral to both open and glass-enclosed refrigerator and freezer cases
5. Lighting integral to food warming and food preparation equipment
6. Lighting specifically designed for the life support of nonhuman life forms
7. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions
8. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark
9. Lighting that is an integral part of advertising or directional signage
10. Exit signs
11. Lighting that is for sale or lighting educational demonstration systems
12. Lighting for theatrical purposes, including performance, stage, and film and video production
13. Lighting for television broadcasting in sporting activity areas
14. Casino gaming areas
15. Furniture-mounted supplemental task lighting that is controlled by automatic shutoff and complies with Section 9.4.1.3(c)
16. Mirror lighting in dressing rooms and accent lighting in religious pulpit and choir areas
17. Parking garage transition lighting—lighting for covered vehicle entrances and exits from buildings and parking structures—that complies with Section 9.4.1.2(a) and 9.4.1.2(c); each transition zone shall not exceed a depth of 66 ft inside the structure and a width of 50 ft

9.3 (Not Used)

9.4 Mandatory Provisions

9.4.1 Lighting Control. Building lighting controls shall be installed to meet the provisions of Sections 9.4.1.1, 9.4.1.2, 9.4.1.3, and 9.4.1.4.

9.4.1.1 Interior Lighting Controls. For each space in the building, all of the lighting control functions indicated in Table 9.6.1, for the appropriate space type in column A, and as described below, shall be implemented. All control functions labeled with an "REQ" are mandatory and shall be implemented. If a space type has control functions labeled "ADD1" then at least one of those functions indicated as "ADD1" shall be implemented. If a space type has control functions labeled "ADD2" then at least one of those functions indicated as "ADD2" shall be implemented. For space types not listed, select a reasonably equivalent type.

If using the Space-by-Space Method for LPD requirements, the space type used for determining control requirements shall be the same space type used to determine the LPD.

a. *Local control:* There shall be one or more manual lighting controls in the space that controls all of the lighting in the space. Each control device shall control an area (1) no larger than 2500 ft^2 (232.25 m^2) if the space is 10,000 ft^2 (929.03 m^2), and (2) no larger than 10,000 ft^2 (929.03 m^2) otherwise. The device installed to comply with this provision shall be readily accessible and located so that the occupants can see the controlled lighting when using the control device.

Exception: Remote location of this local control device or devices shall be permitted for reasons of safety or security when each remote control device has an indicator pilot light as part of or next to the control device and the light is clearly labeled to identify the controlled lighting.

b. *Restricted to manual ON:* None of the lighting shall be automatically turned on.

Exception: Manual ON is not required where manual ON operation of the general lighting would endanger the safety or security of the room or building occupants.

c. *Restricted to partial automatic ON:* No more than 50% of the lighting power for the general lighting shall be allowed to be automatically turned on, and none of the remaining lighting shall be automatically turned on.

d. *Bilevel lighting control:* The general lighting in the space shall be controlled so as to provide at least one intermediate step in lighting power or continuous dimming in addition to full ON and full OFF. At least one intermediate step shall be between 30% and 70% (inclusive) of full lighting power.

Exception: Existing and/or renovation spaces shall not be required to provide bi-level lighting control in areas where no work is to be performed or where only the existing light switch is being relocated due to door relocations.

e. *Automatic daylight responsive controls for sidelighting:* In any space where the combined input power of all general lighting completely or partially within the primary side- lighted areas is 150 W or greater, the general lighting in the primary sidelighted areas shall be controlled by photocontrols.

The control system shall have the following characteristics:

1. The calibration adjustments shall be readily accessible.
2. The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.

Exceptions: The following areas are exempted from Section 9.4.1.1(e):

1. Primary sidelighted areas where the top of any existing adjacent structure is twice as high above the windows as its distance away from the windows.
2. Sidelighted areas where the total glazing area is less than 20 ft^2.
3. Retail spaces.
4. Where the total interior lighting power (watts) of the building is no more than 80% of the interior lighting power allowance calculated by the Building Area Method in Section 9.5, or no more than 80% of the interior lighting power allowance calculated by the Space by-Space Method in Section 9.6.

f. Automatic daylight responsive controls for toplighting: In any space where the combined input power for all general lighting completely or partially within daylight areas under skylights and daylight areas under roof monitors is 105 W or greater, general lighting in the daylight area shall be controlled by photocontrols having the following characteristics:

1. The calibration adjustments shall be readily accessible.
2. The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point that is between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.

3. General lighting in overlapping toplighted and sidelighted daylight areas shall be controlled together with general lighting in the daylight area under skylights or daylight areas under roof monitors.

Exceptions: The following areas are exempted from Section 9.4.1.1(f):

1. Daylight areas under skylights where it is documented that existing adjacent structures or natural objects block direct sunlight for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
2. Daylight areas where the skylight visual transmittance (VT) is less than 0.4.
3. In each space within buildings in Climate Zone 8 where the input power of the general lighting within daylight areas is less than 200 W.
4. Where the total interior lighting power (watts) of the building is no more than 80% of the interior lighting power allowance calculated by the Building Area Method in Section 9.5, or no more than 80% of the interior lighting power allowance calculated by the Space-by-Space Method in Section 9.6.

g. *Automatic partial OFF (full OFF complies):* The general lighting power in the space shall be automatically reduced by at least 50% within 20 minutes of all occupants leaving the space.

Exceptions: This requirement does not have to be complied with in spaces that meet all three of the following requirements:

1. The space has an LPD of no more than 0.80 W/ft^2
2. The space is lighted by HID.
3. The general lighting power in the space is automatically reduced by at least 30% within 20 minutes of all occupants leaving the space.

h. *Automatic full OFF:* All lighting shall be automatically shut off within 20 minutes of all occupants leaving the space, except for restrooms, which shall be set to a maximum of 30 minutes. A control device meeting this requirement shall control no more than 5000 ft^2.

Exceptions: The following lighting is not required to be automatically shut off:

1. General lighting and task lighting in shop and laboratory classrooms.
2. General lighting and task lighting in spaces where automatic shutoff would endanger the safety or security of room or building occupants.
3. Lighting required for 24/7 operation or emergency lighting.

i. *Scheduled shutoff:* All lighting in the space not exempted by Exception (1) to Section 9.1.1 shall be automatically shut off during periods when the space is scheduled to be unoccupied using either (1) a time-of-day operated control device that automatically turns the lighting off at specific programmed times or (2) a signal from another automatic control device or alarm/security system. The control device or system shall provide independent control sequences that (1) control the lighting for an area of no more than 25,000 ft^2, (2) include no more than one floor, and (3) shall be programmed to account for weekends and holidays. Any manual control installed to provide override of the scheduled shutoff control shall not turn the lighting on for more than two hours per activation during scheduled off periods and shall not control more than 5000 ft^2.

Exceptions: The following lighting is not required to be on scheduled shutoff:

1. Lighting in spaces where lighting is required for 24/7 continuous operation.
2. Lighting in spaces where patient care is rendered.
3. Lighting in spaces where automatic shutoff would endanger the safety or security of the room or building occupants.

9.4.1.2 Parking Garage Lighting Control. Lighting for parking garages shall comply with the following requirements:

a. Parking garage lighting shall have automatic lighting shutoff per Section 9.4.1.1(i).

b. Lighting power of each luminaire shall be automatically reduced by a minimum of 30% when there is no activity detected within a lighting zone for 20 minutes. Lighting zones for this requirement shall be no larger than 3600 ft^2.

Exceptions: The following areas are exempt:

1. Daylight transitions zones and ramps without parking

c. Lighting for covered vehicle entrances and exits from buildings and parking structures shall be separately controlled by a device that automatically reduces the lighting by at least 50% from sunset to sunrise.

d. The power to luminaires within 20 ft of any perimeter wall structure that has a net opening-to-wall ratio of at least 40% and no exterior obstructions within 20 ft, shall be automatically reduced in response to daylight.

Exceptions: Lighting in the following areas is exempt:

1. Lighting in daylight transitions zones and ramps without parking

9.4.1.3 Special Applications

a. The following lighting shall be separately controlled from the general lighting in all spaces:

1. Display or accent lighting
2. Lighting in display cases
3. Nonvisual lighting, such as for plant growth or food warming

4. Lighting equipment that is for sale or used for demonstrations in lighting education

b. Guestrooms

1. All lighting and all switched receptacles in guestrooms and suites in hotels, motels, boarding houses, or similar buildings shall be automatically controlled such that the power to the lighting and switched receptacles in each enclosed space will be turned off within 20 minutes after all occupants leave that space.

Exception: Enclosed spaces where the lighting and switched receptacles are controlled by captive key systems and bathrooms are exempt.

2. Bathrooms shall have a separate control device installed to automatically turn off the bathroom lighting within 30 minutes after all occupants have left the bathroom.

Exception: Night lighting of up to 5 W per bathroom is exempt.

c. All supplemental task lighting, including permanently installed undershelf or undercabinet lighting, shall be controlled from either (1) a control device integral to the luminaires or (2) by a wall-mounted control device that is readily accessible and located so that the occupant can see the controlled lighting.

9.4.1.4 Exterior Lighting Control. Lighting for exterior applications not exempted in Section 9.1 shall meet the following requirements:

a. Lighting shall be controlled by a device that automatically turns off the lighting when sufficient daylight is available.

b. All building façade and landscape lighting shall be automatically shut off between midnight or business closing, whichever is later, and 6 a.m. or business opening, whichever comes first, or between times established by the authority having jurisdiction.

c. Lighting not specified in Section 9.4.1.4(b) and lighting for signage shall be controlled by a device that automatically reduces the connected lighting power by at least 30% for at least one of the following conditions:

1. From 12 midnight or within one (1) hour of the end of business operations, whichever is later, until 6 a.m. or business opening, whichever is earlier.

2. During any period when no activity has been detected for a time of no longer than 15 minutes.

All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least ten hours.

Exceptions:

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

2. Lighting that is integral to signage and installed in the signage by the manufacturer.

9.4.1.4.1 Parking Lighting. This section supersedes Section 9.4.1.4 for lighting serving uncovered parking areas. Outdoor luminaires serving uncovered parking areas shall be controlled by all of the following:

a. Luminaires shall be controlled by a device that automatically turns off the luminaire during daylight hours.

b. Luminaires shall be controlled by a timeclock or other control that automatically turns off the luminaire according to a timed schedule.

c. For luminaires having a rated input wattage of more than 50 W and where the bottom of the luminaire is mounted 24 ft (7.3 m) or less above the ground, the luminaires shall be controlled by one or more devices that automatically reduce lighting power of each luminaire by a minimum of 40% when there is no activity detected in the controlled zone for a period no longer than 15 minutes. No more than 1,500 input watts of lighting power shall be controlled together.

Exceptions:

1. Lighting serving uncovered parking areas does not include lighting for outdoor sales, including vehicle sales lots.
2. Lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security, or eye adaptation.

9.4.2 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 designed to be illuminated and are permitted in Table 9.4.2-2 for the applicable lighting zone. The installed exterior lighting power identified in accordance with Section 9.1.3 shall not exceed the exterior lighting power allowance developed in accordance with this section. Tradeoffs are allowed only among exterior lighting applications listed in the Table 9.4.2-2 "Tradable Surfaces" section. The lighting zone for the building exterior is determined from Table 9.4.2-1 unless otherwise specified by the local jurisdiction.

Exceptions:

1. Lighting used for the following exterior applications is exempt when equipped with a control device that complies with the requirements of Section 9.4.1.4 and is independent of the control of the nonexempt lighting:
   a. Lighting that is integral to signage and installed in the signage by the manufacturer
   b. Lighting for athletic playing areas
   c. Lighting for industrial production, material handling, transportation sites, and associated storage areas

TABLE 9.4.2-1 Exterior Lighting Zones

Lighting Zone	Description
0	Undeveloped areas within national parks, state parks, forest land, rural areas, and other undeveloped areas as defined by the authority having jurisdiction
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 jurisdiction

d. Theme elements in theme/amusement parks
e. Lighting used to highlight features of public monuments and registered historic landmark structures or buildings.
f. Lighting for water features

2. Lighting used for the following exterior applications is exempt when controlled separately:
   a. Specialized signal, directional, and marker lighting associated with transportation
   b. Lighting integral to equipment or instrumentation and installed by its manufacturer
   c. Lighting for theatrical purposes, including performance, stage, film production, and video production
   d. Temporary lighting
   e. Lighting for hazardous locations
   f. Lighting for swimming pools
   g. Searchlights

9.4.3 Functional Testing. Lighting control devices and control systems shall be tested to ensure that control hardware and software are calibrated, adjusted, programmed, and in proper working condition in accordance with the construction documents and manufacturer's installation instructions. When occupant sensors, time switches, programmable schedule controls, or photosensors are installed, at a minimum, the following procedures shall be performed:

a. Occupant Sensors
   1. Certify that the sensor has been located and aimed in accordance with manufacturer recommendations.
   2. For projects with up to seven (7) occupancy sensors, all occupancy sensors shall be tested.
   3. For projects with more than seven (7) occupancy sensors, testing shall be done for each unique combination of sensor type and space geometry.
      (a) For each sensor to be tested, verify the following:
         (1) Status indicator (as applicable) operates correctly
         (2) Controlled lights turn off or down to the permitted level within the required time
         (3) For auto-on occupant sensors, the lights turn on to the permitted level when someone enters the space
         (4) For manual-on sensors, the lights turn on only when manually activated
         (5) The lights are not incorrectly turned on by movement in nearby areas or by HVAC operation

b. Automatic Time Switches
   1. Confirm that the automatic time-switch control is programmed with appropriate weekday, weekend, and holiday (as applicable) schedules.
   2. Document for the owner automatic time-switch programming, including weekday, weekend, and holiday schedules, as well as all setup and preference program settings.
   3. Verify that correct time and date are properly set in the time switch.
   4. Verify that any battery backup (as applicable) is installed and energized.
   5. Verify that the override time limit is set to no more than two (2) hours.
   6. Simulate occupied condition. Verify and document the following:
      (a) All lights can be turned on and off by their respective area control switch.
      (b) The switch only operates lighting in the enclosed space in which the switch is located.
   7. Simulate unoccupied condition. Verify and document the following:
      (a) All nonexempt lighting turns off
      (b) Manual override switch allows only the lights in the enclosed space where the override switch is located to turn on or remain on until the next scheduled shut off occurs

TABLE 9.4.2-2 INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (base allowance may be used in tradable or non-tradable surfaces)					
	No base site in Zone 0	500 W	600 W	750 W	1300 W
Tradable Surfaces (LPDs for uncovered parking areas, building grounds, building entrances, exits and loading docks, canopies and overhangs, and outdoor sales areas may be traded.)					
Uncovered Parking Areas					
Parking areas and drives	No allowance	0.03 W/ft^2	0.05 W/ft^2	0.09 W/ft^2	0.12 W/ft^2
Building Grounds					
Walkways less than 10 ft wide	No allowance	0.63 W/linear foot	0.63 W/linear foot	0.76 W/linear foot	0.95 W/linear foot
Walkways 10 ft wide or greater Plaza areas Special feature areas	No allowance	0.12 W/ft^2	0.12 W/ft^2	0.15 W/ft^2	0.19 W/ft^2
Stairways	No allowance	0.67 W/ft^2	0.9 W/ft^2	0.95 W/ft^2	0.95 W/ft^2
Pedestrian tunnels	No allowance	0.13 W/ft^2	0.13 W/ft^2	0.19 W/ft^2	0.28 W/ft^2
Landscaping	No allowance	0.03 W/ft^2	0.04 W/ft^2	0.04 W/ft^2	0.04 W/ft^2
Building Entrances, Exits, and Loading Docks					
Main entries	No allowance	18 W/lin ft of door width	18 W/lin ft of door width	28.5 W/lin ft of door width	28.5 W/lin ft of door width
Other doors	No allowance	18 W/lin ft of door width	18 W/lin ft of door width	19 W/lin ft of door width	19 W/lin ft of door width
Entry canopies	No allowance	0.22 W/ft^2	0.22 W/ft^2	0.38 W/ft^2	0.38 W/ft^2
Loading docks	No allowance	0.45 W/ft^2	0.45 W/ft^2	0.47 W/ft^2	0.47 W/ft^2
Sales Canopies					
Free standing and attached	No allowance	0.54 W/ft^2	0.54 W/ft^2	0.76 W/ft^2	0.95 W/ft^2
Outdoor Sales					
Open areas (including vehicle sales lots)	No allowance	0.22 W/ft^2	0.22 W/ft^2	0.47 W/ft^2	0.66 W/ft^2
Street frontage for vehicle sales lots in addition to “open area” allowance	No allowance	No allowance	9 W/linear foot	9.5 W/linear foot	28.5 W/linear foot

TABLE 9.4.2-2 INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS *(Continued)*

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Nontradable Surfaces (LPD 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 façades	No allowance	No allowance	0.09 W/ft^2 for each illuminated wall or surface or 2.37 W/ linear foot for each illuminated wall or surface length	0.14 W/ft^2 for each illuminated wall or surface or 3.56 W/ linear foot for each illuminated wall or surface length	0.19 W/ft^2 for each illuminated wall or surface or 4.75 W/ linear foot for each illuminated wall or surface length
Automated teller machines and night depositories	No allowance	256.5 W per location plus 85.5 W per additional ATM per location	256.5 W per location plus 85.5 W per add itional ATM per location	256.5 W per location plus 85.5 W per additional ATM per location	256.5 W per location plus 85.5 W per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities	No allowance	0.71 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.71 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.71 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.71 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles	No allowance	0.47 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.47 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.47 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.47 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Drive-through windows/ doors	No allowance	380 W per drive-through	380 W per drive-through	380 W per drive-through	380 W per drive-through
Parking near 24-hour retail entrances	No allowance	760 W per main entry	760 W per main entry	760 W per main entry	760 W per main entry
Roadway/parking entry, trail head, and toilet facility, or other locations approved by the authority having jurisdiction.	A single luminaire of 60 W or less may be installed for each roadway/ parking entry, trail head, and toilet facility, or other locations approved by the authority having jurisdiction	No allowance	No allowance	No allowance	No allowance

c. Daylight Controls

1. All control devices (photocontrols) have been properly located, field-calibrated, and set for appropriate setpoints and threshold light levels.
2. Daylight controlled lighting loads adjust to appropriate light levels in response to available daylight.

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	LPD, W/ft^2
Automotive facility	0.80
Convention center	1.01
Courthouse	0.95
Dining: Bar lounge/leisure	1.01
Dining: Cafeteria/fast food	0.85
Dining: Family	0.90
Dormitory	0.54
Exercise center	0.79
Fire station	0.67
Gymnasium	0.94
Health-care clinic	0.85
Hospital	0.99
Hotel/Motel	0.87
Library	1.13
Manufacturing facility	1.17
Motion picture theater	0.76
Multifamily	0.48
Museum	1.02
Office	0.77
Parking garage	0.21
Penitentiary	0.76
Performing arts theater	1.39
Police station	0.82
Post office	0.87
Religious building	0.95
Retail	1.26
School/university	0.78
Sports arena	0.91
Town hall	0.84
Transportation	0.66
Warehouse	0.66
Workshop	1.19

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

3. The location where calibration adjustments are made is readily accessible only to authorized personnel.

The individual(s) responsible for the functional testing shall not be directly involved in either the design or construction of the project and shall provide documentation certifying that the installed lighting controls meet or exceed all documented performance criteria.

9.5 Building Area Method Compliance Path

9.5.1 Building Area Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the Building Area Method:

a. Determine the appropriate building area type from Table 9.5.1 and the allowed LPD (watts per unit area) from the "Building Area Method" column. For building area types not listed, selection of a reasonably equivalent type shall be permitted.

b. Determine the gross lighted floor area (square feet) of the building area type.

c. Multiply the gross lighted floor areas of the building area type(s) times the LPD.

d. The interior lighting power allowance for the building is the sum of the lighting power allowances of all building area types. Trade-offs among building area types are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance.

9.5.2 Prescriptive Control Requirements

9.5.2.1 *Automatic* Control of Lights in Group R-1 Occupancies. In Group R-1 occupancies with more than 50 guest rooms, *automatic controls* for the lighting shall be configured according to the following requirements.

9.5.2.1.1 Lighting and Switched Outlet Control. Within 30 minutes of all occupants leaving the guest room, power for lighting shall be automatically turned off.

9.5.2.2 Occupancy Sensor Controls with Multilevel Switching or Dimming. The lighting in commercial and industrial storage stack areas shall be controlled by an occupant sensor with multilevel switching or dimming system that reduces lighting power a minimum of 50% within 20 minutes of all occupants leaving the stack area.

Exception: Storage stack areas illuminated by high- intensity discharge (HID) lighting with a lighting power density of 0.8 W/ft^2 (8.6 W/m^2) or less.

9.5.2.3 *Automatic* Controls for Egress and Security Lighting. Lighting in any area within a building that is required to be continuously illuminated for reasons of building security or emergency egress shall not exceed 0.1 W/ft^2

(1 W/m^2). Additional egress and security lighting shall be allowed, provided it is controlled by an *automatic* control device that turns off the additional lighting.

9.5.2.4 Controls for Exterior Sign Lighting. All exterior sign lighting, including internally illuminated signs and lighting on externally illuminated signs, shall comply with the requirements of Sections 9.5.2.4.1 or 9.5.2.4.2.

Exceptions:

1. Sign lighting that is specifically required by a health or life safety statute, ordinance, or regulation.
2. Signs in tunnels.

9.5.2.4.1 All sign lighting that operates more than one hour per day during *daylight hours* shall include controls to automatically reduce the input power to a maximum of 35% of full power for a period from one hour after sunset to one hour before sunrise.

Exception: Sign lighting using metal halide, high-pressure sodium, induction, cold cathode, or neon lamps that includes controls to automatically reduce the input power to a maximum of 70% of full power for a period from one hour after sunset to one hour before sunrise.

9.5.2.4.2 All other sign lighting shall include the following:

a. Controls to automatically reduce the input power to a maximum of 70% of full power for a period from midnight or within one hour of the end of business operations, whichever is later, until 6:00 am or business opening, whichever is earlier.
b. Controls to automatically turn off during daylight hours.

9.6 Alternative Compliance Path: Space-by-Space Method

9.6.1 Space-by-Space Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the Space-by-Space Method:

a. For each space enclosed by partitions that are 80% of the ceiling height or taller, determine the appropriate space type from Table 9.6.1. If a space has multiple functions, where more than one space type is applicable, that space shall be broken up into smaller subspaces, each using its own space type from Table 9.6.1. Any of these subspaces that are smaller in floor area than 20% of the original space and less than 1000 ft^2 need not be broken out separately. Include the floor area of balconies and other projections in this calculation.
b. In calculating the area of each space and subspace, the limits of the area are defined by the centerline of interior walls, the dividing line between subspaces, and the outside surface of exterior walls.
c. Based on the space type selected for each space or subspace, determine the lighting power allowance of each space or subspace by multiplying the calculated area of the space or subspace by the appropriate LPD determined in Section 9.6.1(a). For space types not listed, selection of a reasonable equivalent category shall be permitted.
d. The interior lighting power allowance is the sum of lighting power allowances of all spaces and subspaces. Tradeoffs among spaces and subspaces are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance.

9.6.2 Additional Interior Lighting Power. When using the Space-by-Space Method, an increase in the interior lighting power allowance is allowed for specific lighting functions. Additional power shall be allowed only if the specified lighting is installed and automatically controlled, separately from the general lighting, to be turned off during nonbusiness hours. This additional power shall be used only for the specified luminaires and shall not be used for any other purpose unless otherwise indicated.

An increase in the interior lighting power allowance is permitted in the following cases:

a. For spaces in which lighting is specified to be installed in addition to the general lighting for the purpose of decorative appearance or for highlighting art or exhibits, provided that the additional lighting power shall not exceed 5% of the lighting power allowance across the entire project space permitted in Sections 9.5.1 or 9.6.1.
b. For lighting equipment installed in sales areas and specifically designed and directed to highlight merchandise, calculate the additional lighting power as follows:

+ (For Retail Area 2, 10% base power allowance for the sales area per Table 9.5.1 or Table 9.6.1)

+ (For Retail Area 3, 30% base power allowance for the sales area per Table 9.5.1 or Table 9.6.1)

+ (For Retail Area 4, 50% base power allowance for the sales area per Table 9.5.1 or Table 9.6.1),

Retail Area 1 = the floor area for all products not listed in Retail Areas 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 may 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.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/ft^2	RCR Threshold	Local Control (See Section 9.4.1.1[a])	Restricted to Manual ON (See Section 9.4.1.1[b])	Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	Bilevel Lighting Control (See Section 9.4.1.1[d])	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	Automatic Full OFF (See Section 9.4.1.1[h])	Scheduled Shutoff (See Section 9.4.1.1[i])
			a	b	c	d	e	f	g	h	i
Atrium											
… that is <20 ft in height	0.03/ft total height	NA	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… that is ≥20 ft and ≤40 ft in height	0.03/ft total height	NA	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… that is >40 ft in height	0.40 + 0.02/ft total height	NA	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Audience Seating Area											
... in an auditorium	0.63	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a convention center	0.82	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a gymnasium	0.65	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a motion picture theater	1.14	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a penitentiary	0.28	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
... in a performing arts theater	2.43	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a religious building	1.53	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a sports arena	0.43	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… all other audience seating areas	0.43	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Banking Activity Area	1.01	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Breakroom (See Lounge/Breakroom)											
Classroom/Lecture Hall/Training Room											
… in a penitentiary	1.34	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… all other classrooms/lecture halls/ training rooms	1.24	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare,senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft^2. The additional 0.53 w/ft^2 allowance shall not be used for any other purpose.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method *(Continued)*

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/ft²	RCR Threshold	Local Control (See Section 9.4.1.1[a]) a	Restricted to Manual ON (See Section 9.4.1.1[b]) b	Restricted to Partial Automatic ON (See Section 9.4.1.1[c]) c	Bilevel Lighting Control (See Section 9.4.1.1[d]) d	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6]) e	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6]) f	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies]) g	Automatic Full OFF (See Section 9.4.1.1[h]) h	Scheduled Shutoff (See Section 9.4.1.1[i]) i
Conference/Meeting/Multipurpose Room	1.10	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Confinement Cells	0.81	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Copy/Print Room	0.72	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Corridor[2]											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	0.92	width <8 ft	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… in a hospital	0.99	width <8 ft	REQ	—	—	—	REQ	REQ	ADD2	ADD2	ADD2
… in a manufacturing facility	0.41	width <8 ft	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… all other corridors	0.56	width <8 ft	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
Courtroom	1.46	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Computer Room	1.71	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Dining Area											
… in a penitentiary	0.96	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a facility for the visually impaired (and not used primarily by staff)[3]	2.65	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in bar/lounge or leisure dining	1.07	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in cafeteria or fast food dining	0.65	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in family dining	0.75	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… all other dining areas	0.58	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft². The additional 0.53 w/ft² allowance shall not be used for any other purpose.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method *(Continued)*

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/ft²	RCR Threshold	a Local Control (See Section 9.4.1.1[a])	b Restricted to Manual ON (See Section 9.4.1.1[b])	c Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	d Bilevel Lighting Control (See Section 9.4.1.1[d])	e Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	f Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	g Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	h Automatic Full OFF (See Section 9.4.1.1[h])	i Scheduled Shutoff (See Section 9.4.1.1[i])
Electrical/Mechanical Room[7]	0.42	6	REQ	—	—	—	REQ	REQ	—	—	—
Emergency Vehicle Garage	0.56	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Food Preparation Area	1.21	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Guest Room	0.91	6	See Section 9.4.1.3b.								
Laboratory											
… in or as a classroom	1.43	6	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
… all other laboratories	1.71	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Laundry/Washing Area	0.57	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Loading Dock, Interior	0.47	6	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Lobby											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	1.80	4	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… for an elevator	0.54	6	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… in a hotel	1.06	4	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… in a motion picture theater	0.56	4	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… in a performing arts theater	2.00	6	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… all other lobbies	0.85	4	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
Locker Room	0.75	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Lounge/Breakroom											
… in a healthcare facility	0.78	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… all other lounges/breakrooms	0.62	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft². The additional 0.53 w/ft² allowance shall not be used for any other purpose.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method *(Continued)*

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/ft²	RCR Threshold	a Local Control (See Section 9.4.1.1[a])	b Restricted to Manual ON (See Section 9.4.1.1[b])	c Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	d Bilevel Lighting Control (See Section 9.4.1.1[d])	e Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	f Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	g Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	h Automatic Full OFF (See Section 9.4.1.1[h])	i Scheduled Shutoff (See Section 9.4.1.1[i])
Office											
… enclosed and ≤250 ft²	1.05	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… enclosed and >250 ft²	1.05	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… open plan	0.93	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Parking Area, Interior	0.19	4	See Section 9.4.1.2.								
Pharmacy Area	1.68	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Restroom											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	1.21	8	REQ	—	—	—	REQ	REQ	—	REQ	—
… all other restrooms	0.98	8	REQ	—	—	—	REQ	REQ	—	REQ	—
Sales Area[4]	1.36	6	REQ	ADD1	ADD1	REQ	—	REQ	—	ADD2	ADD2
Seating Area, General	0.54	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Stairway			The space containing the stairway shall determine the LPD and control requirements for the stairway.								
Stairwell	0.69	10	REQ	—	—	REQ	REQ	REQ	REQ	ADD2	ADD2
Storage Room											
… <50 ft²	1.24	6	REQ	—	—	—	—	—	—	ADD2	ADD2
… ≥50 ft² and ≤ 1000 ft²	0.63	6	REQ	ADD1	ADD1	—	REQ	REQ	—	REQ	—
… all other storage rooms	0.63	6	REQ	ADD1	ADD1	—	REQ	REQ	REQ	ADD2	ADD2
Vehicular Maintenance Area	0.67	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Workshop	1.59	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft². The additional 0.53 w/ft² allowance shall not be used for any other purpose.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method *(Continued)*

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Building Type Specific/Space Types[1]	LPD W/ft²	RCR Threshold	Local Control (See Section 9.4.1.1[a]) a	Restricted to Manual ON (See Section 9.4.1.1[b]) b	Restricted to Partial Automatic ON (See Section 9.4.1.1[c]) c	Bilevel Lighting Control (See Section 9.4.1.1[d]) d	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6]) e	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6]) f	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies]) g	Automatic Full OFF (See Section 9.4.1.1[h]) h	Scheduled Shutoff (See Section 9.4.1.1[i]) i
Facility for the Visually Impaired[3]											
… in a chapel (used primarily by residents)	2.21	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a recreation room/common living room (and not used primarily by staff)	2.41	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Automotive (See "Vehicular Maintenance Area")											
Convention Center—Exhibit Space	1.23	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Dormitory—Living Quarters	0.38	8	REQ	—	—	—	—	—	—	—	—
Fire Station—Sleeping Quarters	0.22	6	REQ	—	—	—	—	—	—	—	—
Facility for the Visually Impaired [3]											
Gymnasium/Fitness Center											
… in an exercise area	0.61	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a playing area	1.20	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Healthcare Facility											
… in an exam/treatment room	1.41	8	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in an imaging room	1.51	6	REQ	—	—	REQ	—	—	—	ADD2	ADD2
….in a medical supply room	0.66	6	(See "Storage Room" under "Common Space Types" for control requirements)								
… in a nursery	0.74	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft². The additional 0.53 w/ft² allowance shall not be used for any other purpose.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method *(Continued)*

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Building Type Specific/Space Types[1]	LPD W/ft^2	RCR Threshold	a Local Control (See Section 9.4.1.1[a])	b Restricted to Manual ON (See Section 9.4.1.1[b])	c Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	d Bilevel Lighting Control (See Section 9.4.1.1[d])	e Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	f Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	g Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	h Automatic Full OFF (See Section 9.4.1.1[h])	i Scheduled Shutoff (See Section 9.4.1.1[i])
… in a nurse's station	0.63	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in an operating room	2.48	6	REQ	—	—	REQ	—	—	—	ADD2	ADD2
… in a patient room	0.55	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in a physical therapy room	0.77	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in a recovery room	1.15	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
Library											
… in a reading area	1.06	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in the stacks	1.62	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Manufacturing Facility											
… in a detailed manufacturing area	1.29	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in an equipment room	0.74	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in an extra high bay area (>50 ft floor-to-ceiling height)	1.05	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a high bay area (25–50 ft floor-to-ceiling height)	1.04	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a low bay area (<25 ft floor-to-ceiling height)	1.01	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Museum											
… in a general exhibition area	1.05	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a restoration room	1.02	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Performing Arts Theater—Dressing Room	0.61	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
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4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft^2. The additional 0.53 w/ft^2 allowance shall not be used for any other purpose.

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method *(Continued)*

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
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(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Building Type Specific/Space Types[1]	LPD W/ft^2	RCR Threshold	a Local Control (See Section 9.4.1.1[a])	b Restricted to Manual ON (See Section 9.4.1.1[b])	c Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	d Bilevel Lighting Control (See Section 9.4.1.1[d])	e Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	f Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	g Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	h Automatic Full OFF (See Section 9.4.1.1[h])	i Scheduled Shutoff (See Section 9.4.1.1[i])
Post Office—Sorting Area	0.94	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Religious Buildings											
… in a fellowship hall	0.64	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a worship/pulpit/choir area	1.53	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Retail Facilities											
… in a dressing/fitting room	0.71	8	REQ	ADD1	ADD1	REQ		REQ	—	REQ	—
… in a mall concourse	1.10	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Sports Arena—Playing Area											
… for a Class I facility	3.68	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… for a Class II facility	2.40	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… for a Class III facility	1.80	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… for a Class IV facility	1.20	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Transportation Facility											
… in a baggage/carousel area	0.47	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… in an airport concourse	0.32	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… at a terminal ticket counter	0.68	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Warehouse—Storage Area											
…for medium to bulky, palletized items	0.49	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
… for smaller, hand-carried items[5]	0.95	6	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft. and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft^2. The additional 0.53 w/ft^2 allowance shall not be used for any other purpose.

9.6.3 Prescriptive Controls. Projects shall comply with the prescriptive control requirements of Section 9.5.2.

TABLE 9.6.3 [Reserved]

9.6.4 Room Geometry Adjustment. When using the Space-by-Space Method, an adjustment of the space LPD is allowed for individual spaces where room cavity ratio (RCR) calculated for the empty room is documented to be greater than the RCR threshold for that space type shown in Table 9.6.1.

$$RCR = 2.5 \times \text{Room Cavity Height} \times \text{Room Perimeter Length} / \text{Room Area}$$

where

Room Cavity Height = Luminaire Mounting Height – Workplane

For corridor/transition spaces, this adjustment is allowed when the corridor is less than 8 ft wide, regardless of the RCR.

The LPD allowance for these spaces may be increased by the following amount:

$$\text{LPD Increase} = \text{Base Space LPD} \times 0.20$$

where

Base Space LPD = the applicable LPD from Table 9.6.1.

9.7 Submittals

9.7.1 General. Where required by the authority having jurisdiction, the submittal of compliance documentation and supplemental information shall be in accordance with Section 4.2.2.

9.7.2 Completion requirements. The following requirements are mandatory provisions and are necessary for compliance with this standard.

9.7.2.1 Drawings. Construction documents shall require that within 90 days after the date of system acceptance, record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include, as a minimum, the location, luminaire identifier, control, and circuiting for each piece of lighting equipment.

9.7.2.2 Manuals. Construction documents shall require for all lighting equipment and lighting controls, an operating and maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of system acceptance. These manuals shall include, at a minimum, the following:

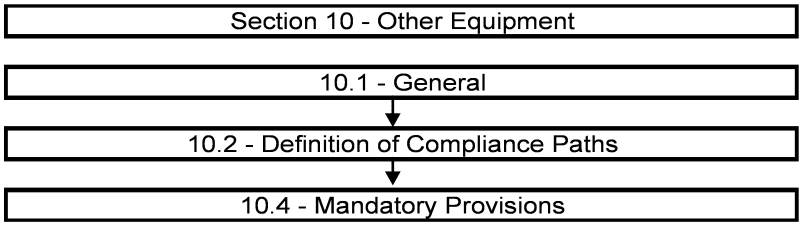
a. Submittal data indicating all selected options for each piece of lighting equipment, including but not limited to lamps, ballasts, drivers, and lighting controls.

b. Operation and maintenance manuals for each piece of lighting equipment and lighting controls with routine maintenance clearly identified including, as a minimum, a recommended relamping/cleaning program and a schedule for inspecting and recalibrating all lighting controls.

c. A complete narrative of how each lighting control system is intended to operate including recommended settings.

9.7.2.3 Daylighting Documentation. The design documents shall identify all luminaires for general lighting that are located within daylight areas under skylights, daylight areas under roof monitors as well as primary sidelighted areas and secondary sidelighted areas.

9.8 Product Information (Not Used)



10. OTHER EQUIPMENT

10.1 General

10.1.1 Scope. This section applies only to the equipment described below.

10.1.1.1 New Buildings. Other equipment installed in new buildings shall comply with the requirements of this section.

10.1.1.2 Additions to Existing Buildings. Other equipment installed in additions to existing buildings shall comply with the requirements of this section.

10.1.1.3 Alterations to Existing Buildings

10.1.1.3.1 Alterations to other building service equipment or systems shall comply with the requirements of this section applicable to those specific portions of the building and its systems that are being altered.

10.1.1.3.2 Any new equipment subject to the requirements of this section that is installed in conjunction with the alterations as a direct replacement of existing equipment or control devices shall comply with the specific requirements applicable to that equipment or control devices.

Exception: Compliance shall not be required for the relocation or reuse of existing equipment.

10.2 Compliance Paths

10.2.1 Compliance. Compliance with Section 10 shall be achieved by meeting all requirements of Section 10.1, "General"; Section 10.4, "Mandatory Provisions"; and Section 10.8, "Product Information."

10.2.2 Projects using the Energy Cost Budget Method (Section 11 of this standard) must comply with Section 10.4, the mandatory provisions of this section, as a portion of that compliance path.

10.3 Simplified/Small Building Option (Not Used)

10.4 Mandatory Provisions

10.4.1 Electric Motors. Electric motors manufactured alone or as a component of another piece of equipment with a power rating of 1 hp or more, and less than or equal to 200 hp, shall comply with the requirements of the Energy Independence and Security Act of 2007, as shown in Table 10.8-1 for general purpose electric motors (subtype I) and Table 10.8-2 for general purpose electric motors (subtype II).

General purpose electric motors with a power rating of more than 200 hp, but no more than 500 hp, shall have a minimum nominal full-load efficiency that is not less than as shown in Table 10.8-3.

Fire-pump electric motors shall have a minimum nominal full-load efficiency that is not less than that shown in Table 10.8-6.

Motors that are not included in the scope of the Energy Independence and Security Act of 2007, Section 313, have no performance requirements in this section.

10.4.2 Service Water Pressure Booster Systems. Service water pressure booster systems shall be designed such that

a. one or more pressure sensors shall be used to vary pump speed and/or start and stop pumps. The sensor(s) shall either be located near the critical fixture(s) that determine the pressure required, or logic shall be employed that adjusts the setpoint to simulate operation of remote sensor(s).

b. no device(s) shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster system pump or booster system, except for safety devices.

c. no booster system pumps shall operate when there is no service water flow.

10.4.3 Elevators. Elevator systems shall comply with the requirements of this section.

10.4.3.1 Lighting. For the luminaires in each elevator cab, not including signals and displays, the sum of the lumens divided by the sum of the watts (as described in Section 9.1.4) shall be no less than 35 lm/W.

10.4.3.2 Ventilation Power Limitation. Cab ventilation fans for elevators without air conditioning shall not consume over 0.33 W/cfm at maximum speed.

10.4.3.3 Standby Mode. When stopped and unoccupied with doors closed for over 15 minutes, cab interior lighting and ventilation shall be de-energized until required for operation.

10.4.4 Escalators and Moving Walks. Escalators and moving walks shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 or applicable local code when not conveying passengers.

10.4.5 Whole-Building Energy Monitoring. Measurement devices shall be installed at the building site to monitor the energy use of each new building.

10.4.5.1 Monitoring. Measurement devices shall be installed to monitor the building use of the following types of energy supplied by a utility, energy provider, or plant that is not within the building:

a. Natural gas

b. Fuel oil

c. Propane

d. Steam

e. Chilled water

f. Hot water

10.4.5.2 Recording and Reporting. The energy use of each building on the building site shall be recorded at a minimum of every 60 minutes and reported at least hourly, daily, monthly, and annually. The system shall be capable of maintaining all data collected for a minimum of 36 months and creating user reports showing at least hourly, daily, monthly, and annual energy consumption and demand.

Exceptions to 10.4.5.1 and 10.4.5.2:

1. Buildings or additions less than 25,000 ft^2
2. Individual tenant spaces less than 10,000 ft^2
3. Dwelling units
4. Residential buildings with less than 10,000 ft^2 of common area
5. Fuel used for on-site emergency equipment

10.5 Prescriptive Compliance Path. All building projects shall comply with the requirements in Section 10.5.1, 10.5.3 and 10.5.4. All building projects complying with the Alternate Renewables Approach in Section 13.1.1.2 shall also comply with Section 10.5.2.

10.5.1 ENERGY STAR Requirements for New Equipment not Covered by Federal Appliance Efficiency Regulations (All *Building Projects*). The following equipment within the scope of the applicable ENERGY STAR program shall comply with the equivalent criteria required to achieve the ENERGY STAR label if installed prior to the issuance of the certificate of occupancy:

a. Appliances

1. Room air cleaners: ENERGY STAR Program Requirements for Room Air Cleaners
2. Water coolers: ENERGY STAR Program Requirements for Water Coolers

b. Heating and Cooling

1. Programmable thermostats: ENERGY STAR Program Requirements for Programmable Thermostats
2. Ventilating fans: ENERGY STAR Program Requirements for *Residential* Ventilating Fans

c. Lighting

1. Integral LED lamps: ENERGY STAR Program Requirements for Integral LED Lamps

d. Commercial Food Service

1. Commercial fryers: ENERGY STAR Program Requirements for Commercial Fryers
2. Commercial hot food holding cabinets: ENERGY STAR Program Requirements for Hot Food Holding Cabinets
3. Commercial steam cookers: ENERGY STAR Program Requirements for Commercial Steam Cookers (see also water efficiency requirements in Section 6.4.2.2)
4. Commercial dishwashers: ENERGY STAR Program Requirements for Commercial Dishwashers
5. Commercial griddles: ENERGY STAR Program Requirements for Commercial Griddles
6. Commercial ovens: ENERGY STAR Program Requirements for Commercial Ovens (see also water efficiency requirements in Section 6.4.2.2)

Exception: Products with minimum efficiencies addressed in the Energy Policy Act (EP Act) and the Energy Independence and Security Act (EISA) when complying with Section 13.1.1.2 are exempted from Section 10.5.1.

10.5.2 ENERGY STAR Requirements for New Equipment Covered by Federal Appliance Efficiency Regulations (Alternate Renewables Approach). For all *building projects* complying with the Alternate Renewables Approach in Section 13.1.1.2, the following equipment within the scope of the applicable ENERGY STAR program shall comply with the equivalent criteria required to achieve the ENERGY STAR label if installed prior to the issuance of the certificate of occupancy. For those products listed below that are also contained in Normative Appendix B, the installed equipment shall comply by meeting or exceeding both the requirements in this section and in Normative Appendix B.

a. Appliances

1. Clothes washers: ENERGY STAR Program Requirements for Clothes Washers (see also the water efficiency requirements in Section 6.3.2.2 of ASHRAE 189.1)
2. Dehumidifiers: ENERGY STAR Program Requirements for Dehumidifiers
3. Dishwashers: ENERGY STAR Program Requirements Product Specifications for *Residential Dishwashers* (see also the water efficiency requirements in Section 6.3.2.2 of ASHRAE 189.1)
4. Refrigerators and freezers: ENERGY STAR Program Requirements for Refrigerators and Freezers
5. Room air conditioners: ENERGY STAR Program Requirements and Criteria for Room Air Conditioners

b. Heating and Cooling

1. *Residential* air-source heat pumps: ENERGY STAR Program Requirements for ASHPs and Central Air Conditioners (see also the energy efficiency requirements in Section 13.1)
2. *Residential* boilers: ENERGY STAR Program Requirements for Boilers (see also the energy efficiency requirements in Section 13.1)
3. *Residential* central air conditioners: ENERGY STAR Program Requirements for ASHPs and Central Air Conditioners (see also the energy efficiency requirements in Section 13.1)
4. *Residential* ceiling fans: ENERGY STAR Program Requirements for *Residential* Ceiling Fans
5. Dehumidifiers: ENERGY STAR Program Requirements for Dehumidifiers
6. *Residential* warm air furnaces: ENERGY STAR Program Requirements for Furnaces
7. *Residential* geothermal heat pumps: ENERGY STAR Program Requirements for Geothermal Heat Pumps

c. Water Heaters: ENERGY STAR Program Requirements for Residential Water Heaters

d. Lighting

1. Lamps: ENERGY STAR Program Requirements for Lamps (Light Bulbs)
2. Luminaires: ENERGY STAR Program Requirements for Luminaires

TABLE 10.8-1 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype I), Except Fire-Pump Electric Motors[a]

	Full-Load Efficiency, %					
	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	2	4	6	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	77.0	85.5	82.5	77.0	85.5	82.5
1.5	84.0	86.5	86.5	84.0	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	89.5	88.5	89.5	89.5
7.5	88.5	91.0	90.2	89.5	91.7	91.0
10	89.5	91.7	91.7	90.2	91.7	91.0
15	90.2	93.0	91.7	91.0	92.4	91.7
20	91.0	93.0	92.4	91.0	93.0	91.7
25	91.7	93.6	93.0	91.7	93.6	93.0
30	91.7	94.1	93.6	91.7	93.6	93.0
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93.0	94.5	94.1	93.0	94.5	94.1
60	93.6	95.0	94.5	93.6	95.0	94.5
75	93.6	95.0	94.5	93.6	95.4	94.5
100	93.6	95.4	95.0	94.1	95.4	95.0
125	94.1	95.4	95.0	95.0	95.4	95.0
150	94.1	95.8	95.4	95.0	95.8	95.8
200	95.0	95.8	95.4	95.4	96.2	95.8

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

3. *Residential* light fixtures: ENERGY STAR Program Requirements for *Residential* Light Fixtures

e. Commercial Food Service

1. Commercial refrigerators and freezers: ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers
2. Commercial ice machines: ENERGY STAR Program Requirements for Commercial Ice Machines

10.5.3 Programmable Thermostats. *Residential* programmable thermostats shall meet the requirements of NEMA Standards Publication DC 3, Annex A, "Energy-Efficiency Requirements for Programmable Thermostats."

10.5.4 Refrigerated Display Cases. All open refrigerated display cases shall be covered by using field-installed strips, curtains, or doors.

10.6 Alternative Compliance Path (Not Used)

10.7 Submittals (Not Used)

10.8 Product Information

TABLE 10.8-2 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype II), Except Fire-Pump Electric Motors[a]

Full-Load Efficiency, %								
	Open Drip-Proof Motors				Totally Enclosed Fan-Cooled Motors			
Number of Poles ⇒	2	4	6	8	2	4	6	8
Synchronous Speed (RPM) ⇒	3600	1800	1200	900	3600	1800	1200	900
Motor Horsepower								
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement

TABLE 10.8-3 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype I and II), Except Fire-Pump Electric Motors[a]

Full-Load Efficiency, %								
	Open Drip-Proof Motors				Totally Enclosed Fan-Cooled Motors			
Number of Poles ⇒	2	4	6	8	2	4	6	8
Synchronous Speed (RPM) ⇒	3600	1800	1200	900	3600	1800	1200	900
Motor Horsepower								
250	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
350	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
400	95.4	95.4	NR	NR	95.4	95.4	NR	NR
450	95.8	95.8	NR	NR	95.4	95.4	NR	NR
500	95.8	95.8	NR	NR	95.4	95.8	NR	NR

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement

TABLE 10.8-4 Minimum Average Full-Load Efficiency for Polyphase Small Electric Motors[a]

Full-Load Efficiency for Motors Manufactured on or after March 9, 2015, %			
	Open Motors		
Number of Poles ⇒	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200
Motor Horsepower			
0.25	65.6	69.5	67.5
0.33	69.5	73.4	71.4
0.50	73.4	78.2	75.3
0.75	76.8	81.1	81.7
1	77.0	83.5	82.5
1.5	84.0	86.5	83.8
2	85.5	86.5	N/A
3	85.5	86.9	N/A

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

TABLE 10.8-5 Minimum Average Full-Load Efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run Small Electric Motors[a]

Full-Load Efficiency for Motors Manufactured on or after March 9, 2015, %			
	Open Motors		
Number of Poles ⇒	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200
Motor Horsepower			
0.25	66.6	68.5	62.2
0.33	70.5	72.4	66.6
0.50	72.4	76.2	76.2
0.75	76.2	81.8	80.2
1	80.4	82.6	81.1
1.5	81.5	83.8	N/A
2	82.9	84.5	N/A
3	84.1	N/A	N/A

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

TABLE 10.8-6 Minimum Nominal Full-Load Efficiency for Fire-Pump Electric Motors[a]

Full-Load Efficiency, %								
	Open Drip-Proof Motors				Totally Enclosed Fan-Cooled Motors			
Number of Poles ⇒	2	4	6	8	2	4	6	8
Synchronous Speed (RPM) ⇒	3600	1800	1200	900	3600	1800	1200	900
Motor Horsepower								
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
350	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
400	95.4	95.4	NR	NR	95.4	95.4	NR	NR
450	95.8	95.8	NR	NR	95.4	95.4	NR	NR
500	95.8	95.8	NR	NR	95.4	95.8	NR	NR

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement

11. CONSTRUCTION AND PLANS FOR OPERATION

11.1 Scope. This section specifies requirements for construction and plans for operation, including the *commissioning (C_x) process*, building acceptance testing, measurement and *verification*, and energy use reporting. *Projects* shall comply with the following conditions as applicable:

a. All projects shall comply with Section 11.3.1.1—Acceptance Testing.

b. The following projects shall comply with Section 11.3.1.2—Project Commissioning:

   1. New construction (including additions) 10,000 sf (929 m^2) or greater.
   2. Level III alterations, *alteration area* of 10,000 sf (929 m^2) or greater.
   3. Alterations of 20,000 sf (1858.06 m^2) or greater.
   4. New, replaced, or relocated mechanical, electrical, or plumbing equipment that serves 20,000 sf (1858.06 m^2) or larger.
   5. Projects having a new, replaced, and/or relocated, HVAC system with a heating equipment size of 480,000 BTUs or greater, or with a cooling equipment size of 600,000 BTUs or greater.

c. The following projects shall comply with Section 11.3.1.3—Building Envelope Commissioning (BECx):

   1. New Construction or additions 50,000 sf (4645.12 m^2) or greater.
   2. Alterations and/or additions: for buildings over 50,000 sf (4645.12 m^2), where at least 25 percent of the vertical, above-grade building envelope is being replaced, altered, and/or added.

11.1.1 Systems. The following systems and associated controls, if included in the *project*, shall be commissioned:

a. Heating, ventilating, air-conditioning, and refrigeration systems (mechanical and/or passive).

b. *Building envelope* systems, components, and assemblies to verify the airtightness and thermal and moisture integrity. Building envelope airtightness commissioning shall also comply with Section 11.3.1.3.

c. Lighting systems.

d. *Fenestration* control systems: *Automatic* controls for shading devices and *dynamic glazing*.

e. Irrigation.

f. Domestic and process water pumping and mixing systems.

g. *Service water heating* systems.

h. Renewable energy systems.

i. Water measurement devices.

j. Energy measurement devices.

11.2 Compliance. All of the provisions of Section 11 are mandatory provisions.

11.3 Mandatory Provisions

11.3.1 Construction.

11.3.1.1 Building Acceptance Testing. Acceptance testing shall be performed on all buildings in accordance with this section using *generally accepted engineering standards* and handbooks acceptable to the *authority having jurisdiction* (*AHJ*).

An acceptance testing process shall be incorporated into the design and construction of the *project* that verifies systems specified in this section perform in accordance with *construction documents*.

11.3.1.1.1 Activities Prior to Building Permit. Complete the following:

a. Designate a project *acceptance* representative to lead, review, and oversee completion of acceptance testing activities.

b. An *acceptance representative* shall review *construction documents* to verify that relevant sensor locations, devices, and control sequences are properly documented.

11.3.1.1.2 Activities Prior to Building Occupancy. Complete the following:

a. Verify proper installation and start up of the systems per manufacturer requirements, code requirements, owner's requirements, permit drawings, and designer's intent of operation.

b. Perform acceptance tests. For each acceptance test, complete test form and include date, a signature, and license number, as appropriate, for the party who has performed the test. Acceptance testing shall include, but not be limited to, Testing and Balancing, for applicable systems and system components.

c. Verify that a systems manual has been prepared that includes operation and maintenance (O&M) documentation and full warranty information and provides operating staff the information needed to operate building systems.

11.3.1.1.3 Acceptance Testing. The following systems, if included in the *project*, shall have acceptance testing:

a. Mechanical systems: heating, ventilating, air conditioning and refrigeration systems (mechanical and/or passive) and associated controls.

b. Lighting systems: automatic daylighting controls, manual daylighting controls, occupancy sensing devices, and *automatic* shut-off controls.

c. *Fenestration* control systems: *Automatic* controls for shading devices and *dynamic glazing*.

d. Renewable energy systems.

e. Water measurement devices.

f. Energy measurement devices.

11.3.1.1.4 Documentation. The *owner* shall retain completed acceptance test forms. Completed acceptance testing forms shall be provided to the *AHJ* for review upon request from the code official.

11.3.1.2 *Project* Commissioning. Commissioning shall be performed in accordance with this section using *generally accepted engineering standards* and handbooks acceptable to the *AHJ*. Reference *AHJ Cx* guidelines.

A *Cx process* shall be incorporated into the predesign, design, construction, and post-occupancy of the *project* that verifies that the delivered building and its components, assemblies, and systems comply with the documented *owner's project requirements* (*OPR*). Procedures, documentation, tools, and training shall be provided to the building operating staff to sustain features of the building assemblies and systems for the service life of the building. This material shall be assembled and organized into a systems manual that provides necessary information to the building operating staff to operate and maintain all commissioned systems identified within the *project.*

11.3.1.2.1 Activities Prior to Building Permit. The following activities shall be completed:

a. The project owner or owner representative, but not a design firm or construction firm involved in the design or construction of the project, shall contract with a project *commissioning authority (CxA)* to lead, review, and oversee completion of the *Cx process* activities prior to completion of schematic design. The *CxA* shall be approved by the *AHJ* to conduct commissioning, having credentials set forth by the *AHJ*. The *CxA* shall not be a member of any construction or design firm involved in the design or construction of the project.

b. The *owner*, in conjunction with the design team as necessary, shall develop the *OPR* during the predesign phase. The *OPR* shall be updated during the design phase as necessary by the design team, in conjunction with the owner and the *Cx* team. The *OPR* will be distributed to all parties participating in project programming, design, construction, and operations, and to the *Cx* team members.

c. The design team shall develop the *Basis of Design (BoD)*. The *BoD* document shall include all the information required in Section 6.2, "Documentation," of ANSI/ ASHRAE Standard 55. Once the project is Permitted, the *BoD* shall include the *AHJ* approved permit drawings and documents, and any deviations from these plans shall be noted by the *CxA* as a deficiency in their *Cx* reports unless updated and *AHJ* approved construction documents are provided.

d. The *CxA* shall review both the *OPR* and *BoD* to ensure that no conflicting requirements or goals exist and that the *OPR* and *BoD*, based on the professional judgment and experience of the *CxA*, are sufficiently detailed for the project being undertaken.

e. Construction phase commissioning requirements shall be incorporated into project specifications and other *construction documents* developed by the design team.

f. The *CxA* shall conduct two focused OPR reviews of the construction documents, the first at near 50% design completion and the second of the final *construction documents* prior to delivery to the contractor. The purpose of these reviews is to verify that the documents achieve the construction phase *OPR* and that the *BoD* document fully supports the *OPR* with sufficient details.

11.3.1.2.2 Activities Prior to Building Rough Inspection completion. The following activities shall be completed:

a. Develop and implement a commissioning *(Cx)* plan containing required forms and procedures for the complete testing of equipment, systems, and controls. Include all Acceptance testing forms to be used by the acceptance testers, all Functional Performance Tests written out including test sequence, measurable criteria for performance pass/fail, required test instruments, and expected/ acceptable response of operating parameters.

b. Provide complete *commissioning (Cx) plan* to the *AHJ* for review.

c. Provide complete *commissioning (Cx) plan* to project owner, project general contractor, and sub-contractors with whom are performing work related to the commissioning process.

11.3.1.2.3 Activities Prior to Building Occupancy. The following activities shall be completed:

a. Verify the installation and performance of the systems to be commissioned, including completion of the *construction checklist* and *verification*. The *AHJ* has the authority to provide flexibility in accepting the preliminary *Cx* report without all required Functional Performance Tests completed, provided that these tests have been substantially completed, completed test results have been provided, and a schedule for completion has been provided.

Exception to 11.3.1.2.3(a): Systems that, because their operation is seasonally dependent, cannot be fully commissioned in accordance with the *Cx plan* at time of occupancy. These systems shall be commissioned at the earliest time after occupancy when operation of systems is allowed to be fully demonstrated as determined by *CxA*.

b. It shall be verified that the owner requirements for the training of operating personnel and building occupants is completed. Where systems cannot be fully commissioned at the time of occupancy because of seasonal dependence, the training of personnel and building occupants shall be completed when the systems' operation can be fully demonstrated by the *CxA*.

c. Complete *preliminary Cx report*. This shall include all deficiencies identified by the *CxA* or acceptance testing throughout the *Cx* process listing corrective measures taken, and identified as corrected, outstanding, and/or accepted by the owner. Any deficiencies in violation with any sections listed in Chapters 6, 7, 8, 9, 10, or 13 of the *Energy Conservation Code—Commercial Provisions* or applicable section of the *Green Construction Code*, if applicable, shall be listed as a deficiency in acceptance testing and/or *Cx* testing and verification. Such code violation deficiencies shall be corrected prior to submitting the completed *preliminary Cx report* to *AHJ* for review.

d. Verify that a systems manual has been prepared that includes O&M documentation and full warranty information and provides operating staff the information needed to operate the commissioned systems as designed.

e. A copy of the completed *preliminary Cx report* shall be provided to, reviewed by, and approved by the *AHJ* and to the project owner.

f. Completed *Preliminary Cx report* shall include testing and/or verification of all applicable energy code requirements for the project within Chapters 6, 7, 8, 9, 10, and 13 of the *Energy Conservation Code—Commercial Provisions* and all applicable section of the *Green Construction Code*, if applicable.

11.3.1.2.4 Post-occupancy Activities. Complete the following:

a. Complete any commissioning activities called out in the *Cx plan* for systems whose commissioning can only be completed subsequent to building occupancy, including trend logging and off-season testing.

b. Verify that the owner requirements for training operating personnel and building occupants are completed for those systems whose seasonal operational dependence mean they were unable to be fully commissioned prior to building occupancy.

c. Complete a final *Cx* report with all deficiencies identified in *preliminary Cx report* either corrected with corrective measures taken listed or accepted by the owner. Any deficiencies in violation with any sections listed in chapters 6, 7, 8, 9, 10, or 13 of the *Energy Conservation Code—Commercial Provisions* can only be approved by the *AHJ* and shall be listed in the final *CX* report as an unresolved deficiency. This report shall be submitted for review to the *AHJ* and project owner within 180 days of the project completion (first Certificate of Occupancy for an above grade floor for the project).

11.3.1.3 *Building Envelope* Commissioning (BECx). *BECx* shall comply with one of the following:

a. Whole building pressurization testing shall be conducted in accordance with ASTM E779, CAN/CGSB-149.10-M86, CAN/CGSB-149.15-96 or equivalent. The measured air leakage rate of the *building envelope* shall not exceed 0.25 cfm/ft^2 (1.25 L/s·m^2) under a pressure differential of 0.3 in. wc (75 Pa), with this air leakage rate normalized by the sum of the above- and below-grade *building envelope* areas of the *conditioned* and *semi-heated space*.

Exception: For multifamily buildings, projects may be deemed to comply with the pressurization testing if individual tenant spaces can show compartmentalization when tested to not exceed 0.30 CFM per square feet of enclosure at 50 Pascal using ASTM E779 2010 or ASTM E1827. Sampling procedures are described in the ENERGY STAR Multifamily Midrise T&V Protocols Section 8.1, "Fan Pressure Testing" and "Sampling Requirements."

b. A building envelope commissioning authority, *(BECxA,)* with building envelope commissioning credentials as approved by the *AHJ*, shall be contracted by the project owner to conduct building air-barrier commissioning prior to permit for the project. A fundamental envelope commissioning program consistent with ASTM E2813-12 that consists of the following elements shall be implemented:

1. A *BECxA* design review shall be conducted and documented to assess the design documentation describing the air-barrier systems and materials, the manner in which continuity will be maintained across joints between air-barrier components and at all envelope penetrations, and the constructability of the air-barrier systems. This review shall be completed prior to permit application and results and documentation of this review provided with construction documents in permit drawings and supporting documentation.

2. Incremental field inspection and testing of air-barrier components shall be conducted and documented during construction to ensure proper construction of key components while they are still accessible for inspection and repair.

3. The Fundamental *BECx* program shall include addressing ASTM E2813—12 sections relating to air infiltration, condensation resistance, thermal performance, and water penetrations at a minimum.

4. The *BECx* plan shall be provided to the *AHJ* prior to building envelope installation.

5. The *BECx* report shall be submitted to the *AHJ* for review at or prior to final inspection.

11.3.1.4 Documentation. The *owner* shall retain the systems manual and final *Cx* report.

12. NORMATIVE REFERENCES

Reference	Title
Air Conditioning, Heating and Refrigeration Institute (AHRI) 2111 Wilson Blvd., Suite 500, Arlington, VA 22201	
AHRI 210/240-200 with Addendum 1 and 2	Unitary Air Conditioning and Air-Source Heat Pump Equipment
AHRI 310/380-2004	Packaged Terminal Air-Conditioners and Heat Pumps
AHRI 340/360-2007 with Addenda 1 and 2	Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
AHRI 365-2009	Commercial and Industrial Unitary Air-Conditioning Condensing Units
AHRI 390-2003	Performance Rating of Single Packaged Vertical Air-Conditioners and Heat Pumps
AHRI 400-2001 with Addendum 2	Liquid-to-Liquid Heat Exchangers
AHRI 460-2005	Remote Mechanical Draft Air Cooled Refrigerant Condensers
AHRI 550/590-2011 (I-P) with Addendum 1 and AHRI 551/591 (SI)	Performance Rating of Water-Chilling and Heat-Pump Water-Heating Packages Using the Vapor Compression Cycle
AHRI 560-2000	Absorption Water Chilling and Water Heating Packages
AHRI 1160-2009	Performance Rating of Heat Pump Pool Heaters
AHRI 1200-2010	Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets
AHRI 1230-2010 with Addendum 1	Performance Rating of Variable Refrigerant Flow (VRF) Multi-split Air-Conditioning and Heat Pump Equipment
BTS 2000	Testing Standard Method to Determine Efficiency of Commercial Space Heating Boilers
Air Movement and Control Association International (AMCA) 30 West University Drive, Arlington Heights, IL 60004-1806	
AMCA 205-12	Energy Efficiency Classification for Fans
ANSI/AMCA 500-D-12	Laboratory Methods of Testing Dampers for Rating
American Architectural Manufacturers Association (AAMA) 1827 Walden Office Square, Suite 550, Schaumburg, IL 60173-4268	
AAMA/WDMA/CSA 101/I.S.2/A440-08	Standard/Specification for Windows, Doors, and Unit Skylights
American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036	
ANSI Z21.10.3-2011	Gas Water Heater, Volume 3, Storage, with Input Ratings above 75,000 Btu/h, Circulating and Instantaneous Water Heaters
ANSI Z21.47-2012	Gas-Fired Central Furnaces
ANSI Z83.8-2009	Gas Unit Heaters and Duct Furnaces
American Society of Mechanical Engineers (ASME) Three Park Avenue, New York, NY 10016-5990	
ASME A17.1-2010/CSA B44-10	Safety Code for Elevators and Escalators

Reference	Title
ASHRAE **1791 Tullie Circle, NE, Atlanta, GA 30329**	
ANSI/ASHRAE/IESNA Standard 90.1-2007	Energy Standard for Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE/ACCA Standard 183-2007	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE Standard 62.1-2013	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE Standard 127-2007	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners
ANSI/ASHRAE Standard 140-2011	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
ANSI/ASHRAE Standard 154-2003	Ventilation for Commercial Cooking Operations
Briggs, R.S., R.G. Lucas, and Z.T. Taylor. 2003	Climate classification for building energy codes and standards: Part 1—Development process
ANSI/ASHRAE Standard 55-2010	Thermal Environmental Conditions for Human Occupancy
ANSI/ASHRAE Standard 189.1-2014	Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings
ASHRAE D RP-1365	Thermal Performance of Building Envelope Details for Mid- and High-Rise Buildings
Association of Home Appliance Manufacturers (AHAM) **1111 19th Street NW, Suite 402, Washington, DC 20036**	
ANSI/AHAM HRF-1-2008	Energy and Internal Volume of Refrigerating Appliances (including errata issued November 17, 2009)
ANSI/AHAM RAC-1-R2008	Room Air Conditioners
ASTM International **100 Barr Harbor Dr., West Conshohocken, PA 19428-2959**	
ASTM C90-03	Standard Specification for Loadbearing Concrete Masonry Units
ASTM C177-97	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM C272-01	Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM C518-04	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus
ASTM C835-01	Standard Test Method for Total Hemispherical Emittance of Surfaces From 20°C to 1400°C
ASTM C1363-97	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM D1003-00	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
ASTM E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

Reference	Title
ASTM E779-10	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
ASTM E972-96 (2002)	Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight
ASTM E1175-87 (2003)	Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere
ASTM E1677-2005	Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls
ASTM E1680-95 (2003)	Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems
ASTM E1827-11	Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
ASTM E1918 (2006)	Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-Sloped Surfaces in the Field
ASTM E1980 (2001)	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low Sloped Opaque Surfaces
ASTM E2178-03	Standard Test Method for Air Permeance of Building Materials
ASTM E2357-05	Standard Test Method for Determining Air Leakage of Air Barrier Assemblies
ASTM E2813-12	Standard Practice for Building Enclosure Commissioning
Canadian General Standards Board (CGSB) Place du Portage III, 6B1, 11 Laurier Street, Gatineau, Quebec, K1A 1G6 Canada	
CAN/CGSB-149.10-M86	Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method
CAN/CGSB 149.15-96	Determination of the Overall Envelope Airtightness of Buildings by the Fan Pressurization Method Using the Building's Air Handling Systems
Canadian Standards Association (CSA) 5060 Spectrum Way, Mississauga, Ontario, Canada L4W 5N6	
AAMA/WDMA/CSA 101/I.S.2/A440-08	Standard/Specification for Windows, Doors, and Unit Skylights
Cool Roof Rating Council (CRRC) 1610 Harrison Street, Oakland, CA 94612	
ANSI/CRRC-1 Standard-2012	Cool Roof Rating Council—ANSI/CRRC-1 Standard
Cooling Technology Institute (CTI) 2611 FM 1960 West, Suite A-101, Houston, TX 77068-3730; P.O. Box 73383, Houston, TX 77273-3383	
CTI ATC-105 (00)	Acceptance Test Code for Water Cooling Towers
CTI ATC-105S (11)	Acceptance Test Code for Closed-Circuit Cooling Towers
CTI ATC-106 (11)	Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers
CTI STD-201 (11)	Standard for Thermal Performance Certification of Evaporative Heat Transfer Equipment

Reference	Title
Door and Access Systems Manufacturers Association (DASMA) 1300 Sumner Avenue, Cleveland, OH 44115-2851	
ANSI/DASMA 105-92 (R 1998)	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors
ENERGY STAR, United States Department of Energy Office of Energy Efficiency & Renewable Energy, 1000 Independence Ave., SW, Washington, DC 20585	
ENERGY STAR Multifamily Midrise T&V Protocols, 8.1	Fan Pressure Testing; Sampling Requirements
Illuminating Engineering Society (IES) 120 Wall street, Floor 17, New York, NY 10005-4001	
ANSI/IES RP-28-2007	Lighting and the Visual Environment for Senior Living
International Organization for Standardization (ISO) 1, rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland	
ISO 13256-1 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps
ISO 13256-2 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 2: Water-to-Water and Brine-to-Water Heat Pumps
National Electrical Manufacturers Association (NEMA) 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209	
ANSI/NEMA MG 1-2006	Motors and Generators
National Fenestration Rating Council (NFRC) 6305 Ivy Lane, Suite 140, Greenbelt, MD 20770-6323	
NFRC 100-2010	Procedure for Determining Fenestration Product U-Factors
NFRC 200-2010	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence
NFRC 300-2010	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems
NFRC 301-2010	Test Method for Emittance of Specular Surfaces Using Spectrometric Measurements
NFRC 400-2010	Procedure for Determining Fenestration Product Air Leakage
National Fire Protection Association (NFPA) 1 Battery March Park, P.O. Box 9101, Quincy, MA 02269-9101	
ANSI/NFPA 70-2008	**National Electric Code**
NFPA 70 Article 708-2011	**Critical Operations Power Systems (COPS)**
NFPA 96-12	**Ventilation Control and Fire Protection of Commercial Cooking Operations**
Telecommunications Industry Association (TIA) 2500 Wilson Boluevard, Arlington, VA 22201	
ANSI/TIA-942-2005	Telecommunication Infrastructure Standard for Data Centers

Reference	Title
Underwriters Laboratories, Inc. (UL) 333 Pfingsten Rd., Northbrook, IL 60062	
UL 181A-2005	Closure Systems for Use with Rigid Air Ducts and Air Connectors
UL 181B-2005	Closure Systems for Use with Flexible Air Ducts and Air Connectors
UL 727-06	UL Standard for Safety—Oil Fired Central Furnaces
UL 731-12	UL Standard for Safety—Oil-Fired Unit Heaters
U.S. Department of Energy (DOE) 1000 Independence Avenue, SW, Washington, DC 20585	
10 CFR Part 430, App N	Uniform Test Method for Measuring the Energy Consumption of Furnaces
10 CFR 431 Subpart K, App A	Uniform Test Method for Measuring the Energy Consumption of Distribution Transformers
10 CFR Part 431, Subpart B, App B	Uniform Test Method for Measuring Nominal Full-Load Efficiency of Electric Motors
42 USC 6831, et seq., Public Law 102-486	Energy Policy Act of 1992
U.S. Security and Exchange Commission (SEC) 100 F Street, NE, Washington, DC 2-549	
The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System	The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System, April 7, 2003
Window and Door Manufacturers Association (WDMA) 2025 M Street, NW, Washington, DC 20036	
AAMA/WDMA/CSA 101/I.S.2/A440-08	North American Fenestration Standard/Specification for Windows, Doors, and Skylights

13. RENEWABLE ENERGY

13.1 Prescriptive Renewable Path

13.1.1 *On-Site Renewable Energy Systems*. *Building projects* shall comply with either the Standard Renewables Approach in Section 13.1.1.1 or the Alternate Renewables Approach in Section 13.1.1.2 where any of the following conditions are met:

1. New construction of 10,000 sf (929 m^2) or greater, not including first time tenant fit-outs within a newly constructed core and shell building/space.
2. Additions of 10,000 sf (929 m^2) or greater.
3. *Alteration* area of 10,000 sf (929 m^2) or greater in Level 3 *alteration*.
4. Combined Level 3 *alteration* and addition area of 10,000 sf (929 m^2) or greater.

Exceptions: Buildings that demonstrate compliance with both of the following conditions are not required to contain *on-site renewable energy systems*:

1. An annual daily average incident solar radiation available to a flat plate collector oriented due south at an angle from horizontal equal to the latitude of the collector location less than 4.0 kWh/m^2·day (1.2 kBtu/ft^2/day), accounting for existing buildings, permanent infrastructure that is not part of the *building project*, topography, and trees.
2. A commitment to purchase renewable electricity products complying with the Green-e Energy National Standard for Renewable Electricity Products of at least 7 kWh/ft^2 (75 kWh/m^2) of *conditioned space* each year until the cumulative purchase totals 70 kWh/ft^2 (750 kWh/m^2) of *conditioned space*.

13.1.1.1 Standard Renewables Approach: Baseline *On-Site Renewable Energy Systems.* *Building projects* shall contain *on-site renewable energy systems* that provide the annual energy production equivalent of not less than 6.0 kBtu/ft^2 (20 kWh/m^2) multiplied by the *gross roof area* in ft^2 (m^2) for single-story buildings, and not less than 10.0 kBtu/ft^2 (32 kWh/m^2) multiplied by the *gross roof area* in ft^2 (m^2) for all other buildings. The annual energy production shall be the combined sum of all *on-site renewable energy systems.*

13.1.1.2 Alternate Renewables Approach: Reduced *On-Site Renewable Energy Systems* and Higher-Efficiency Equipment. *Building projects* complying with this approach shall comply with the applicable equipment efficiency requirements in Normative Appendix B of ASHRAE 189.1 (Prescriptive Equipment Efficiency Tables for the Alternate Reduced Renewables and Increased Equipment Efficiency Approach in Section 7.4.1.1.2), the water-heating efficiency requirements in Section 7.4.4.1 of ASHRAE 189.1, equipment efficiency requirements in Section 10.6 of ASHRAE 189.1, and the applicable ENERGY STAR® requirements in Section 10.11.2 of 189.1, and shall contain *on-site renewable energy systems* that provide the annual energy production equivalent of not less than 4.0 kBtu/ft^2 (13 kWh/m^2) multiplied by the *gross roof area* in ft^2 (m^2) for single-story buildings, and not less than 7.0 kBtu/ft^2 (22 kWh/m^2) multiplied by the *gross roof area* in ft^2 (m^2) for all other buildings. The annual energy production shall be the combined sum of all *on-site renewable energy systems.* For equipment listed in Section 10.11.2 of ASHRAE 189.1 that is also contained in Normative Appendix B of ASHRAE 189.1, the installed equipment shall comply by meeting or exceeding both requirements.

Exception: If *building project* includes less than 75% of build-out of net-occupiable floor area, then the project team cannot use Alternate Renewables Approach in Section 13.1.1.2, and shall use the Standard Renewables Approach in Section 13.1.1.1.

13.2 Adoption of ASHRAE 189.1 Normative Appendices

The following Normative Appendices of ANSI/ASHRAE/USGBC/IES Standard 189.1—2014, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*, are hereby adopted, in whole or in part, in the District of Columbia and incorporated by reference into the *Energy Conservation Code—Commercial Provisions* as provided below.

1. Normative Appendix B, *Prescriptive Equipment Efficiency Tables for the Alternate Reduced Renewables* and Increased Equipment Efficiency Approach in Section 7.4.1.1.2;
2. Normative Appendix A, Table A-2, Minimum Duct Installation R-Value Heating and Cooling-Only Supply Ducts and Return Ducts (I-P), and Table A-3, Minimum Duct Installation R-Value Combined Heating and Cooling Supply Ducts and Return Ducts (I-P).

NORMATIVE APPENDICES

Normative Appendix A in ASHRAE 90.1, *RATED R-VALUE OF INSULATION AND ASSEMBLY U-FACTOR, C-FACTOR, AND F-FACTOR DETERMINATIONS*, is adopted in the District of Columbia as Normative Appendix A in the *Energy Conservation Code—Commercial Provisions*.

Normative Appendix B in ASHRAE 90.1, *BUILDING ENVELOPE CLIMATE CRITERIA,* is adopted in the District of Columbia as Normative Appendix B in the *Energy Conservation Code—Commercial Provisions* with the following amendments:

Revise the list of U.S. Climate Zones in Normative Appendix B in ASHRAE 90.1 to delete the names of all U.S. States with the exception of the District of Columbia.

Strike the table titled "Canadian Climatic Zones" in Normative Appendix B in ASHRAE 90.1 in its entirety without substitution.

Strike Tables B1-3 and B1-4 in Normative Appendix B in ASHRAE 90.1 in their entirety without substitution.

Normative Appendix C in ASHRAE 90.1, *METHODOLOGY FOR BUILDING ENVELOPE TRADE-OFF OPTION IN SECTION 5.6,* is adopted in the District of Columbia as Normative Appendix C in the *Energy Conservation Code—Commercial Provisions*.

Normative Appendix D in ASHRAE 90.1, *CLIMATIC DATA*, is adopted in the District of Columbia as Normative Appendix D in the *Energy Conservation Code—Commercial Provisions* with the following amendments:

Revise Table D-1 in Normative Appendix D in ASHRAE 90.1 to delete the names of all US states and territories with the exception of the District of Columbia.

Strike Tables D-2 and D-3 in Normative Appendix D in ASHRAE 90.1 in their entirety without substitution.

Informative Appendix E in ASHRAE 90.1, *INFORMATIVE REFERENCES,* is adopted in the District of Columbia as Informative Appendix E in the *Energy Conservation Code—Commercial Provisions*.

Informative Appendix F in ASHRAE 90.1, *ADDENDA DESCRIPTION INFORMATION,* is adopted in the District of Columbia as Informative Appendix F in the *Energy Conseva-tion Code—Commercial Provisions*.

(Normative Appendix A is adopted in the District of Columbia.)

NORMATIVE APPENDIX A RATED R-VALUE OF INSULATION AND ASSEMBLY U-FACTOR, C-FACTOR, AND F-FACTOR DETERMINATIONS

A1. GENERAL

A1.1 Pre-Calculated Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. The U-factors, C-factors, F-factors, and heat capacities for typical construction assemblies are included in Sections A2 through A8. These values shall be used for all calculations unless otherwise allowed by Section A1.2. Interpolation between values in a particular table in Normative Appendix A is allowed for rated R-values of insulation, including insulated sheathing. Extrapolation beyond values in a table in Normative Appendix A is not allowed.

A1.2 Applicant-Determined Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. If the building official determines that the proposed construction assembly is not adequately represented in Sections A2 through A8, the applicant shall determine appropriate values for the assembly using the assumptions in Section A9. An assembly is deemed to be adequately represented if:

a. the interior structure, hereafter referred to as the base assembly, for the class of construction is the same as described in Sections A2 through A8 and

b. changes in exterior or interior surface building materials added to the base assembly do not increase or decrease the R-value by more than 2 from that indicated in the descriptions in Sections A2 through A8.

Insulation, including insulated sheathing, is not considered a building material.

A2. ROOFS

A2.1 General. The buffering effect of suspended ceilings or attic spaces shall not be included in U-factor calculations.

A2.2 Roofs with Insulation Entirely Above Deck

A2.2.1 General. For the purpose of Section A1.2, the base assembly is continuous insulation over a structural deck. The U-factor includes R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. Added insulation is continuous and uninterrupted by framing. The framing factor is zero.

A2.2.2 Rated R-Value of Insulation. For roofs with insulation entirely above deck, the rated R-value of insulation is for continuous insulation.

Exception: Interruptions for framing and pads for mechanical equipment are permitted with a combined total area not exceeding one percent of the total opaque assembly area.

A2.2.3 U-Factor. U-factors for roofs with insulation entirely above deck shall be taken from Table A2.2.3. It is not acceptable to use these U-factors if the insulation is not entirely above deck or not continuous.

TABLE A2.2.3 Assembly U-Factors for Roofs with Insulation Entirely Above Deck

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
R-0	U-1.282
R-1	U-0.562
R-2	U-0.360
R-3	U-0.265
R-4	U-0.209
R-5	U-0.173
R-6	U-0.147
R-7	U-0.129
R-8	U-0.114
R-9	U-0.102
R-10	U-0.093
R-11	U-0.085
R-12	U-0.078
R-13	U-0.073
R-14	U-0.068
R-15	U-0.063
R-16	U-0.060
R-17	U-0.056
R-18	U-0.053
R-19	U-0.051
R-20	U-0.048
R-21	U-0.046
R-22	U-0.044
R-23	U-0.042
R-24	U-0.040
R-25	U-0.039
R-26	U-0.037
R-27	U-0.036
R-28	U-0.035
R-29	U-0.034
R-30	U-0.032
R-35	U-0.028
R-40	U-0.025
R-45	U-0.022
R-50	U-0.020
R-55	U-0.018
R-60	U-0.016

A2.3 Metal Building Roofs

A2.3.1 General. For the purpose of Section A1.2, the base assembly is a roof with thermal spacer blocks where the insulation is draped over the steel structure (purlins), spaced nominally 5 fton center and compressed when the metal roof panels are attached to the steel structure (purlins).

A2.3.2 Rated R-Value of Insulation

A2.3.2.1 Single Layer. The rated R-value of insulation is for insulation installed perpendicular to and draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

A2.3.2.2 Double Layer. The first rated R-value of insulation is for insulation installed perpendicular to and draped over purlins. The second rated R-value of insulation is for unfaced insulation installed above the first layer and parallel to the purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

A2.3.2.3 Continuous Insulation. For assemblies with continuous insulation the continuous insulation is installed above or below the purlins, uncompressed and uninterrupted by framing members.

A2.3.2.4 Liner System (Ls). A continuous membrane is installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins. For multilayer installations, the last rated R-Value of insulation is for unfaced insulation draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3. thermal spacer block between the purlins and the metal roof panels is required unless compliance is shown by the overall assembly U-factor.

A2.3.2.5 Filled Cavity. The first rated R-value of insulation represents faced or unfaced insulation installed between the purlins. The second rated R-value of insulation represents unfaced insulation installed above the first layer, perpendicular to the purlins and compressed when the metal roof panels are attached. A supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of insulation. A minimum R-5 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

A2.3.3 U-factors for Metal Building Roofs. U-factors for metal building roofs shall be taken from Table A2.3.3 or determined in accordance with Section A9.2, provided the average purlin spacing for systems with compressed insulation is at least 52 in. U-factors for metal building roof assemblies with average purlin spacing less than 52 in. shall be determined in accordance with Section A9.2. U-factors in Table A2.3.3 shall not be used where the insulation is substantially compressed by the bracing between the purlins.

A2.4 Attic Roofs with Wood Joists

A2.4.1 General. For the purpose of Section A1.2, the base attic roof assembly is a roof with nominal 4 in. deep wood as the lower chord of a roof truss or ceiling joist. The ceiling is attached directly to the lower chord of the truss and the attic space above is ventilated. Insulation is located directly on top of the ceiling, first filling the cavities between the wood and then later covering both the wood and cavity areas. No credit is given for roofing materials. The single-rafter roof is similar to the base attic roof, with the key difference being that there is a single, deep rafter to which both the roof and the ceiling are attached. The heat flow path through the rafter is calculated to be the same depth as the insulation. Additional assemblies include continuous insulation, uncompressed and uninterrupted by framing. The U-factors include R-0.46 for semi-exterior air film, R-0.56 for 0.625 in. gypsum board, and R-0.61 for interior air film heat flow up. U-factors are provided for the following configurations:

a. Attic roof, standard framing: insulation is tapered around the perimeter with a resultant decrease in thermal resistance. Weighting factors are 85% full-depth insulation, 5% half-depth insulation, and 10% joists.

b. Attic roof, advanced framing: full and even depth of insulation extending to the outside edge of exterior walls. Weighting factors are 90% full-depth insulation and 10% joists.

c. Single-rafter roof: an attic roof where the roof sheathing and ceiling are attached to the same rafter. Weighting factors are 90% full-depth insulation and 10% joists.

A2.4.2 Rated R-Value of Insulation

A2.4.2.1 For attics and other roofs, the rated R-value of insulation is for insulation installed both inside and outside the roof or entirely inside the roof cavity.

A2.4.2.2 Occasional interruption by framing members is allowed but requires that the framing members be covered with insulation when the depth of the insulation exceeds the depth of the framing cavity.

TABLE A2.3.3 Assembly U-Factors for Metal Building Roofs

Insulation System	Rated R-Value of Insulation	Overall U-Factor for Entire Base Roof Assembly	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing)								
			Rated R-Value of Continuous Insulation								
			R-6.5	R-9.8	R-13	R-15.8	R-19	R-22.1	R-25	R-32	R-38
Standing Seam Roofs with Thermal Spacer Blocks[a, b]											
Single Layer	None	1.280	0.137	0.095	0.073	0.060	0.051	0.044	0.039	0.031	0.026
	R-10	0.115	0.066	0.054	0.046	0.041	0.036	0.032	0.030	0.025	0.021
	R-11	0.107	0.063	0.052	0.045	0.040	0.035	0.032	0.029	0.024	0.021
	R-13	0.101	0.061	0.051	0.044	0.039	0.035	0.031	0.029	0.024	0.021
	R-16	0.096	0.059	0.049	0.043	0.038	0.034	0.031	0.028	0.024	0.021
	R-19	0.082	0.053	0.045	0.040	0.036	0.032	0.029	0.027	0.023	0.020
Double Layer	R-10 + R-10	0.088	0.056	0.047	0.041	0.037	0.033	0.030	0.028	0.023	0.020
	R-10 + R-11	0.086	0.055	0.047	0.041	0.036	0.033	0.030	0.027	0.023	0.020
	R-11 + R-11	0.085	0.055	0.046	0.040	0.036	0.033	0.030	0.027	0.023	0.020
	R-10 + R-13	0.084	0.054	0.046	0.040	0.036	0.032	0.029	0.027	0.023	0.020
	R-11 + R-13	0.082	0.053	0.045	0.040	0.036	0.032	0.029	0.027	0.023	0.020
	R-13 + R-13	0.075	0.050	0.043	0.038	0.034	0.031	0.028	0.026	0.022	0.019
	R-10 + R-19	0.074	0.050	0.043	0.038	0.034	0.031	0.028	0.026	0.022	0.019
	R-11 + R-19	0.072	0.049	0.042	0.037	0.034	0.030	0.028	0.026	0.022	0.019
	R-13 + R-19	0.068	0.047	0.041	0.036	0.033	0.030	0.027	0.025	0.021	0.019
	R-16 + R-19	0.065	0.046	0.040	0.035	0.032	0.029	0.027	0.025	0.021	0.019
	R-19 + R-19	0.060	0.043	0.038	0.034	0.031	0.028	0.026	0.024	0.021	0.018
Liner System	R-19 + R-11	0.037									
	R-25 + R-8	0.037									
	R-25 + R-11	0.031									
	R-30 + R-11	0.029									
	R-25 + R-11 + R-11	0.026									
Filled Cavity with Thermal Spacer Blocks[c]											
	R-10+R-19	0.041	0.032	0.029	0.027	0.025	0.023	0.022	0.020	0.018	0.016
Standing Seam Roofs without Thermal Spacer Blocks											
Liner System	R-19+R-11	0.040									
Through-Fastened Roofs without Thermal Spacer Blocks											
	R-10	0.184	0.084	0.066	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-11	0.182	0.083	0.065	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-13	0.174	0.082	0.064	0.053	0.046	0.040	0.036	0.033	0.026	0.023
	R-16	0.157	0.078	0.062	0.052	0.045	0.039	0.035	0.032	0.026	0.023
	R-19	0.151	0.076	0.061	0.051	0.045	0.039	0.035	0.032	0.026	0.022
Liner System	R-19+R-11	0.044									

(Multiple R-values are listed in order from inside to outside)

a. A standing seam roof clip that provides a minimum 1.5 in. distance between the top of the purlins and the underside of the metal roof panels is required.

b. A minimum R-3 thermal spacer block is required.

c. A minimum R-5 thermal spacer block is required.

A2.4.2.3 Insulation in such roofs shall be permitted to be tapered at the eaves where the building structure does not allow full depth.

A2.4.2.4 For single-rafter roofs, the requirement is the lesser of the values for attics and other roofs and those listed in Table A2.4.2.

A2.4.3 U-factors for Attic Roofs with Wood Joists. U-factors for attic roofs with wood joists shall be taken from Table A2.4.3. It is not acceptable to use these U-factors if the framing is not wood. For attic roofs with steel joists, see Section A2.5.

A2.5 Attic Roofs with Steel Joists

A2.5.1 General. For the purpose of Section A1.2, the base assembly is a roof supported by steel joists with insulation between the joists. The assembly represents a roof in many ways similar to a roof with insulation entirely above deck and a metal building roof. It is distinguished from the metal building roof category in that there is no metal exposed to the exterior. It is distinguished from the roof with insulation entirely above deck in that the insulation is located below the deck and is interrupted by metal trusses that provide thermal bypasses to the insulation. The U-factors include R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. The performance of the insulation/framing layer is calculated using the values in Table A9.2-1.

A2.5.2 U-factors for attic roofs with steel joists shall be taken from Table A2.5.2. It is acceptable to use these U-factors for any attic roof with steel joists.

TABLE A2.4.2 Single-Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d* (Actual)		
	$d \leq 8$ in.	$8 < d \leq 10$ in.	$10 < d \leq 12$ in.
1–7	R-19/U-0.055	R-30/U-0.036	R-38/U-0.028
8	R-21/U-0.052	R-30/U-0.036	R-38/U-0.028

TABLE A2.4.3 Assembly U-Factors for Attic Roofs with Wood Joists

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
Wood-Framed Attic, Standard Framing	
None	U-0.613
R-11	U-0.091
R-13	U-0.081
R-19	U-0.053
R-30	U-0.034
R-38	U-0.027
R-49	U-0.021
R-60	U-0.017
R-71	U-0.015
R-82	U-0.013
R-93	U-0.011
R-104	U-0.010
R-115	U-0.009
R-126	U-0.008
Wood-Framed Attic, Advanced Framing	
None	U-0.613
R-11	U-0.088
R-13	U-0.078
R-19	U-0.051
R-30	U-0.032
R-38	U-0.026
R-49	U-0.020
R-60	U-0.016
R-71	U-0.014
R-82	U-0.012
R-93	U-0.011
R-104	U-0.010
R-115	U-0.009
R-126	U-0.008

Wood Joists, Single-rafter Roof

	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing)			
Cavity Insulation R-Value	**Rated R-Value of Continuous Insulation**			
	None	**R-5**	**R-10**	**R-15**
None	U-0.417	U-0.135	U-0.081	U-0.057
R-11	U-0.088	U-0.061	U-0.047	U-0.038
R-13	U-0.078	U-0.056	U-0.044	U-0.036
R-15	U-0.071	U-0.052	U-0.041	U-0.034
R-19	U-0.055	U-0.043	U-0.035	U-0.030
R-21	U-0.052	U-0.041	U-0.034	U-0.029
R-25	U-0.042	U-0.035	U-0.030	U-0.026
R-30	U-0.036	U-0.030	U-0.026	U-0.023
R-38	U-0.029	U-0.025	U-0.022	U-0.020

TABLE A2.5.2 Assembly U-Factors for Attic Roofs with Steel Joists (4.0 ft on Center)

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
R-0	U-1.282
R-4	U-0.215
R-5	U-0.179
R-8	U-0.120
R-10	U-0.100
R-11	U-0.093
R-12	U-0.086
R-13	U-0.080
R-15	U-0.072
R-16	U-0.068
R-19	U-0.058
R-20	U-0.056
R-21	U-0.054
R-24	U-0.049
R-25	U-0.048
R-30	U-0.041
R-35	U-0.037
R-38	U-0.035
R-40	U-0.033
R-45	U-0.031
R-50	U-0.028
R-55	U-0.027

A3. ABOVE-GRADE WALLS

A3.1 Mass Wall

A3.1.1 General. For the purpose of Section A1.2, the base assembly is a masonry or concrete wall. Continuous insulation is installed on the interior or exterior or within the masonry units, or it is installed on the interior or exterior of the concrete. The brick cavity wall has continuous insulation between the brick and the concrete or masonry. The U-factors include R-0.17 for exterior air film and R-0.68 for interior air film, vertical surfaces. For insulated walls, the U-factor also includes R-0.45 for 0.5 in. gypsum board. For the cavity wall, the U-factor includes R-0.74 for brick. U-factors are provided for the following configurations:

a. Concrete wall: 8 in. normal weight concrete wall with a density of 145 lb/ft^3.
b. Solid grouted concrete block wall: 8 in. medium weight ASTM C90 concrete block with a density of 115 lb/ft^3 and solid grouted cores.
c. Partially grouted concrete block wall: 8 in. medium weight ASTM C90 concrete block with a density of 115 lb/ft^3 having reinforcing steel every 32 in. vertically and every 48 in. horizontally, with cores grouted in those areas only. Other cores are filled with insulating material only if there is no other insulation.

A3.1.2 Mass Wall Rated R-Value of Insulation

A3.1.2.1 Mass wall HC shall be determined from Table A3.1-2 or A3.1-3.

A3.1.2.2 The rated R-value of insulation is for continuous insulation uninterrupted by framing other than 20 gage 1 in. metal clips spaced no closer than 24 in. on center horizontally and 16 in. on center vertically.

A3.1.2.3 Where other framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly U-factor.

A3.1.2.4 Where rated R-value of insulation is used for concrete sandwich panels, the insulation shall be continuous throughout the entire panel.

A3.1.3 Mass Wall U-Factor

A3.1.3.1 U-factors for mass walls shall be taken from Table A3.1-1 or determined by the procedure in this subsection. It is acceptable to use the U-factors in Table A3.1-1 for all mass walls, provided that the grouting is equal to or less than that specified. HC for mass walls shall be taken from Table A3.1-2 or A3.1-3.

A3.1.3.2 Determination of Mass Wall U-Factors. If not taken from Table A3.1-1, mass wall U-factors shall be determined from Tables A3.1-2, A3.1-3, or A3.1-4 using the following procedure:

a. If the mass wall is uninsulated or only the cells are insulated:
    1. For concrete walls, determine the U-factor from Table A3.1-2 based on the concrete density and wall thickness.
    2. For concrete block walls, determine the U-factor from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.
b. If the mass wall has additional insulation:
    1. For concrete walls, determine the R_u from Table A3.1-2 based on the concrete density and wall thickness. Next, determine the effective R-value for the insulation/framing layer from Table A3.1-4 based on the rated R-value of insulation installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the U-factor by adding the R_u and the effective R-value together and taking the inverse of the total.
    2. For concrete block walls, determine the R_u from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated. Next, determine the effective R-value for the insulation/framing layer from Table A3.1-4 based on the rated R-value of insulation installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the U-factor by adding the R_u and the effective R-value together and taking the inverse of the total.

A3.2 Metal Building Walls

A3.2.1 General. For the purpose of Section A1.2, the base assembly is a wall where the insulation is compressed between metal wall panels and the metal structure. Additional assemblies include continuous insulation, uncompressed and uninterrupted by framing. Insulation exposed to a conditioned space or semiheated space shall have a facing, and all insulation shall be continuously sealed to provide a continuous air barrier.

A3.2.2 Rated R-Value of Insulation for Metal Building Walls

A3.2.2.1 Single Layer. The first rated R-value of insulation is for insulation compressed between metal wall panels and the steel structure.

A3.2.2.2 Continuous Insulation. For assemblies with continuous insulation, the continuous insulation is installed on the outside or inside the girts, uncompressed and uninterrupted by the framing members.

A3.2.3 U-Factors for Metal Building Walls. U-factors for metal building walls shall be taken from Table A3.2.3 or determined in accordance with Section A9.2, provided the average girt spacing is at least 52 in. U-factors for metal building wall assemblies with average girt spacing less than 52 in. shall be determined in accordance with Section A9.2.

A3.3 Steel-Framed Walls

A3.3.1 General. For the purpose of Section A1.2, the base assembly is a wall where the insulation is installed within the cavity of the steel stud framing but where there is not a metal exterior surface spanning member. The steel stud framing is a minimum uncoated thickness of 0.043 in. for 18 gage or 0.054 in. for 16 gage. The U-factors include R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625 in. gypsum board on the exterior, R-0.56 for 0.625 in. gypsum board on the interior, and R-0.68 for interior vertical surfaces air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2-2. Additional assemblies include continuous insulation, uncompressed and uninterrupted by framing. U-factors are provided for the following configurations:

a. Standard framing: steel stud framing at 16 in. on center with cavities filled with 16 in. wide insulation for both 3.5 in. deep and 6.0 in. deep wall cavities.

b. Advanced framing: steel stud framing at 24 in. on center with cavities filled with 24 in. wide insulation for both3.5 in. deep and 6.0 in. deep wall cavities.

A3.3.2 Rated R-Value of Insulation for Steel-Framed Walls

A3.3.2.1 The first rated R-value of insulation is for uncompressed insulation installed in the cavity between steel studs. It is acceptable for this insulation to also be continuous insulation uninterrupted by framing.

A3.3.2.2 If there are two values, the second rated R-value of insulation is for continuous insulation uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.3.2.3 Opaque mullions in spandrel glass shall be covered with insulation complying with the steel-framed wall requirements.

A3.3.3 U-Factors for Steel-Framed Walls

A3.3.3.1 U-factors for steel-framed walls shall be taken from Table A3.3.3.1.

A3.3.3.2 For steel-framed walls with framing at less than 24 in. on center, use the standard framing values as described in Section A3.3.1(a).

A3.3.3.3 For steel-framed walls with framing from 24 to 32 in. on center, use the advanced framing values as described in Section A3.3.1(b).

A3.3.3.4 For steel-framed walls with framing greater than 32 in. on center, use the metal building wall values in Table A3.2.

A3.4 Wood-Framed Walls

A3.4.1 General. For the purpose of Section A1.2, the base assembly is a wall where the insulation is installed between 2 in. nominal wood framing. Cavity insulation is full depth, but values are taken from Table A9.4.2 for R-19 insulation, which is compressed when installed in a 5.5 in. cavity. Headers are double 2 in. nominal wood framing. The U-factors include R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625 in. gypsum board on the exterior, R-0.56 for 0.625 in. gypsum board on the interior, and R-0.68 for interior air film, vertical surfaces. Additional assemblies include continuous insulation, uncompressed and uninterrupted by framing. U-factors are provided for the following configurations:

a. Standard framing: wood framing at 16 in. on center with cavities filled with 14.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep wall cavities. Double headers leave no cavity. Weighting factors are 75% insulated cavity, 21% studs, plates, and sills, and 4% headers.

b. Advanced framing: wood framing at 24 in. on center with cavities filled with 22.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep wall cavities. Double headers leave uninsulated cavities. Weighting factors are 78% insulated cavity, 18% studs, plates, and sills, and 4% headers.

c. Advanced framing with insulated headers: wood framing at 24 in. on center with cavities filled with 22.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep wall cavities. Double header cavities are insulated. Weighting factors are 78% insulated cavity, 18% studs, plates, and sills, and 4% headers.

A3.4.2 Rated R-value of Insulation for Wood-Framed and Other Walls

A3.4.2.1 The first rated R-value of insulation is for uncompressed insulation installed in the cavity between wood studs. It is acceptable for this insulation to also be continuous insulation uninterrupted by framing.

A3.4.2.2 If there are two values, the second rated R-value of insulation is for continuous insulation uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.4.3 U-Factors for Wood-Framed Walls

A3.4.3.1 U-factors for wood-framed walls shall be taken from Table A3.4.3.1.

A3.4.3.2 For wood-framed walls with framing at less than 24 in. on center, use the standard framing values as described in Section A3.4.1(a).

A3.4.3.3 For wood-framed walls with framing from 24 to 32 in. on center, use the advanced framing values as described in Section A3.4.1(b) if the headers are uninsulated or the advanced framing with insulated header values as described in Section A3.4.1(c) if the headers are insulated.

A3.4.3.4 For wood-framed walls with framing greater than 32 in. on center, U-factors shall be determined in accordance with Section A9.

TABLE A3.1-1 Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Partially Grouted (Cores Uninsulated Except here specified)
No Framing	**R-0**	**U-0.740**	**U-0.580**	**U-0.480**
	Ungrouted Cores Filled with Loose-Fill Insulation	**NA**	**NA**	**U-0.350**
Continuous Metal Framing at 24 in. on Center Horizontally				
1.0 in.	R-0	U-0.414	U-0.359	U-0.318
1.0 in.	R-3.8	U-0.325	U-0.290	U-0.263
1.0 in.	R-5	U-0.314	U-0.281	U-0.255
1.0 in.	R-6.5	U-0.305	U-0.274	U-0.249
1.5 in.	R-11	U-0.267	U-0.243	U-0.223
2.0 in.	R-7.6	U-0.230	U-0.212	U-0.197
2.0 in.	R-10	U-0.219	U-0.202	U-0.188
2.0 in.	R-13	U-0.210	U-0.195	U-0.182
3.0 in.	R-11.4	U-0.178	U-0.167	U-0.157
3.0 in.	R-15	U-0.168	U-0.158	U-0.149
3.0 in.	R-19.0	U-0.161	U-0.152	U-0.144
3.5 in.	R-11.0	U-0.168	U-0.158	U-0.149
3.5 in.	R-13.0	U-0.161	U-0.152	U-0.144
3.5 in.	R-15.0	U-0.155	U-0.147	U-0.140
4.5 in.	R-17.1	U-0.133	U-0.126	U-0.121
4.5 in.	R-22.5	U-0.124	U-0.119	U-0.114
4.5 in.	R-25.2	U-0.122	U-0.116	U-0.112
5.0 in.	R-19.0	U-0.122	U-0.117	U-0.112
5.0 in.	R-25.0	U-0.115	U-0.110	U-0.106
5.0 in.	R-28.0	U-0.112	U-0.107	U-0.103
5.0 in.	R-32.0	U-0.109	U-0.105	U-0.101
5.5 in.	R-19.0	U-0.118	U-0.113	U-0.109
5.5 in.	R-20.9	U-0.114	U-0.109	U-0.105
5.5 in.	R-21.0	U-0.113	U-0.109	U-0.105
5.5 in.	R-27.5	U-0.106	U-0.102	U-0.099
5.5 in.	R-30.8	U-0.104	U-0.100	U-0.096
6.0 in.	R-22.8	U-0.106	U-0.102	U-0.098
6.0 in.	R-30.0	U-0.099	U-0.095	U-0.092
6.0 in.	R-33.6	U-0.096	U-0.093	U-0.090
6.5 in.	R-24.7	U-0.099	U-0.096	U-0.092
7.0 in.	R-26.6	U-0.093	U-0.090	U-0.087
7.5 in.	R-28.5	U-0.088	U-0.085	U-0.083
8.0 in.	R-30.4	U-0.083	U-0.081	U-0.079
1 in. Metal Clips at 24 in. on Center Horizontally and 16 in. Vertically				
1.0 in.	R-3.8	U-0.210	U-0.195	U-0.182
1.0 in.	R-5.0	U-0.184	U-0.172	U-0.162
1.0 in.	R-5.6	U-0.174	U-0.163	U-0.154
1.5 in.	R-5.7	U-0.160	U-0.151	U-0.143
1.5 in.	R-7.5	U-0.138	U-0.131	U-0.125
1.5 in.	R-8.4	U-0.129	U-0.123	U-0.118
2.0 in.	R-7.6	U-0.129	U-0.123	U-0.118
2.0 in.	R-10.0	U-0.110	U-0.106	U-0.102

TABLE A3.1-1 Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls *(Continued)*

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Partially Grouted (Cores Uninsulated Except here specified)
No Framing	**R-0**	**U-0.740**	**U-0.580**	**U-0.480**
	Ungrouted Cores Filled with Loose-Fill Insulation	**NA**	**NA**	**U-0.350**
2.0 in.	R-11.2	U-0.103	U-0.099	U-0.096
2.5 in.	R-9.5	U-0.109	U-0.104	U-0.101
2.5 in.	R-12.5	U-0.092	U-0.089	U-0.086
2.5 in.	R-14.0	U-0.086	U-0.083	U-0.080
3.0 in.	R-11.4	U-0.094	U-0.090	U-0.088
3.0 in.	R-15.0	U-0.078	U-0.076	U-0.074
3.0 in.	R-16.8	U-0.073	U-0.071	U-0.069
3.5 in.	R-13.3	U-0.082	U-0.080	U-0.077
3.5 in.	R-17.5	U-0.069	U-0.067	U-0.065
3.5 in.	R-19.6	U-0.064	U-0.062	U-0.061
4.0 in.	R-15.2	U-0.073	U-0.071	U-0.070
4.0 in.	R-20.0	U-0.061	U-0.060	U-0.058
4.0 in.	R-22.4	U-0.057	U-0.056	U-0.054
5.0 in.	R-28.0	U-0.046	U-0.046	U-0.045
6.0 in.	R-33.6	U-0.039	U-0.039	U-0.038
7.0 in.	R-39.2	U-0.034	U-0.034	U-0.033
8.0 in.	R-44.8	U-0.030	U-0.030	U-0.029
9.0 in.	R-50.4	U-0.027	U-0.027	U-0.026
10.0 in.	R-56.0	U-0.024	U-0.024	U-0.024
11.0 in.	R-61.6	U-0.022	U-0.022	U-0.022
Continuous Insulation Uninterrupted by Framing				
No Framing	R-1.0	U-0.425	U-0.367	U-0.324
No Framing	R-2.0	U-0.298	U-0.269	U-0.245
No Framing	R-3.0	U-0.230	U-0.212	U-0.197
No Framing	R-4.0	U-0.187	U-0.175	U-0.164
No Framing	R-5.0	U-0.157	U-0.149	U-0.141
No Framing	R-6.0	U-0.136	U-0.129	U-0.124
No Framing	R-7.0	U-0.120	U-0.115	U-0.110
No Framing	R-8.0	U-0.107	U-0.103	U-0.099
No Framing	R-9.0	U-0.097	U-0.093	U-0.090
No Framing	R-10.0	U-0.088	U-0.085	U-0.083
No Framing	R-11.0	U-0.081	U-0.079	U-0.076
No Framing	R-12.0	U-0.075	U-0.073	U-0.071
No Framing	R-13.0	U-0.070	U-0.068	U-0.066
No Framing	R-14.0	U-0.065	U-0.064	U-0.062
No Framing	R-15.0	U-0.061	U-0.060	U-0.059
No Framing	R-16.0	U-0.058	U-0.056	U-0.055
No Framing	R-17.0	U-0.054	U-0.053	U-0.052
No Framing	R-18.0	U-0.052	U-0.051	U-0.050
No Framing	R-19.0	U-0.049	U-0.048	U-0.047
No Framing	R-20.0	U-0.047	U-0.046	U-0.045
No Framing	R-21.0	U-0.045	U-0.044	U-0.043
No Framing	R-22.0	U-0.043	U-0.042	U-0.042

TABLE A3.1-1 Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls *(Continued)*

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Partially Grouted (Cores Uninsulated Except here specified)
No Framing	**R-0**	**U-0.740**	**U-0.580**	**U-0.480**
	Ungrouted Cores Filled with Loose-Fill Insulation	**NA**	**NA**	**U-0.350**
No Framing	R-23.0	U-0.041	U-0.040	U-0.040
No Framing	R-24.0	U-0.039	U-0.039	U-0.038
No Framing	R-25.0	U-0.038	U-0.037	U-0.037
No Framing	R-30.0	U-0.032	U-0.032	U-0.031
No Framing	R-35.0	U-0.028	U-0.027	U-0.027
No Framing	R-40.0	U-0.024	U-0.024	U-0.024
No Framing	R-45.0	U-0.022	U-0.021	U-0.021
No Framing	R-50.0	U-0.019	U-0.019	U-0.019
No Framing	R-55.0	U-0.018	U-0.018	U-0.018
No Framing	R-60.0	U-0.016	U-0.016	U-0.016
Brick Cavity Wall with Continuous Insulation				
No Framing	R-0	U-0.337	U-0.299	U-0.270
No Framing	R-3.8	U-0.148	U-0.140	U-0.133
No Framing	R-5.0	U-0.125	U-0.120	U-0.115
No Framing	R-6.5	U-0.106	U-0.102	U-0.098
No Framing	R-7.6	U-0.095	U-0.091	U-0.088
No Framing	R-10	U-0.077	U-0.075	U-0.073
No Framing	R-10.5	U-0.079	U-0.077	U-0.075
No Framing	R-11.4	U-0.070	U-0.068	U-0.066
No Framing	R-15	U-0.056	U-0.055	U-0.053
No Framing	R-16.5	U-0.054	U-0.053	U-0.052
No Framing	R-19.0	U-0.046	U-0.045	U-0.044
No Framing	R-22.5	U-0.041	U-0.040	U-0.039
No Framing	R-28.5	U-0.033	U-0.032	U-0.032
Continuous Insulation Uninterrupted by Framing with Stucco and Continuous Metal Framing at 24 in. on Center Horizontally				
1.0 in.	R-0+R-19.0 c.i.	U-0.047	U-0.046	U-0.045
1.0 in.	R-3.8+R-19.0 c.i.	U-0.045	U-0.044	U-0.044
1.0 in.	R-5+R-19.0 c.i.	U-0.045	U-0.044	U-0.043
1.0 in.	R-6.5+R-19.0 c.i.	U-0.045	U-0.044	U-0.043
1.5 in.	R-11+R-19.0 c.i.	U-0.044	U-0.043	U-0.043
2.0 in.	R-7.6+R-19.0 c.i.	U-0.043	U-0.042	U-0.041
2.0 in.	R-10+R-19.0 c.i.	U-0.042	U-0.041	U-0.041
2.0 in.	R-13+R-19.0 c.i.	U-0.042	U-0.041	U-0.041
3.0 in.	R-11.4+R-19.0 c.i.	U-0.041	U-0.040	U-0.039
3.0 in.	R-15+R-19.0 c.i.	U-0.040	U-0.039	U-0.039
3.0 in.	R-19.5+R-19.0 c.i.	U-0.040	U-0.039	U-0.038
3.5 in.	R-11.0+R-19.0 c.i.	U-0.040	U-0.039	U-0.039
3.5 in.	R-13.0+R-19.0 c.i.	U-0.040	U-0.039	U-0.038
5.0 in.	R-19.0+R-19.0 c.i.	U-0.037	U-0.036	U-0.036
5.0 in.	R-25+R-19.0 c.i.	U-0.036	U-0.035	U-0.035
5.0 in.	R-32.5+R-19.0 c.i.	U-0.035	U-0.035	U-0.034
5.5 in.	R-19.0+R-19.0 c.i.	U-0.036	U-0.036	U-0.035
5.5 in.	R-21.0+R-19.0 c.i.	U-0.035	U-0.035	U-0.035

TABLE A3.1-2 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete

Density, lb/ft^3	Properties	Thickness, in.									
		3	4	5	6	7	8	9	10	11	12
20	U-factor	0.22	0.17	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06
	C-factor	0.27	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07
	R_u	4.60	5.85	7.10	8.35	9.60	10.85	12.10	13.35	14.60	15.85
	R_c	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	15.00
	HC	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0
30	U-factor	0.28	0.22	0.19	0.16	0.14	0.12	0.11	0.10	0.09	0.09
	C-factor	0.37	0.28	0.22	0.18	0.16	0.14	0.12	0.11	0.10	0.09
	R_u	3.58	4.49	5.40	6.30	7.21	8.12	9.03	9.94	10.85	11.76
	R_c	2.73	3.64	4.55	5.45	6.36	7.27	8.18	9.09	10.00	10.91
	HC	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
40	U-factor	0.33	0.27	0.23	0.19	0.17	0.15	0.14	0.13	0.11	0.11
	C-factor	0.47	0.35	0.28	0.23	0.20	0.18	0.16	0.14	0.13	0.12
	R_u	2.99	3.71	4.42	5.14	5.85	6.56	7.28	7.99	8.71	9.42
	R_c	2.14	2.86	3.57	4.29	5.00	5.71	6.43	7.14	7.86	8.57
	HC	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0
50	U-factor	0.38	0.31	0.26	0.23	0.20	0.18	0.16	0.15	0.14	0.13
	C-factor	0.57	0.43	0.34	0.28	0.24	0.21	0.19	0.17	0.15	0.14
	R_u	2.61	3.20	3.79	4.38	4.97	5.56	6.14	6.73	7.32	7.91
	R_c	1.76	2.35	2.94	3.53	4.12	4.71	5.29	5.88	6.47	7.06
	HC	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0
85	U-factor	0.65	0.56	0.50	0.44	0.40	0.37	0.34	0.31	0.29	0.27
	C-factor	1.43	1.08	0.86	0.71	0.61	0.54	0.48	0.43	0.39	0.36
	R_u	1.55	1.78	2.01	2.25	2.48	2.71	2.94	3.18	3.41	3.64
	R_c	0.70	0.93	1.16	1.40	1.63	1.86	2.09	2.33	2.56	2.79
	HC	4.3	5.7	7.1	8.5	9.9	11.3	12.8	14.2	15.6	17.0
95	U-factor	0.72	0.64	0.57	0.52	0.48	0.44	0.41	0.38	0.36	0.33
	C-factor	1.85	1.41	1.12	0.93	0.80	0.70	0.62	0.56	0.51	0.47
	R_u	1.39	1.56	1.74	1.92	2.10	2.28	2.46	2.64	2.81	2.99
	R_c	0.54	0.71	0.89	1.07	1.25	1.43	1.61	1.79	1.96	2.14
	HC	4.8	6.3	7.9	9.5	11.1	12.7	14.3	15.8	17.4	19.0
105	U-factor	0.79	0.71	0.65	0.59	0.54	0.51	0.47	0.44	0.42	0.39
	C-factor	2.38	1.79	1.43	1.18	1.01	0.88	0.79	0.71	0.65	0.59
	R_u	1.27	1.41	1.56	1.70	1.84	1.98	2.12	2.26	2.40	2.54
	R_c	0.42	0.56	0.70	0.85	0.99	1.13	1.27	1.41	1.55	1.69
	HC	5.3	7.0	8.8	10.5	12.3	14.0	15.8	17.5	19.3	21.0

TABLE A3.1-2 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete *(Continued)*

Density, lb/ft^3	Properties	Thickness, in.									
		3	4	5	6	7	8	9	10	11	12
	U-factor	0.84	0.77	0.70	0.65	0.61	0.57	0.53	0.50	0.48	0.45
	C-factor	2.94	2.22	1.75	1.47	1.25	1.10	0.98	0.88	0.80	0.74
115	R_u	1.19	1.30	1.42	1.53	1.65	1.76	1.87	1.99	2.10	2.21
	R_c	0.34	0.45	0.57	0.68	0.80	0.91	1.02	1.14	1.25	1.36
	HC	5.8	7.7	9.6	11.5	13.4	15.3	17.3	19.2	21.1	23.0
	U-factor	0.88	0.82	0.76	0.71	0.67	0.63	0.60	0.56	0.53	0.51
	C-factor	3.57	2.70	2.17	1.79	1.54	1.35	1.20	1.03	0.98	0.90
125	R_u	1.13	1.22	1.31	1.41	1.50	1.59	1.68	1.78	1.87	1.96
	R_c	0.28	0.37	0.46	0.56	0.65	0.74	0.83	0.93	1.02	1.11
	HC	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0
	U-factor	0.93	0.87	0.82	0.77	0.73	0.69	0.66	0.63	0.60	0.57
	C-factor	4.55	3.33	2.70	2.22	1.92	1.67	1.49	1.33	1.22	1.11
135	R_u	1.07	1.15	1.22	1.30	1.37	1.45	1.52	1.60	1.67	1.75
	R_c	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.75	0.82	0.90
	HC	6.8	9.0	11.3	13.5	15.8	18.0	20.3	22.5	24.8	27.0
	U-factor	0.96	0.91	0.86	0.81	0.78	0.74	0.71	0.68	0.65	0.63
	C-factor	5.26	4.00	3.23	2.63	2.27	2.00	1.79	1.59	1.45	1.33
144	R_u	1.04	1.10	1.16	1.23	1.29	1.35	1.41	1.48	1.54	1.60
	R_c	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75
	HC	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0	26.4	28.8

The U-factors and R_u include standard air film resistances.
The C-factors and R_c are for the same assembly without air film resistances.
Note that the following assemblies do not qualify as a mass wall or mass floor: 3 in. thick concrete with densities of 85, 95, 125, and 135 lb/ft^3.

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls

Product Size, in.	Density, lb/ft^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
6 in. Block	85	U-factor	0.57	0.46	0.34	0.40	0.20
		C-factor	1.11	0.75	0.47	0.60	0.23
		R_u	1.75	2.18	2.97	2.52	5.13
		R_c	0.90	1.33	2.12	1.67	4.28
		HC	10.9	6.7	7.0	4.2	4.6
	95	U-factor	0.61	0.49	0.36	0.42	0.22
		C-factor	1.25	0.83	0.53	0.65	0.27
		R_u	1.65	2.06	2.75	2.38	4.61
		R_c	0.80	1.21	1.90	1.53	3.76
		HC	11.4	7.2	7.5	4.7	5.1
	105	U-factor	0.64	0.51	0.39	0.44	0.24
		C-factor	1.38	0.91	0.58	0.71	0.30
		R_u	1.57	1.95	2.56	2.26	4.17
		R_c	0.72	1.10	1.71	1.41	3.32
		HC	11.9	7.7	7.9	5.1	5.6
	115	U-factor	0.66	0.54	0.41	0.46	0.26
		C-factor	1.52	0.98	0.64	0.76	0.34
		R_u	1.51	1.87	2.41	2.16	3.79
		R_c	0.66	1.02	1.56	1.31	2.94
		HC	12.3	8.1	8.4	5.6	6.0
	125	U-factor	0.70	0.56	0.45	0.49	0.30
		C-factor	1.70	1.08	0.73	0.84	0.40
		R_u	1.44	1.78	2.23	2.04	3.38
		R_c	0.59	0.93	1.38	1.19	2.53
		HC	12.8	8.6	8.8	6.0	6.5
	135	U-factor	0.73	0.60	0.49	0.53	0.35
		C-factor	1.94	1.23	0.85	0.95	0.49
		R_u	1.36	1.67	2.02	1.90	2.89
		R_c	0.51	0.82	1.17	1.05	2.04
		HC	13.2	9.0	9.3	6.5	6.9

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls *(Continued)*

Product Size, in.	Density, lb/ft^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
8 in. Block	85	U-factor	0.49	0.41	0.28	0.37	0.15
		C-factor	0.85	0.63	0.37	0.53	0.17
		R_u	2.03	2.43	3.55	2.72	6.62
		R_c	1.18	1.58	2.70	1.87	5.77
		HC	15.0	9.0	9.4	5.4	6.0
	95	U-factor	0.53	0.44	0.31	0.39	0.17
		C-factor	0.95	0.70	0.41	0.58	0.20
		R_u	1.90	2.29	3.27	2.57	5.92
		R_c	1.05	1.44	2.42	1.72	5.07
		HC	15.5	9.6	10.0	6.0	6.6
	105	U-factor	0.55	0.46	0.33	0.41	0.19
		C-factor	1.05	0.76	0.46	0.63	0.22
		R_u	1.81	2.17	3.04	2.44	5.32
		R_c	0.96	1.32	2.19	1.59	4.47
		HC	16.1	10.2	10.6	6.6	7.2
	115	U-factor	0.58	0.48	0.35	0.43	0.21
		C-factor	1.14	0.82	0.50	0.68	0.25
		R_u	1.72	2.07	2.84	2.33	4.78
		R_c	0.87	1.22	1.99	1.48	3.93
		HC	16.7	10.8	11.2	7.2	7.8
	125	U-factor	0.61	0.51	0.38	0.45	0.24
		C-factor	1.27	0.90	0.57	0.74	0.30
		R_u	1.64	1.96	2.62	2.20	4.20
		R_c	0.79	1.11	1.77	1.35	3.35
		HC	17.3	11.4	11.8	7.8	8.4
	135	U-factor	0.65	0.55	0.42	0.49	0.28
		C-factor	1.44	1.02	0.67	0.83	0.37
		R_u	1.54	1.83	2.35	2.05	3.55
		R_c	0.69	0.98	1.50	1.20	2.70
		HC	17.9	12.0	12.4	8.4	9.0

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls *(Continued)*

Product Size, in.	Density, lb/ft^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
10 in. Block	85	U-factor	0.44	0.38	0.25	0.35	0.13
		C-factor	0.70	0.57	0.31	0.50	0.14
		R_u	2.29	2.61	4.05	2.84	7.87
		R_c	1.44	1.76	3.20	1.99	7.02
		HC	19.0	11.2	11.7	6.5	7.3
	95	U-factor	0.47	0.41	0.27	0.37	0.14
		C-factor	0.77	0.62	0.35	0.55	0.16
		R_u	2.15	2.46	3.73	2.67	6.94
		R_c	1.30	1.61	2.88	1.82	6.09
		HC	19.7	11.9	12.4	7.3	8.1
	105	U-factor	0.49	0.43	0.29	0.39	0.16
		C-factor	0.85	0.68	0.39	0.59	0.19
		R_u	2.03	2.33	3.45	2.54	6.17
		R_c	1.18	1.48	2.60	1.69	5.32
		HC	20.4	12.6	13.1	8.0	8.8
10 in. Block	115	U-factor	0.52	0.45	0.31	0.41	0.18
		C-factor	0.92	0.73	0.42	0.64	0.21
		R_u	1.94	2.22	3.21	2.42	5.52
		R_c	1.09	1.37	2.36	1.57	4.67
		HC	21.1	13.4	13.9	8.7	9.5
	125	U-factor	0.54	0.48	0.34	0.44	0.21
		C-factor	1.01	0.80	0.48	0.70	0.25
		R_u	1.84	2.10	2.95	2.28	4.81
		R_c	0.99	1.25	2.10	1.43	3.96
		HC	21.8	14.1	14.6	9.4	10.2
	135	U-factor	0.58	0.51	0.38	0.47	0.25
		C-factor	1.14	0.90	0.56	0.79	0.32
		R_u	1.72	1.96	2.64	2.12	4.00
		R_c	0.87	1.11	1.79	1.27	3.15
		HC	22.6	14.8	15.3	10.2	11.0

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls *(Continued)*

Product Size, in.	Density, lb/ft^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
12 in. Block	85	U-factor	0.40	0.36	0.22	0.34	0.11
		C-factor	0.59	0.52	0.27	0.48	0.12
		R_u	2.53	2.77	4.59	2.93	9.43
		R_c	1.68	1.92	3.74	2.08	8.58
		HC	23.1	13.3	14.0	7.5	8.5
	95	U-factor	0.42	0.38	0.24	0.36	0.12
		C-factor	0.66	0.57	0.30	0.52	0.13
		R_u	2.30	2.60	4.22	2.76	8.33
		R_c	1.53	1.75	3.37	1.91	7.48
		HC	23.9	14.2	14.8	8.3	9.3
	105	U-factor	0.44	0.41	0.26	0.38	0.14
		C-factor	0.71	0.62	0.33	0.57	0.15
		R_u	2.25	2.47	3.90	2.62	7.35
		R_c	1.40	1.62	3.05	1.77	6.50
		HC	24.7	15.0	15.6	9.1	10.2
	115	U-factor	0.47	0.42	0.28	0.40	0.15
		C-factor	0.77	0.66	0.36	0.61	0.18
		R_u	2.15	2.36	3.63	2.49	6.54
		R_c	1.30	1.51	2.78	1.64	5.69
		HC	25.6	15.8	16.4	10.0	11.0
	125	U-factor	0.49	0.45	0.30	0.42	0.18
		C-factor	0.84	0.72	0.40	0.66	0.21
		R_u	2.04	2.23	3.34	2.36	5.68
		R_c	1.19	1.38	2.49	1.51	4.83
		HC	26.4	16.6	17.3	10.8	11.8
	135	U-factor	0.52	0.48	0.34	0.46	0.21
		C-factor	0.94	0.81	0.47	0.74	0.26
		R_u	1.91	2.08	2.98	2.19	4.67
		R_c	1.06	1.23	2.13	1.34	3.82
		HC	27.2	17.5	18.1	11.6	12.6

TABLE A3.1-4 Effective R-Values for Insulation/Framing Layers Added to Above-Grade Mass Walls and Below-Grade Walls

Depth, in.	Framing Type	Rated R-Value of Insulation																									
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Effective R-value if Continuous Insulation Uninterrupted by Framing (Includes Gypsum Board)																											
	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5
Effective R-value if Insulation is Installed in Cavity between Framing (Includes Gypsum Board)																											
0.5	Wood	1.3	1.3	1.9	2.4	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.9	0.9	1.1	1.1	1.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.75	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.0	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.5	Wood	1.3	1.5	2.4	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.5	6.8	7.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.1	1.2	1.6	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.0	Wood	1.4	1.5	2.5	3.3	4.0	4.7	5.3	5.9	6.4	6.9	7.3	7.7	8.1	8.4	8.7	9.0	9.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.1	1.2	1.7	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.3	3.4	3.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.5	Wood	1.4	1.5	2.5	3.4	4.2	4.9	5.6	6.3	6.8	7.4	7.9	8.4	8.8	9.2	9.6	10.0	10.3	10.6	10.9	11.2	11.5	NA	NA	NA	NA	NA
	Metal	1.2	1.3	1.8	2.3	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	NA	NA	NA	NA	NA
3.0	Wood	1.4	1.5	2.5	3.5	4.3	5.1	5.8	6.5	7.2	7.8	8.3	8.9	9.4	9.9	10.3	10.7	11.1	11.5	11.9	12.2	12.5	12.9	NA	NA	NA	NA
	Metal	1.2	1.3	1.9	2.4	2.8	3.1	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8	NA	NA	NA	NA
3.5	Wood	1.4	1.5	2.6	3.5	4.4	5.2	6.0	6.7	7.4	8.1	8.7	9.3	9.8	10.4	10.9	11.3	11.8	12.2	12.6	13.0	13.4	13.8	14.1	14.5	14.8	15.1
	Metal	1.2	1.3	2.0	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.2	5.3	5.4	5.4	5.4	5.5
4.0	Wood	1.4	1.6	2.6	3.6	4.5	5.3	6.1	6.9	7.6	8.3	9.0	9.6	10.2	10.8	11.3	11.9	12.4	12.8	13.3	13.7	14.2	14.6	14.9	15.3	15.7	16.0
	Metal	1.2	1.3	2.0	2.6	3.0	3.4	3.7	4.0	4.2	4.5	4.6	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8	5.9	5.9	6.0	6.0
4.5	Wood	1.4	1.6	2.6	3.6	4.5	5.4	6.2	7.1	7.8	8.5	9.2	9.9	10.5	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.2	15.7	16.1	16.5	16.9
	Metal	1.2	1.3	2.1	2.6	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.4	6.5	6.6
5.0	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.3	7.2	8.0	8.7	9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.3	15.8	16.3	16.7	17.2	17.6
	Metal	1.2	1.4	2.1	2.7	3.2	3.7	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.7	6.8	6.8	6.9	7.0	7.1
5.5	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.4	7.3	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.7	15.3	15.8	16.3	16.8	17.3	17.8	18.2
	Metal	1.3	1.4	2.1	2.8	3.3	3.8	4.2	4.6	4.9	5.2	5.4	5.7	5.9	6.1	6.3	6.4	6.6	6.7	6.8	7.0	7.1	7.2	7.3	7.4	7.5	7.6

TABLE A3.2.3 Assembly U-Factors for Metal Building Walls

Insulation System	Rated R-Value of Insulation	Overall U-Factor for Entire Base Wall Assembly	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing)								
			R-6.5	R-9.8	R-13	R-15.8	R-19	R-22.1	R-25	R-32	R-38
Single Layer of Mineral Fiber											
	None	1.180	0.136	0.094	0.072	0.060	0.050	0.044	0.039	0.030	0.026
	R-10	0.186	0.084	0.066	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-11	0.185	0.084	0.066	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-13	0.162	0.079	0.063	0.052	0.046	0.040	0.035	0.032	0.026	0.023
	R-16	0.155	0.077	0.062	0.051	0.045	0.039	0.035	0.032	0.026	0.022
	R-19	0.147	0.075	0.060	0.050	0.044	0.039	0.035	0.031	0.026	0.022

TABLE A3.3.3.1 Assembly U-Factors for Steel-Frame Walls

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed [see Table A9.2B])	Overall U-Factor for Entire Base Wall Assembly	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Steel Framing at 16 in. on Center																						
3.5 in. depth	None (0.0)	0.352	0.260	0.207	0.171	0.146	0.128	0.113	0.102	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (5.5)	0.132	0.117	0.105	0.095	0.087	0.080	0.074	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.036	0.031	0.027	0.024	0.021
	R-13 (6.0)	0.124	0.111	0.100	0.091	0.083	0.077	0.071	0.066	0.062	0.059	0.055	0.052	0.050	0.048	0.045	0.043	0.036	0.030	0.026	0.023	0.021
	R-15 (6.4)	0.118	0.106	0.096	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.035	0.030	0.026	0.023	0.021
6.0 in. depth	R-19 (7.1)	0.109	0.099	0.090	0.082	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.034	0.029	0.026	0.023	0.020
	R-21 (7.4)	0.106	0.096	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.022	0.020
Steel Framing at 24 in. on Center																						
3.5 in.depth	None (0.0)	0.338	0.253	0.202	0.168	0.144	0.126	0.112	0.100	0.091	0.084	0.077	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (6.6)	0.116	0.104	0.094	0.086	0.079	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.035	0.030	0.026	0.023	0.021
	R-13 (7.2)	0.108	0.098	0.089	0.082	0.075	0.070	0.066	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.023	0.020
	R-15 (7.8)	0.102	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.034	0.029	0.025	0.022	0.020
6.0 in. depth	R-19 (8.6)	0.094	0.086	0.079	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.033	0.028	0.025	0.022	0.020
	R-21 (9.0)	0.090	0.083	0.077	0.071	0.066	0.062	0.059	0.055	0.052	0.050	0.048	0.045	0.043	0.042	0.040	0.038	0.032	0.028	0.024	0.022	0.020

TABLE A3.3.3.1 Assembly U-Factors for Wood-Frame Walls

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed [see Table A9.4C])	Overall U-Factor for Entire Base Wall Assembly	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation																		
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Wood Studs at 16 in. on Center																					
3.5 in. depth	None (0.0)	0.292	0.223	0.181	0.152	0.132	0.116	0.104	0.094	0.086	0.079	0.073	0.068	0.064	0.060	0.056	0.053	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	0.096	0.087	0.079	0.073	0.068	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.032	0.028	0.024	0.022	0.020
	R-13 (13.0)	0.089	0.080	0.074	0.068	0.063	0.059	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.031	0.027	0.024	0.021	0.019
	R-15 (15.0)	0.083	0.075	0.069	0.064	0.060	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.020	0.019
5.5 in. depth	R-19 (18.0)	0.067	0.062	0.058	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.027	0.024	0.021	0.019	0.018
	R-21 (21.0)	0.063	0.058	0.054	0.051	0.048	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.032	0.031	0.030	0.026	0.023	0.021	0.019	0.017
+ R-10 headers	R-19 (18.0)	0.063	0.059	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.031	0.027	0.024	0.021	0.019	0.017
	R-21 (21.0)	0.059	0.055	0.051	0.049	0.046	0.044	0.042	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.026	0.023	0.020	0.018	0.017
Wood Studs at 24 in. on Center																					
3.5 in. depth	None (0.0)	0.298	0.227	0.183	0.154	0.133	0.117	0.105	0.095	0.086	0.079	0.074	0.068	0.064	0.060	0.057	0.054	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	0.094	0.085	0.078	0.072	0.067	0.062	0.059	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.032	0.027	0.024	0.022	0.019
	R-13 (13.0)	0.086	0.078	0.072	0.067	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.031	0.026	0.023	0.021	0.019
	R-15 (15.0)	0.080	0.073	0.067	0.062	0.058	0.055	0.052	0.049	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.029	0.026	0.023	0.020	0.018
5.5 in. depth	R-19 (18.0)	0.065	0.060	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.027	0.024	0.021	0.019	0.018
	R-21 (21.0)	0.060	0.056	0.052	0.049	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.026	0.023	0.020	0.018	0.017
+ R-10 headers	R-19 (18.0)	0.062	0.058	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.034	0.033	0.032	0.031	0.027	0.024	0.021	0.019	0.017
	R-21 (21.0)	0.057	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.029	0.025	0.023	0.020	0.018	0.017

A4. BELOW-GRADE WALLS

A4.1 General. For the purpose of Section A1.2, The base assembly is 8 in. medium-weight concrete block with a density of 115 lb/ft^3 and solid grouted cores. Continuous insulation is installed on the interior or exterior. In contrast to the U-factor for above-grade walls, the C-factor for below-grade walls does not include R-values for exterior or interior air films or for soil. For insulated walls, the C-factor does include R-0.45 for 0.5 in. gypsum board.

A4.2 C-Factors for Below-Grade Walls

A4.2.1 C-factors for below-grade walls shall be taken from Table A4.2.1 or determined by the procedure described in this subsection.

A4.2.2 It is acceptable to use the C-factors in Table A4.2.1 for all below-grade walls.

A4.2.3 If not taken from Table A4.2.1, below-grade wall C-factors shall be determined from Tables A3.1-2, A3.1-3, or A3.1-4 using the following procedure:

a. If the below-grade wall is uninsulated or only the cells are insulated:
    1. For concrete walls, determine the C-factor from Table A3.1-2 based on the concrete density and wall thickness.
    2. For concrete block walls, determine the C-factor from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.

b. If the mass wall has additional insulation:
    1. For concrete walls, determine the R_c from Table A3.1-2 based on the concrete density and wall thickness. Next, determine the effective R-value for the insulation/framing layer from Table A3.1-4 based on the rated R-value of insulation installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the C-factor by adding the R_c and the effective R-value together and taking the inverse of the total.
    2. For concrete block walls, determine the R_c from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated. Next, determine the effective R-value for the insulation/framing layer from Table A3.1-4 based on the rated R-value of insulation installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the C-factor by adding the R_c and the effective R-value together and taking the inverse of the total.

TABLE A4.2.1 Assembly C-Factors for Below-Grade Walls

Framing Type and Depth	Rated R-Value of Insulation Alone	Specified C-Factors (Wall Only, without Soil and Air Films)
No Framing	R-0	C-1.140
Exterior Insulation, Continuous and Uninterrupted by Framing		
No Framing	R-5.0	C-0.170
No Framing	R-7.5	C-0.119
No Framing	R-10.0	C-0.092
No Framing	R-12.5	C-0.075
No Framing	R-15.0	C-0.063
No Framing	R-17.5	C-0.054
No Framing	R-20.0	C-0.048
No Framing	R-25.0	C-0.039
No Framing	R-30.0	C-0.032
No Framing	R-35.0	C-0.028
No Framing	R-40.0	C-0.025
No Framing	R-45.0	C-0.022
No Framing	R-50.0	C-0.020
Continuous Metal Framing at 24 in. on Center Horizontally		
3.5 in.	R-11.0	C-0.182
3.5 in.	R-13.0	C-0.174
3.5 in.	R-15.0	C-0.168
5.5 in.	R-19.0	C-0.125
5.5 in.	R-21.0	C-0.120
1 in. Metal Clips at 24 in. on Center Horizontally and 16 in. Vertically		
1.0 in.	R-3.8	C-0.233
1.0 in.	R-5.0	C-0.201
1.0 in.	R-5.6	C-0.189
1.5 in.	R-5.7	C-0.173
1.5 in.	R-7.5	C-0.147
1.5 in.	R-8.4	C-0.138
2.0 in.	R-7.6	C-0.138
2.0 in.	R-10.0	C-0.116
2.0 in.	R-11.2	C-0.108
2.5 in.	R-9.5	C-0.114
2.5 in.	R-12.5	C-0.096
2.5 in.	R-14.0	C-0.089
3.0 in.	R-11.4	C-0.098
3.0 in.	R-15.0	C-0.082
3.0 in.	R-16.8	C-0.076
3.5 in.	R-13.3	C-0.085
3.5 in.	R-17.5	C-0.071
3.5 in.	R-19.6	C-0.066
4.0 in.	R-15.2	C-0.076
4.0 in.	R-20.0	C-0.063
4.0 in.	R-22.4	C-0.058

A5. FLOORS

A5.1 General. The buffering effect of crawlspaces or parking garages shall not be included in U-factor calculations. See Section A6 for slab-on-grade floors.

A5.2 Mass Floors

A5.2.1 General. For the purpose of Section A1.2, the base assembly is continuous insulation over or under a solid concrete floor. The U-factors include R-0.92 for interior air film-heat flow down, R-1.23 for carpet and rubber pad, R-0.50 for 8 in. concrete, and R-0.46 for semi-exterior air film. Added insulation is continuous and uninterrupted by framing. Framing factor is zero.

A5.2.2 Rated R-Value of Insulation for Mass Floors

A5.2.2.1 The rated R-value of insulation is for continuous insulation uninterrupted by framing.

A5.2.2.2 Where framing, including metal and wood joists, is used, compliance shall be based on the maximum assembly U-factor rather than the minimum rated R-value of insulation.

A5.2.2.3 For waffle-slab floors, the floor shall be insulated either on the interior above the slab or on all exposed surfaces of the waffle.

A5.2.2.4 For floors with beams that extend below the floor slab, the floor shall be insulated either on the interior above the slab or on the exposed floor and all exposed surfaces of the beams that extend 24 in. and less below the exposed floor.

A5.2.3 U-Factors for Mass Floors

A5.2.3.1 The U-factors for mass walls shall be taken from Table A5.2.3.1.

A5.2.3.2 It is not acceptable to use the U-factors in Table A5.2.3.1 if the insulation is not continuous.

A5.3 Steel-Joist Floors

A5.3.1 General. For the purpose of Section A1.2, the base assembly is a floor where the insulation is either placed between the steel joists or is sprayed on the underside of the floor and the joists. In both cases, the steel provides a thermal bypass to the insulation. The U-factors include R-0.92 for interior air film—heat flow down, R-1.23 for carpet and pad, R-0.25 for 4 in. concrete, R-0 for metal deck, and R-0.46 for semi-exterior air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2-1.

A5.3.2 Rated R-Value of Insulation for Steel-Joist Floors

A5.3.2.1 The first rated R-value of insulation is for uncompressed insulation installed in the cavity between steel joists or for spray-on insulation.

A5.3.2.2 It is acceptable for this insulation to also be continuous insulation uninterrupted by framing. All continuous insulation shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.3.3 U-Factors for Steel-Joist Floors

A5.3.3.1 The U-factors for steel-joist floors shall be taken from Table A5.3.3.1.

A5.3.3.2 It is acceptable to use these U-factors for any steel-joist floor.

A5.4 Wood-Framed and Other Floors

A5.4.1 General. For the purpose of Section A1.2, the base assembly is a floor attached directly to the top of the wood joist with insulation located directly below the floor and ventilated airspace below the insulation. The heat flow path through the joist is calculated to be the same depth as the insulation. The U-factors include R-0.92 for interior air film—heat flow down, R-1.23 for carpet and pad, R-0.94 for 0.75 in. wood subfloor, and R-0.46 for semi-exterior air film. The weighting factors are 91% insulated cavity and 9% framing.

A5.4.2 Rated R-Value of Insulation for Wood-Framed and Other Floors

A5.4.2.1 The first rated R-value of insulation is for uncompressed insulation installed in the cavity between wood joists.

A5.4.2.2 It is acceptable for this insulation to also be continuous insulation uninterrupted by framing. All continuous insulation shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.4.3 U-Factors for Wood-Framed Floors

A5.4.3.1 The U-factors for wood-framed floors shall be taken from Table A5.4.3.1.

A5.4.3.2 It is not acceptable to use these U-factors if the framing is not wood.

TABLE A5.2.3.1 Assembly U-Factors for Mass Floors

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed)	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation																		
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Concrete Floor with Rigid Foam																					
	None (0.0)	0.322	0.243	0.196	0.164	0.141	0.123	0.110	0.099	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.043	0.036	0.030	0.026	0.023
Concrete Floor with Pinned Boards																					
	R-4.2 (4.2)	0.137	0.121	0.108	0.097	0.089	0.081	0.075	0.070	0.065	0.061	0.058	0.055	0.052	0.049	0.047	0.045	0.037	0.031	0.027	0.024	0.021
	R-6.3 (6.3)	0.107	0.096	0.088	0.081	0.075	0.070	0.065	0.061	0.058	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.023	0.020
	R-8.3 (8.3)	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.032	0.027	0.024	0.022	0.019
	R-10.4 (10.4)	0.074	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.021	0.019
	R-12.5 (12.5)	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.028	0.025	0.022	0.020	0.018
	R-14.6 (14.6)	0.056	0.053	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.033	0.032	0.031	0.027	0.023	0.021	0.019	0.017
	R-16.7 (16.7)	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.032	0.031	0.030	0.030	0.029	0.025	0.022	0.020	0.018	0.017
Concrete Floor with Spray-On Insulation																					
1 in.	R-4 (4.0)	0.141	0.123	0.110	0.099	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.037	0.031	0.027	0.024	0.021
2 in.	R-8 (8.0)	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.032	0.028	0.024	0.022	0.020
3 in.	R-12 (12.0)	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.028	0.025	0.022	0.020	0.018
4 in.	R-16 (16.0)	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.026	0.023	0.020	0.018	0.017
5 in.	R-20 (20.0)	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.023	0.021	0.019	0.017	0.016
6 in.	R-24 (24.0)	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.021	0.019	0.018	0.016	0.015

TABLE A5.3.3.1 Assembly U-Factors for Steel-Joist Floors

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed [See Table A9.2-1])	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Steel Joist Floor with Rigid Foam																						
	None (0.0)	0.350	0.259	0.206	0.171	0.146	0.127	0.113	0.101	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
Steel Joist Floor with Spray-on Insulation																						
1 in.	R-4 (3.88)	0.148	0.129	0.114	0.103	0.093	0.085	0.078	0.073	0.068	0.064	0.060	0.056	0.053	0.051	0.048	0.046	0.037	0.032	0.027	0.024	0.021
2 in.	R-8 (7.52)	0.096	0.088	0.081	0.075	0.070	0.065	0.061	0.058	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.033	0.028	0.025	0.022	0.020
3 in.	R-12 (10.80)	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.021	0.019
4 in.	R-16 (13.92)	0.060	0.056	0.053	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.032	0.031	0.027	0.024	0.021	0.019	0.018
5 in.	R-20 (17.00)	0.050	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.030	0.029	0.025	0.022	0.020	0.018	0.017
6 in.	R-24 (19.68)	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.024	0.021	0.019	0.017	0.016
Steel Joist Floor with Batt Insulation																						
	None (0.0)	0.350	0.259	0.206	0.171	0.146	0.127	0.113	0.101	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (10.01)	0.078	0.072	0.067	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.030	0.026	0.023	0.021	0.019
	R-13 (11.70)	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.029	0.025	0.022	0.020	0.018
	R-15 (13.20)	0.062	0.059	0.055	0.052	0.050	0.047	0.045	0.043	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.028	0.024	0.022	0.020	0.018
	R-19 (16.34)	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.026	0.023	0.020	0.018	0.017
	R-21 (17.64)	0.049	0.047	0.044	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.025	0.022	0.020	0.018	0.017
	R-25 (20.25)	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.023	0.021	0.019	0.017	0.016
	R-30C (23.70)	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.025	0.024	0.021	0.019	0.018	0.016	0.015
	R-30 (23.70)	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.025	0.024	0.021	0.019	0.018	0.016	0.015
	R-38C (28.12)	0.032	0.031	0.030	0.029	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014
	R-38 (28.12)	0.032	0.031	0.030	0.029	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014

TABLE A5.4.3.1 Assembly U-Factors for Wood-Joist Floors

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed)	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Wood Joists																						
5.5 in.	None (0.0)	0.282	0.220	0.180	0.153	0.132	0.117	0.105	0.095	0.087	0.080	0.074	0.069	0.064	0.060	0.057	0.054	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	0.074	0.069	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.030	0.026	0.023	0.020	0.019
	R-13 (13.0)	0.066	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.028	0.025	0.022	0.020	0.018
	R-15 (15.0)	0.060	0.057	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.027	0.024	0.021	0.019	0.017
	R-19 (18.0)	0.051	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.025	0.022	0.020	0.018	0.017
	R-21 (21.0)	0.046	0.043	0.042	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.023	0.021	0.019	0.017	0.016
7.25 in.	R-25 (25.0)	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.025	0.025	0.024	0.022	0.019	0.018	0.016	0.015
	R-30C (30.0)	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.020	0.018	0.016	0.015	0.014
9.25 in.	R-30 (30.0)	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014
11.25 in.	R-38C (38.0)	0.027	0.026	0.025	0.025	0.024	0.024	0.023	0.022	0.022	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.017	0.016	0.015	0.014	0.013
13.25 in.	R-38 (38.0)	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.017	0.016	0.015	0.014	0.013

A6. SLAB-ON-GRADE FLOORS

A6.1 General. For the purpose of Section A1.2, the base assembly is a slab floor of 6 in. concrete poured directly on to the earth, the bottom of the slab is at grade line, and soil conductivity is 0.75 Btu/h·ft·°F. In contrast to the U-factor for floors, the F-factor for slab-on-grade floors is expressed per linear foot of building perimeter. F-factors are provided for unheated slabs and for heated slabs. Unheated slab-on-grade floors do not have heating elements, and heated slab-on-grade floors do have heating elements within or beneath the slab. F-factors are provided for three insulation configurations:

a. Horizontal Insulation: continuous insulation is applied directly to the underside of the slab and extends inward horizontally from the perimeter for the distance specified or continuous insulation is applied downward from the top of the slab and then extends horizontally to the interior or the exterior from the perimeter for the distance specified.

b. Vertical Insulation: continuous insulation is applied directly to the slab exterior, extending downward from the top of the slab for the distance specified.

c. Fully Insulated Slab: continuous insulation extends downward from the top of the slab and along the entire perimeter and completely covers the entire area under the slab.

A6.2 Rated R-Value of Insulation for Slab-on-Grade Floors

A6.2.1 The rated R-value of insulation shall be installed around the perimeter of the slab-on-grade floor to the distance specified.

Exception: For a monolithic slab-on-grade floor, the insulation shall extend from the top of the slab-on-grade to the bottom of the footing.

A6.2.2 Insulation installed inside the foundation wall shall extend downward from the top of the slab a minimum of the distance specified or to the top of the footing, whichever is less.

A6.2.3 Insulation installed outside the foundation wall shall extend from the top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum of the distance specified. In all climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10 in. thick.

A6.3 F-Factors for Slab-on-Grade Floors

A6.3.1 F-factors for slab-on-grade floors shall be taken from Table A6.3.1.

A6.3.2 These F-factors are acceptable for all slab-on-grade floors.

TABLE A6.3.1 Assembly F-Factors for Slab-on-Grade Floors

Insulation Description	Rated R-Value of Insulation												
	R-0	R-5	R-7.5	R-10	R-15	R-20	R-25	R-30	R-35	R-40	R-45	R-50	R-55
Unheated Slabs													
None	0.73												
12 in. horizontal		0.72	0.71	0.71	0.71								
24 in. horizontal		0.70	0.70	0.70	0.69								
36 in. horizontal		0.68	0.67	0.66	0.66								
48 in. horizontal		0.67	0.65	0.64	0.63								
12 in.vertical		0.61	0.60	0.58	0.57	0.567	0.565	0.564					
24 in. vertical		0.58	0.56	0.54	0.52	0.510	0.505	0.502					
36 in. vertical		0.56	0.53	0.51	0.48	0.472	0.464	0.460					
48 in. vertical		0.54	0.51	0.48	0.45	0.434	0.424	0.419					
Fully insulated slab		0.46	0.41	0.36	0.30	0.261	0.233	0.213	0.198	0.186	0.176	0.168	0.161
Heated Slabs													
None	1.35												
12 in. horizontal		1.31	1.31	1.30	1.30								
24 in. horizontal		1.28	1.27	1.26	1.25								
36 in. horizontal		1.24	1.21	1.20	1.18								
48 in. horizontal		1.20	1.17	1.13	1.11								
12 in. vertical		1.06	1.02	1.00	0.98	0.968	0.964	0.961					
24 in. vertical		0.99	0.95	0.90	0.86	0.843	0.832	0.827					
36 in. vertical		0.95	0.89	0.84	0.79	0.762	0.747	0.740					
48 in. vertical		0.91	0.85	0.78	0.72	0.688	0.671	0.659					
Fully insulated slab		0.74	0.64	0.55	0.44	0.373	0.326	0.296	0.273	0.255	0.239	0.227	0.217

A7. OPAQUE DOORS

All opaque doors with U-factors determined, certified, and labeled in accordance with NFRC 100 shall be assigned those U-factors.

A7.1 Unlabeled Opaque Doors. Unlabeled opaque doors shall be assigned the following U-factors:

a. Uninsulated single-layer metal swinging doors or non-swinging doors, including single-layer uninsulated access hatches and uninsulated smoke vents: 1.45

b. Uninsulated double-layer metal swinging doors or non-swinging doors, including double-layer uninsulated access hatches and uninsulated smoke vents: 0.70

c. Insulated metal swinging doors, including fire-rated doors, insulated access hatches, and insulated smoke vents: 0.50

d. Wood doors, minimum nominal thickness of 1.75 in., including panel doors with minimum panel thickness of 1.125 in., solid core flush doors, and hollow core flush doors: 0.50

e. Any other wood door: 0.60

A8. FENESTRATION

All fenestration with U-factors, SHGC, or visible transmittance determined, certified, and labeled in accordance with NFRC 100, 200, and 300, respectively, shall be assigned those values.

A8.1 Unlabeled Skylights. Unlabeled skylights shall be assigned the U-factors in Table A8.1-1 and are allowed to use the SHGCs and VTs in Table A8.1-2. The metal with thermal break frame category shall not be used unless all frame members have a thermal break equal to or greater than 0.25 in.

A8.2 Unlabeled Vertical Fenestration. Unlabeled vertical fenestration, both operable and fixed, shall be assigned the U-factors, SHGCs, and VTs in Table A8.2.

TABLE A8.1-1 Assembly U-Factors for Unlabeled Skylights

Product Type		Sloped Installation						
		Unlabeled Skylight with Curb (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)				Unlabeled Skylight without Curb (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type							
	Single Glazing							
1	1/8 in. glass	1.98	1.89	1.75	1.47	1.36	1.25	1.25
2	1/4 in. acrylic/polycarb	1.82	1.73	1.60	1.31	1.21	1.10	1.10
3	1/8 in. acrylic/polycarb	1.90	1.81	1.68	1.39	1.29	1.18	1.18
	Double Glazing							
4	1/4 in. airspace	1.31	1.11	1.05	0.84	0.82	0.70	0.66
5	1/2 in. airspace	1.30	1.10	1.04	0.84	0.81	0.69	0.65
6	1/4 in. argon space	1.27	1.07	1.00	0.80	0.77	0.66	0.62
7	1/2 in. argon space	1.27	1.07	1.00	0.80	0.77	0.66	0.62
	Double Glazing, e = 0.60 on surface 2 or 3							
8	1/4 in. airspace	1.27	1.08	1.01	0.81	0.78	0.67	0.63
9	1/2 in. airspace	1.27	1.07	1.00	0.80	0.77	0.66	0.62
10	1/4 in. argon space	1.23	1.03	0.97	0.76	0.74	0.63	0.58
11	1/2 in. argon space	1.23	1.03	0.97	0.76	0.74	0.63	0.58
	Double Glazing, e = 0.40 on surface 2 or 3							
12	1/4 in. airspace	1.25	1.05	0.99	0.78	0.76	0.64	0.60
13	1/2 in. airspace	1.24	1.04	0.98	0.77	0.75	0.64	0.59
14	1/4 in. argon space	1.18	0.99	0.92	0.72	0.70	0.58	0.54
15	1/2 in. argon space	1.20	1.00	0.94	0.74	0.71	0.60	0.56
	Double Glazing, e = 0.20 on surface 2 or 3							
16	1/4 in. airspace	1.20	1.00	0.94	0.74	0.71	0.60	0.56
17	1/2 in. airspace	1.20	1.00	0.94	0.74	0.71	0.60	0.56
18	1/4 in. argon space	1.14	0.94	0.88	0.68	0.65	0.54	0.50
19	1/2 in. argon space	1.15	0.95	0.89	0.68	0.66	0.55	0.51
	Double Glazing, e = 0.10 on surface 2 or 3							
20	1/4 in. airspace	1.18	0.99	0.92	0.72	0.70	0.58	0.54
21	1/2 in. airspace	1.18	0.99	0.92	0.72	0.70	0.58	0.54
22	1/4 in. argon space	1.11	0.91	0.85	0.65	0.63	0.52	0.47
23	1/2 in. argon space	1.13	0.93	0.87	0.67	0.65	0.53	0.49
	Double Glazing, e = 0.05 on surface 2 or 3							
24	1/4 in. airspace	1.17	0.97	0.91	0.70	0.68	0.57	0.52
25	1/2 in. airspace	1.17	0.98	0.91	0.71	0.69	0.58	0.53
26	1/4 in. argon space	1.09	0.89	0.83	0.63	0.61	0.50	0.45
27	1/2 in. argon space	1.11	0.91	0.85	0.65	0.63	0.52	0.47

TABLE A8.1-1 Assembly U-Factors for Unlabeled Skylights *(Continued)*

Product Type		Sloped Installation						
		Unlabeled Skylight with Curb (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)				Unlabeled Skylight without Curb (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type							
	Triple Glazing							
28	1/4 in. airspaces	1.12	0.89	0.84	0.64	0.64	0.53	0.48
29	1/2 in. airspaces	1.10	0.87	0.81	0.61	0.62	0.51	0.45
30	1/4 in. argon spaces	1.09	0.86	0.80	0.60	0.61	0.50	0.44
31	1/2 in. argon spaces	1.07	0.84	0.79	0.59	0.59	0.48	0.42
	Triple Glazing, e = 0.20 on surface 2,3,4, or 5							
32	1/4 in. airspace	1.08	0.85	0.79	0.59	0.60	0.49	0.43
33	1/2 in. airspace	1.05	0.82	0.77	0.57	0.57	0.46	0.41
34	1/4 in. argon space	1.02	0.79	0.74	0.54	0.55	0.44	0.38
35	1/2 in. argon space	1.01	0.78	0.73	0.53	0.54	0.43	0.37
	Triple Glazing, e = 0.20 on surfaces 2 or 3 and 4 or 5							
36	1/4 in. airspace	1.03	0.80	0.75	0.55	0.56	0.45	0.39
37	1/2 in. airspace	1.01	0.78	0.73	0.53	0.54	0.43	0.37
38	1/4 in. argon space	0.99	0.75	0.70	0.50	0.51	0.40	0.35
39	1/2 in. argon space	0.97	0.74	0.69	0.49	0.50	0.39	0.33
	Triple Glazing, e = 0.10 on surfaces 2 or 3 and 4 or 5							
40	1/4 in. airspace	1.01	0.78	0.73	0.53	0.54	0.43	0.37
41	1/2 in. airspace	0.99	0.76	0.71	0.51	0.52	0.41	0.36
42	1/4 in. argon space	0.96	0.73	0.68	0.48	0.49	0.38	0.32
43	1/2 in. argon space	0.95	0.72	0.67	0.47	0.48	0.37	0.31
	Quadruple Glazing, e = 0.10 on surfaces 2 or 3 and 4 or 5							
44	1/4 in. airspace	0.97	0.74	0.69	0.49	0.50	0.39	0.33
45	1/2 in. airspace	0.94	0.71	0.66	0.46	0.47	0.36	0.30
46	1/4 in. argon space	0.93	0.70	0.65	0.45	0.46	0.35	0.30
47	1/2 in. argon space	0.91	0.68	0.63	0.43	0.44	0.33	0.28
48	1/4 in. krypton spaces	0.88	0.65	0.60	0.40	0.42	0.31	0.25

TABLE A8.1-2 Assembly SHGCs and Assembly Visible Transmittances (VTs) for Unlabeled Skylights

Glass Type	Glazing Type: Number of Glazing Layers Number and Emissivity of Coatings (Glazing is Glass Except where Noted)	Unlabeled Skylights (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)					
		Frame:	Metal without Thermal Break		Metal with Thermal Break		Wood/Vinyl/ Fiberglass	
		Characteristic:	SHGC	VT	SHGC	VT	SHGC	VT
Clear	Single glazing, 1/8 in. glass		0.82	0.76	0.78	0.76	0.73	0.73
	Single glazing, 1/4 in. glass		0.78	0.75	0.74	0.75	0.69	0.72
	Single glazing, acrylic/polycarbonate		0.83	0.92	0.83	0.92	0.83	0.92
	Double glazing		0.68	0.66	0.64	0.66	0.59	0.64
	Double glazing, *e* = 0.40 on surface 2 or 3		0.71	0.65	0.67	0.65	0.62	0.63
	Double glazing, *e* = 0.20 on surface 2 or 3		0.66	0.61	0.62	0.61	0.57	0.59
	Double glazing, *e* = 0.10 on surface 2 or 3		0.59	0.63	0.55	0.63	0.51	0.61
	Double glazing, acrylic/polycarbonate		0.77	0.89	0.77	0.89	0.77	0.89
	Triple glazing		0.60	0.59	0.56	0.59	0.52	0.57
	Triple glazing, *e* = 0.40 on surface 2, 3, 4, or 5		0.64	0.60	0.60	0.60	0.56	0.57
	Triple glazing, *e* = 0.20 on surface 2, 3, 4, or 5		0.59	0.55	0.55	0.55	0.51	0.53
	Triple glazing, *e* = 0.10 on surface 2, 3, 4, or 5		0.54	0.56	0.50	0.56	0.46	0.54
	Triple glazing, *e* = 0.40 on surfaces 3 and 5		0.62	0.57	0.58	0.57	0.53	0.55
	Triple glazing, *e* = 0.20 on surfaces 3 and 5		0.56	0.51	0.52	0.51	0.48	0.49
	Triple glazing, *e* = 0.10 on surfaces 3 and 5		0.47	0.54	0.43	0.54	0.40	0.52
	Triple glazing, acrylic/polycarbonate		0.71	0.85	0.71	0.85	0.71	0.85
	Quadruple glazing, *e* = 0.10 on surfaces 3 and 5		0.41	0.48	0.37	0.48	0.33	0.46
	Quadruple glazing, acrylic/polycarbonate		0.65	0.81	0.65	0.81	0.65	0.81
Tinted	Single glazing, 1/8 in. glass		0.70	0.58	0.66	0.58	0.62	0.56
	Single glazing, 1/4 in. glass		0.61	0.45	0.56	0.45	0.52	0.44
	Single glazing, acrylic/polycarbonate		0.46	0.27	0.46	0.27	0.46	0.27
	Double glazing		0.50	0.40	0.46	0.40	0.42	0.39
	Double glazing, *e* = 0.40 on surface 2 or 3		0.59	0.50	0.55	0.50	0.50	0.48
	Double glazing, *e* = 0.20 on surface 2 or 3		0.47	0.37	0.43	0.37	0.39	0.36
	Double glazing, *e* = 0.10 on surface 2 or 3		0.43	0.38	0.39	0.38	0.35	0.37
	Double glazing, acrylic/polycarbonate		0.37	0.25	0.37	0.25	0.37	0.25
	Triple glazing		0.42	0.22	0.37	0.22	0.34	0.21
	Triple glazing, *e* = 0.40 on surface 2, 3, 4, or 5		0.53	0.45	0.49	0.45	0.45	0.44
	Triple glazing, *e* = 0.20 on surface 2, 3, 4, or 5		0.42	0.33	0.38	0.33	0.35	0.32
	Triple glazing, *e* = 0.10 on surface 2, 3, 4, or 5		0.39	0.34	0.35	0.34	0.31	0.33
	Triple glazing, *e* = 0.40 on surfaces 3 and 5		0.51	0.43	0.47	0.43	0.43	0.42
	Triple glazing, *e* = 0.20 on surfaces 3 and 5		0.40	0.31	0.36	0.31	0.32	0.29
	Triple glazing, *e* = 0.10 on surfaces 3 and 5		0.34	0.32	0.30	0.32	0.27	0.31
	Triple glazing, acrylic/polycarbonate		0.30	0.23	0.30	0.23	0.30	0.23
	Quadruple glazing, *e* = 0.10 on surfaces 3 and 5		0.30	0.29	0.26	0.29	0.23	0.28
	Quadruple glazing, acrylic/polycarbonate		0.27	0.25	0.27	0.25	0.27	0.25

TABLE A8.2 Assembly U-Factors, Assembly SHGCs, and Assembly Visible Transmittances (VTs) for Unlabeled Vertical Fenestration

Frame Type	Glazing Type	Unlabeled Vertical Fenestration					
		Clear Glass			Tinted Glass		
		U-Factor	SHGC	VT	U-Factor	SHGC	VT
All frame types	Single glazing	1.25	0.82	0.76	1.25	0.70	0.58
	Glass block	0.60	0.56	0.56	NA	NA	NA
Wood, vinyl, or fiberglass frames	Double glazing	0.60	0.59	0.64	0.60	0.42	0.39
	Triple glazing	0.45	0.52	0.57	0.45	0.34	0.21
Metal and other frame types	Double glazing	0.90	0.68	0.66	0.90	0.50	0.40
	Triple glazing	0.70	0.60	0.59	0.70	0.42	0.22

A9. DETERMINATION OF ALTERNATE ASSEMBLY U-FACTORS, C-FACTORS, F-FACTORS, OR HEAT CAPACITIES

A9.1 General. Component U-factors for other opaque assemblies shall be determined in accordance with Section A9 only if approved by the building official in accordance with Section A1.2. The procedures required for each class of construction are specified in Section A9.2. Testing shall be performed in accordance with Section A9.3. Calculations shall be performed in accordance with Section A9.4.

A9.2 Required Procedures. Two- or three-dimensional finite difference and finite volume computer models shall be an acceptable alternative method to calculating the thermal performance values for all assemblies and constructions listed below. The following procedures shall also be permitted to determine all alternative U-factors, F-factors, and C-factors.

a. Roofs
   1. Roofs with insulation entirely above deck: testing or series calculation method.
   2. Metal building roofs: testing, or for single-layer and double-layer systems, calculation method in Section A9.4.5.
   3. Attic roofs, wood joists: testing or parallel path calculation method.
   4. Attic roofs, steel joists: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2-1 or modified zone calculation method.
   5. Attic roofs, concrete joists: testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
   6. Other attic roofs and other roofs: testing or two-dimensional calculation method.

b. Above-Grade Walls
   1. Mass walls: testing or isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
   2. Metal building walls: testing, or for single-layer and double-layer systems, calculation method in Section A9.4.5.
   3. Steel-framed walls: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2-2 or the modified zone method.
   4. Wood-framed walls: testing or parallel path calculation method.
   5. Other walls: testing or two-dimensional calculation method.

c. Below-Grade Walls
   1. Mass walls: testing or isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
   2. Other walls: testing or two-dimensional calculation method

d. Floors
   1. Mass floors: testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
   2. Steel joist floors: testing or modified zone calculation method.
   3. Wood joist floors: testing or parallel path calculation method or isothermal planes calculation method.
   4. Other floors: testing or two-dimensional calculation method.

e. Slab-on-Grade Floors

   No testing or calculations allowed.

A9.3 Testing Procedures

A9.3.1 Building Material Thermal Properties. If building material R-values or thermal conductivities are determined by testing, one of the following test procedures shall be used:

a. ASTM C177
b. ASTM C518
c. ASTM C1363

For concrete, the oven-dried conductivity shall be multiplied by 1.2 to reflect the moisture content as typically installed.

A9.3.2 Assembly U-Factors. If assembly U-factors are determined by testing, ASTM C1363 test procedures shall be used.

Product samples tested shall be production line material or representative of material as purchased by the consumer or contractor. If the assembly is too large to be tested at one time in its entirety, then either a representative portion shall be tested or different portions shall be tested separately and a weighted average determined. To be representative, the portion tested shall include edges of panels, joints with other panels, typical framing percentages, and thermal bridges.

A9.4 Calculation Procedures and Assumptions. The following procedures and assumptions shall be used for all calculations. R-values for air films, insulation, and building materials shall be taken from Sections A9.4.1 through A9.4.3, respectively. In addition, the appropriate assumptions listed in Sections A2 through A8, including framing factors, shall be used.

A9.4.1 Air Films. Prescribed R-values for air films shall be as follows:

R-Value	Condition
0.17	All exterior surfaces
0.46	All semi-exterior surfaces
0.61	Interior horizontal surfaces, heat flow up
0.92	Interior horizontal surfaces, heat flow down
0.68	Interior vertical surfaces

A9.4.1.1 Exterior surfaces are areas exposed to the wind.

A9.4.1.2 Semi-exterior surfaces are protected surfaces that face attics, crawlspaces, and parking garages with natural or mechanical ventilation.

A9.4.1.3 Interior surfaces are surfaces within enclosed spaces.

TABLE A9.2-1 Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on Center)

Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value	Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value
0.00	1.00	0.00	20.00	0.85	17.00
4.00	0.97	3.88	21.00	0.84	17.64
5.00	0.96	4.80	24.00	0.82	19.68
8.00	0.94	7.52	25.00	0.81	20.25
10.00	0.92	9.20	30.00	0.79	23.70
11.00	0.91	10.01	35.00	0.76	26.60
12.00	0.90	10.80	38.00	0.74	28.12
13.00	0.90	11.70	40.00	0.73	29.20
15.00	0.88	13.20	45.00	0.71	31.95
16.00	0.87	13.92	50.00	0.69	34.50
19.00	0.86	16.34	55.00	0.67	36.85

TABLE A9.2-2 Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity, in.	Actual Depth of Cavity, in.	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on Center	Effective Framing/Cavity R-Value at 24 in. on Center
Empty Cavity, No Insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

A9.4.1.4 The R-value for cavity airspaces shall be taken from Table A9.4.1.4-1 based on the emissivity of the cavity from Table A9.4.1.4-2. No credit shall be given for airspaces in cavities that contain any insulation or are less than 0.5 in. The values for 3.5 in. cavities shall be used for cavities of that width and greater.

A9.4.2 Insulation R-Values. Insulation R-values shall be determined as follows:

a. For insulation that is not compressed, the rated R-value of insulation shall be used.

b. For calculation purposes, the effective R-value for insulation that is uniformly compressed in confined cavities shall be taken from Table A9.4.2.

c. For calculation purposes, the effective R-value for insulation installed in cavities in attic roofs with steel joists shall be taken from Table A9.2-1.

d. For calculation purposes, the effective R-value for insulation installed in cavities in steel-framed walls shall be taken from Table A9.2-2.

A9.4.3 Building Material Thermal Properties. R-values for building materials shall be taken from Table A9.4.3-1. Concrete block R-values shall be calculated using the isothermal planes method or a two-dimensional calculation program, thermal conductivities from Table A9.4.3-2, and dimensions from ASTM C90. The parallel path calculation method is not acceptable.

Exception: R-values for building materials or thermal conductivities determined from testing in accordance with Section A9.3.

A9.4.4 Building Material Heat Capacities. The HC of assemblies shall be calculated using published values for the unit weight and specific heat of all building material components that make up the assembly.

TABLE A9.4.1.4-1 Values for Cavity Air Spaces

Component	Airspace Thickness, in.	R-Value Effective Emissivity				
		0.03	0.05	0.20	0.50	0.82
Roof	0.50	2.13	2.04	1.54	1.04	0.77
	0.75	2.33	2.22	1.64	1.09	0.80
	1.50	2.53	2.41	1.75	1.13	0.82
	3.50	2.83	2.66	1.88	1.19	0.85
Wall	0.50	2.54	2.43	1.75	1.13	0.82
	0.75	3.58	3.32	2.18	1.30	0.90
	1.50	3.92	3.62	2.30	1.34	0.93
	3.50	3.67	3.40	2.21	1.31	0.91
Floor	0.50	2.55	1.28	1.00	0.69	0.53
	0.75	1.44	1.38	1.06	0.73	0.54
	1.50	2.49	2.38	1.76	1.15	0.85
	3.50	3.08	2.90	2.01	1.26	0.90

TABLE A9.4.1.4-2 Emittance Values of Various Surfaces and Effective Emittances of Air Spaces

Surface	Average Emissivity *e*	Effective Emissivity Effective Emissivity of Air Space	
		One Surface *e*; Other, 0.9	Both Surfaces Emissivity *e*
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (>0.7 gr/ft^2)	0.30	0.29	—
Aluminum foil, with condensate clearly visible (>2.9 gr/ft^2)	0.70	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galv., bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

A9.4.5 Metal Building U-Factor Equations. For single-layer metal building roof and wall systems, the calculation procedure outlined in Section A9.4.5.1 shall be used to calculate the assembly U-factor. For double-layer metal building roof and wall systems, the calculation procedure outlined in Section A9.4.5.2 shall be used to calculate the assembly U-factor. The calculation procedures outlined in this section shall not be used for other metal building roof and wall systems.

A9.4.5.1 Single Layer. The U-factor of metal building roofs or walls that are insulated with a single layer of fiberglass insulation (see Figure A9.4.5.1) shall be calculated using the procedure outlined in this section. The procedure assumes the insulation is compressed over the purlin or girt. There may also be a thermal spacer block present.

There are six steps in the calculation process:

Step 1—Characterize the thermal conductivity of the fiberglass,

Step 2—Determine the U-factor for the insulation in the cavity,

Step 3—Determine the U-factor over the structural framing member,

Step 4—Area weight the U-factors calculated in steps 2 and 3,

Step 5—Determine the U-factor from the finite element analysis results,

Step 6—Determine the U-factor for any continuous insulation if present.

TABLE A9.4.2 Effective R-Values for Fiberglass

Insulation R-Value at Standard Thickness									
Rated R-Value		**38**	**30**	**22**	**21**	**19**	**15**	**13**	**11**
Standard Thickness, in.		**12**	**9.5**	**6.5**	**5.5**	**6**	**3.5**	**3.5**	**3.5**
Nominal Lumber Size, in.	**Actual Depth of Cavity, in.**	**Effective Insulation R-Values when Installed in a Confined Cavity**							
2 × 12	11.25	37	—	—	—	—	—	—	—
2 × 10	9.25	32	30	—	—	—	—	—	—
2 ×8	7.25	27	26	22	21	19	—	—	—
2 ×6	5.5	—	21	20	21	18	—	—	—
2 × 4	3.5	—	—	14	—	13	15	13	11
	2.5	—	—	—	—	—	—	9.8	—
	1.5	—	—	—	—	—	—	6.3	6

TABLE A9.4.3-1 R-Values for Building Materials

Material	Nominal Size, in.	Actual Size, in.	R-Value
Carpet and rubber pad	—	–	1.23
Concrete at R-0.0625/in.	—	2	0.13
	—	4	0.25
	—	6	0.38
	—	8	0.5
	—	10	0.63
	—	12	0.75
Flooring, wood subfloor	—	0.75	0.94
Gypsum board	—	0.5	0.45
	—	0.625	0.56
Metal deck	—	—	0
Roofing, built-up	—	0.375	0.33
Sheathing, vegetable fiber board, 0.78 in.	—	0.78	2.06
Soil at R-0.104/in.	—	12	1.25
Steel, mild		1	0.0031807
Stucco	—	0.75	0.08
Wood, 2 × 4 at R-1.25/in.	4	3.5	4.38
Wood, 2 × 4 at R-1.25/in.	6	5.5	6.88
Wood, 2 × 4 at R-1.25/in.	8	7.25	9.06
Wood, 2 × 4 at R-1.25/in.	10	9.25	11.56
Wood, 2 × 4 at R-1.25/in.	12	11.25	14.06
Wood, 2 × 4 at R-1.25/in.	14	13.25	16.56

Step 1—The thermal conductivity of the fiberglass batt insulation is represented by a thermal curve of the form in Equation A9.4-1:

$$k = A + B\rho + \frac{C}{\rho} \quad \text{(A9.4-1)}$$

where

k = thermal conductivity, Btu/h·ft·°F
ρ = density, lb/ft^3
A = 0.014917
B = 0.0004377
C = 0.0056897

Step 2—Assume the fiberglass batt forms a parabolic profile defined by Equation A9.4-2:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{L}\right)\left(2 - \frac{X}{L}\right) = \quad \text{(A9.4-2)}$$

Determine the cavity U-factor (U_c) using Equation A9.4-3:

$$U_c = \frac{C}{\rho_o t_o} + \frac{B\rho_o t_o}{2Y_o Y_m} + \left[A + \frac{B\rho_o t_o}{2Y_m}\right]\frac{1}{2(Y_m - Y_o)}\sqrt{\frac{Y_m - Y_o}{Y_m}}\ln\left(\frac{1 + \frac{Y_m - Y_o}{Y_m}}{1 - \frac{Y_m - Y_o}{Y_m}}\right) \quad \text{(A9.4-3)}$$

where

ρ_o = reference density of the fiberglass, lb/ft^3
t_o = reference thickness of the fiberglass, ft

The properties of fiberglass insulation are presented in Table A9.4.5.1.

TABLE A9.4.3-2 Thermal Conductivity of Concrete Block Material

Concrete Block Density, lb/ft^3	Thermal Conductivity, Btu·in./h·ft^2·°F
80	3.7
85	4.2
90	4.7
95	5.1
100	5.5
105	6.1
110	6.7
115	7.2
120	7.8
125	8.9
130	10.0
135	11.8
140	13.5

TABLE A9.4.5.1 Fiberglass Reference Properties

R-Value, h·ft^2·°F/Btu	Weight, lb/ft^2	Density, lb/ft^3	Thickness, ft
10	0.149	0.605	0.2458
11	0.168	0.630	0.2667
13	0.199	0.628	0.3167
16	0.243	0.634	0.3833
19	0.297	0.653	0.4542
25	0.427	0.742	0.5750
30	0.520	0.766	0.6792

Include the thermal resistances of the interior (R_i) and exterior (R_e) air films to calculate the overall cavity U-factor (U_{co}) using Equation A9.4-4.

$$U_{co} = \frac{1}{\frac{1}{U_c} + R_i + R_e} \qquad \text{(A9.4-4)}$$

Step 3—Determine the U-factor (U_{fo}) over the structural framing member. The variable Y_o represents the total combined thickness of the thermal spacer block and the compressed insulation. The density of the compressed insulation is determined by Equation A9.4-5:

$$\rho_c = \frac{\rho_o t_o}{t_c} \qquad \text{(A9.4-5)}$$

where

ρ_c = density of the compressed insulation over the framing member, lb/ft^3

t_c = thickness of the compressed insulation over the framing member, ft

Determine the thermal resistance of the compressed insulation (R_c) using Equation A9.4-6:

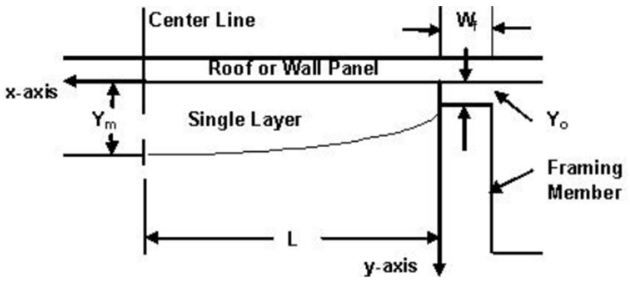


FIGURE A9.4.5.1 Geometry of single-layer fiberglass batt.

where

X = distance from edge of purlin or girt, ft

Y = distance from edge of roof panel or wall panel, ft

L = length from edge of purlin or girt to centerline of cavity, ft

w_f = width of purlin or girt flange, ft

Y_o = distance between purlin or girt and the roof panel or wall panel, ft

Y_m = distance from edge of roof panel or wall panel at the cavity centerline, ft

$$R_c = \frac{t_c}{A + B\rho_c + C/\rho_c} \qquad \text{(A9.4-6)}$$

Determine the overall framing U-factor (U_{fo}) at the structural framing member, including the air film resistances, using Equation A9.4-7:

$$U_{fo} = \frac{1}{R_{TB} + R_c + R_i + R_e} \qquad \text{(A9.4-7)}$$

where

U_{fo} = U-factor over the structural framing member, Btu/h·ft^2·°F

R_{TB} = R-value of the thermal spacer block, h·ft^2·°F/Btu

R_c = R-value of the compressed insulation, h·ft^2·°F/Btu

Step 4—Determine the overall area weighted U-factor for the entire system using Equation A9.4-8:

$$U_{es} = \frac{L \cdot U_{co} + (w_f/2) \cdot U_{fo}}{L + (w_f/2)} \qquad \text{(A9.4-8)}$$

where

U_{es} = area weighted U-factor for the entire system, Btu/h·ft^2·°F

w_f = width of purlin or girt flange, ft

Step 5—Calculate the adjusted overall U-factor (U_{adj}) using Equation A9.4-9:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \qquad \text{(A9.4-9)}$$

where

U_{adj} = adjusted overall U-factor represented by correlation with the finite element modeling, Btu/h·ft^2·°F

Step 6—If there is any continuous insulation present, calculate the overall U-factor using Equation A9.4-10:

$$U = \frac{1}{\frac{1}{U_{adj}} + R_{ci}} \qquad \text{(A9.4-10)}$$

A9.4.5.2 Double Layers. The U-factor of metal building roofs that are insulated with double layers of fiberglass insulation (see Figure A9.4.5.2-1) shall be calculated using the procedure outlined in this section. The procedure assumes the insulation is compressed over the purlin and there may be a thermal spacer block present.

There are six steps in the calculation process:

Step 1—Characterize the thermal conductivity of the fiberglass,

Step 2—Determine the U-factor for the insulation in the cavity,

Step 3—Determine the U-factor over the structural framing member,

Step 4—Area weight the U-factors calculated in steps 2 and 3,

Step 5—Determine the U-factor from the finite element analysis results,

Step 6—Determine the U-factor for any continuous insulation if present.

Step 1—The thermal conductivity of the fiberglass batt insulation is represented by a thermal curve of the form in Equation A9.4-11:

$$k = A + B\rho + \frac{C}{\rho} \qquad \text{(A9.4-11)}$$

where

k = thermal conductivity, Btu/h·ft^2·°F

ρ = density, lb/ft^3

A = 0.014917

B = 0.0004377

C = 0.0056897

Step 2—Assume the double-layer fiberglass batt forms a parabolic profile defined by Equation A9.4-12:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{L}\right)\left(2 - \frac{X}{L}\right) \qquad \text{(A9.4-12)}$$

The presence of two layers of fiberglass adds complexity because each layer has distinct reference properties—see Table A9.4.5.1. As the double layers are compressed, the thickness of each layer needs to be determined by considering that each layer achieves the same compressive force. Instead of having a closed-form analytical solution that predicts the U-factor for the cavity, the double-layer system requires that the parabolic profile be numerically integrated. The compression of the double-layer system is presented in Figure A9.4.5.2-2.

The thickness of the second layer (Y_2) is described by Equation A9.4-13:

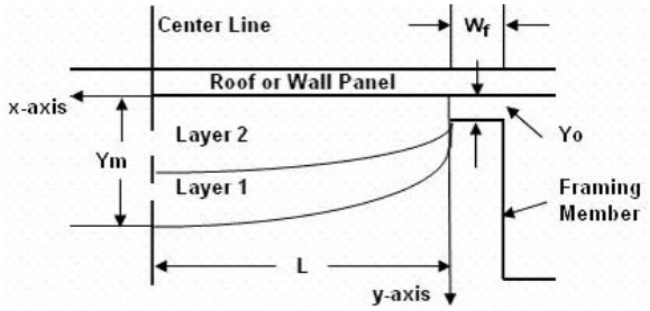


FIGURE A9.4.5.2-1 Geometry of double layers of fiberglass batts.

where

X = distance from edge of purlin or girt, ft

Y = distance from edge of roof panel or wall panel, ft

L = length from edge of purlin or girt to centerline of cavity, ft

w_f = width of purlin or girt flange, ft

Y_o = distance between purlin or girt and the roof panel or wall panel, ft

Y_m = distance from edge of roof panel or wall panel at the cavity centerline, ft

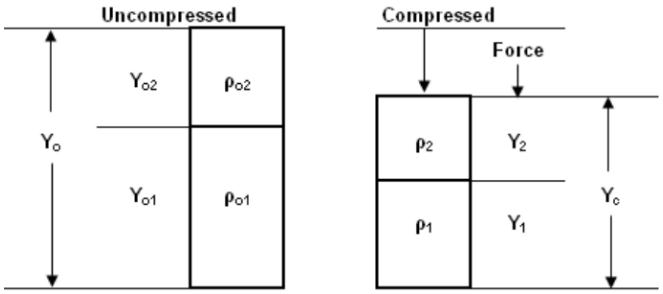


FIGURE A9.4.5.2-2 Compression of double layers of fiberglass insulation.

$$\left(\frac{Y_2}{Y_c}\right)^2 + \left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c/12)} - 1\right]\left(\frac{Y_2}{Y_c}\right) - \frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2) Y_c/12} = 0 \qquad \text{(A9.4-13)}$$

where

Y_c = compressed thickness of the double layers, ft

ρ_{o1} = reference density of first layer, lb/ft^3

ρ_{o2} = reference density of second layer, lb/ft^3

W_1 = reference weight of first layer, lb/ft^2

W_2 = reference weight of second layer, lb/ft^2

The solutions to Equation A9.4-13 are Equation A9.4-14a and A9.4-14b:

$$\frac{Y_{2,a}}{Y_c} = \left|\frac{-b + \sqrt{b^2 - 4ac}}{2a}\right| \qquad \text{(A9.4-14a)}$$

$$\frac{Y_{2,b}}{Y_c} = \left|\frac{-b-\sqrt{b^2-4ac}}{2a}\right| \quad \text{(A9.4-14b)}$$

where

a = 1

b =

$$\left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c/12)} - 1\right]$$

c =

$$\frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2) Y_c/12}$$

Select the smaller value of $Y_{2,a}$ and $Y_{2,b}$ as Y_2. Y_1 shall be calculated as the difference between Y_c and Y_2. Next, the R-values for the two compressed layers of insulation shall be calculated and converted to a U-factor. This process shall be repeated along the entire profile and the results numerically integrated using maximum 0.04167 ft increments.

It is important to note that Equation A9.4-13 does not apply when the two layers of insulation are the same material. In this case, each compressed layer has the same thickness, which simplifies the U-factor calculations. The numerical integration still needs to be completed to determine the U_{co}.

Step 3—Determine the U-factor over the structural framing member. The variable (Y_o) represents the thickness of the thermal spacer block and the thickness of the compressed insulation. The density of the compressed insulation is determined by Equation A9.4-15:

$$\rho_c = \frac{\rho_o t_o}{t_c} \quad \text{(A9.4-15)}$$

where

ρ_c = density of the compressed insulation over the framing member, lb/ft^3

t_c = thickness of the compressed insulation over the framing member, ft

The thermal resistance of the compressed insulation is determined by Equation A9.4-16:

$$R_c = \frac{t_c}{A + B\rho_c + C/\rho_c} \quad \text{(A9.4-16)}$$

Determine the overall framing U-factor (U_{fo}) at the structural framing member including the air film resistances using Equation A9.4-17:

$$U_{f_o} = \frac{1}{R_{TB} + R_c + R_i + R_e} \quad \text{(A9.4-17)}$$

where

U_{fo} = U-factor over the structural framing member, Btu/h·ft^2·°F

R_{TB} = R-value of the thermal spacer block, h·ft^2·°F/Btu

R_c = R-value of the compressed insulation, h·ft^2·°F/Btu

Step 4—Determine the overall area weighted U-factor for the entire system using Equation A9.4-18:

$$U_{es} = \frac{L \cdot U_{co} + (w_f/2) \cdot U_{fo}}{L + (w_f/2)} \quad \text{(A9.4-18)}$$

where

U_{es} = area weighted U-factor for the entire system, Btu/h·ft^2·°F

Step 5—Calculate the adjusted overall U-factor (U_{adj}) using Equation A9.4-19:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \quad \text{(A9.4-19)}$$

where

U_{adj} = adjusted overall U-factor represented by correlation with the finite element modeling, Btu/h·ft^2·°F

Step 6—If there is any continuous insulation present, calculate the overall U-factor using Equation A9.4-20:

$$U_o = \frac{1}{\frac{1}{U_{adj}} + R_c} \quad \text{(A9.4-20)}$$

(Normative Appendix B is adopted in the District of Columbia.)

NORMATIVE APPENDIX B
BUILDING ENVELOPE CLIMATE CRITERIA

B1. GENERAL

This normative appendix provides the information to determine both United States and international climate zones. For US locations, use either Figure B1-1 or Table B1-1 to determine the climate zone number and letter that are required for determining compliance regarding various sections and tables in this standard. Figure B1-1 contains the county-by-county climate zone map for the United States. Table B1-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

Table B1-2 shows the climate zone numbers for a wide variety of Canadian locations. When the climate zone letter is required to determine compliance with this standard, refer to Table B1-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

Table B1-3 shows the climate zone numbers for a wide variety of other international locations besides Canada. When the climate zone letter is required to determine compliance with this standard, refer to Table B1-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

For all international locations that are not listed either in Table B1-2 or B1-3, use Table B1-4 and the Major Climate Type Definitions in Section B2 to determine both the climate zone letter and number.

Informative Note: CDD50 and HDD65 values may be found in Normative Appendix D.

B2. MAJOR CLIMATE TYPE DEFINITIONS

Use the following information along with Table B-4 to determine climate zone numbers and letters for international climate zones.

Marine (C) definition—Locations meeting all four criteria:

1. *Mean temperature* of coldest month between 27°F and 65°F.
2. Warmest month mean <72°F.
3. At least four months with *mean temperatures* over 50°F.
4. Dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Dry (B) definition—Locations meeting the following criteria: not marine and

$$P_{in} < 0.44 \times (TF - 19.5)$$

where

P = annual precipitation, in.

T = annual *mean temperature*, °F

Moist (A) definition—Locations that are not marine and not dry.

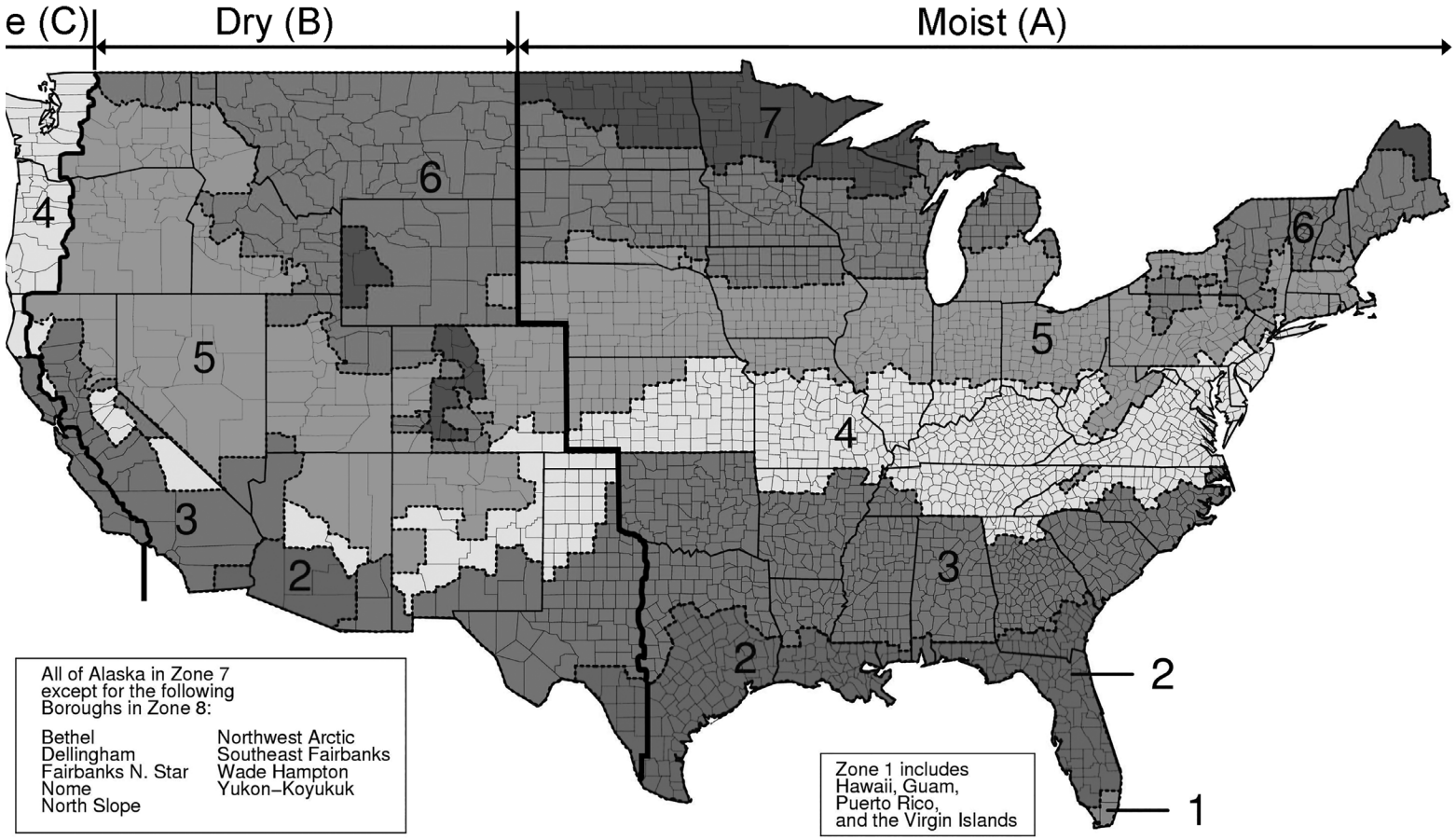


Figure B1-1 U.S. climate zone map *(ASHRAE Transactions,* Briggs et al., 2003).

Table B1-1 U.S. Climate Zones
Key: A—Moist

District of Columbia
4A (all)

(Normative Appendix C is adopted in the District of Columbia.)

NORMATIVE APPENDIX C
METHODOLOGY FOR BUILDING ENVELOPE TRADE-OFF OPTION IN Section 5.6

C1. MINIMUM INFORMATION

The following minimum information shall be specified for the proposed design.

C1.1 At the Building Level. The floor area, broken down by space-conditioning categories and building area type, shall be specified. Each building area type shall be chosen from Table 9.5.1.

C1.2 At the Exterior and Semi-Exterior Surface Level. The building envelope assembly type, gross area, orientation, tilt, and associated space-conditioning category and building area type shall be specified. The surface shall be designated as exterior or semi-exterior. A semi-exterior surface separating a conditioned space from a semi-exterior space shall be specified with two associated space-conditioning categories. A semi-exterior surface separating a conditioned space from an unconditioned space shall be specified with an associated space-conditioning category and with an adjacency to an unconditioned space. Exterior surfaces with the same building envelope assembly type and associated space-conditioning category and building area type whose orientations differ by no more than 22.5 degrees and whose tilts differ by no more than 22.5 degrees are allowed to be described as a single surface.

C1.2.1 For Roofs. The class of construction, opaque area, U-factor, HC, and insulation position shall be specified. Where three-year-aged test data for the solar reflectance and three-year-aged thermal emittance of the exterior roof surface are available, the three-year-aged solar reflectance and three-year-aged thermal emittance shall be specified.

C1.2.2 For Above-Grade Walls. The class of construction, opaque area, U-factor, HC, and insulation position shall be specified.

C1.2.3 For Below-Grade Walls. The opaque area, average depth to the bottom of the wall, C-factor, HC, and insulation position shall be specified.

C1.2.4 For Floors. The class of construction, opaque area, U-factor, HC, and insulation position shall be specified.

C1.2.5 For Slab-on-Grade Floors. The class of construction, perimeter length, F-factor, and HC shall be specified.

C1.2.6 For Uninsulated Assemblies. All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor stabs, concrete floor beams over parking garages, roof parapet) shall be separately modeled.

C1.3 For Opaque Doors. The class of construction, area, and U-factor shall be specified. Each opaque door shall be associated with a surface as defined in Section C1.2 and shall have the orientation of that surface.

C1.4 For Fenestration. The class of construction, area, U-factor, SHGC, VT, and PF shall be specified for fenestration. For skylight wells, the width, depth, and height shall be defined as shown in Figure C1.4. Each fenestration element shall be associated with a surface as defined in Section C1.2 and shall have the orientation of that surface.

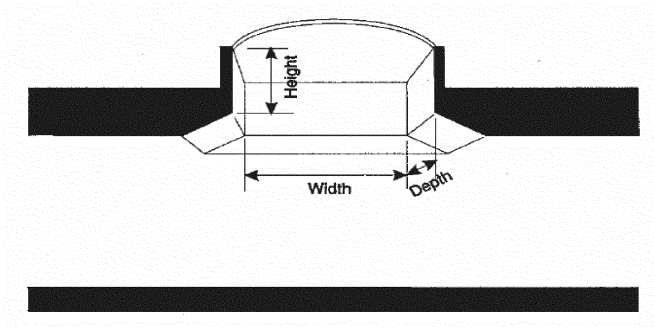


Figure C1.4 Skylight well dimensions.

C2. OUTPUT REQUIREMENTS

Output reports shall contain the following information.

C2.1 Name and contact information of the entity executing the simulation, and date of report.

C2.2 Location of the building, including street address and climate zone.

C2.3 Location corresponding to the weather data used to perform the simulation.

C2.4 Simulation program used to perform the simulation.

C2.5 Tables summarizing the minimum information described in Section C1.

C2.6 All differences between the proposed envelope performance factor and the base envelope performance factor.

C2.7 Total conductive heat gain and conductive heat loss through all opaque classes of construction.

C2.8 Total conductive heat gain, conductive heat loss, and solar heat gain through all fenestration classes of construction.

C3. SIMULATION GENERAL REQUIREMENTS

C3.1 Simulation Program. The simulation program shall be a computer-based program for the analysis of energy consumption in buildings. The simulation program shall include calculation methodologies for the building components being modeled**.**

Informative Note: Simulation programs include, but are not limited to, EnergyPlus and DOE-2.

C3.1.1 The simulation program shall be approved by the adopting authority and shall, at minimum, have the ability to explicitly model all of the following:

a. The base envelope performance factor, using only the input for the proposed envelope performance factor. The calculation procedure shall not allow the user to directly

modify the building component characteristics of the base design.

b. 8760 hours per year.

c. Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays.

d. Thermal mass effects.

e. The number of thermal zones in the proposed building or nine thermal zones, whichever is greater.

f. Air-side economizers with integrated control.

g. Continuous daylight dimming controls and photosensors.

C3.1.2 The simulation program shall have the ability to determine the proposed envelope performance factor and base envelope performance factor by calculating annual energy costs.

C3.1.3 The simulation program shall be capable of performing design load calculations to determine required HVAC equipment capacities and airflow rates in accordance with Section 6.4.2 for both the proposed envelope design and the budget envelope design.

C3.1.4 The simulation program shall be tested according to ASHRAE Standard 140, and the results shall be published by the software provider.

C3.2 Climatic Data. The simulation program shall perform the simulation using hourly values of climatic data, including temperature, humidity, solar radiation, and wind speed and direction from representative climatic data, for the proposed envelope design location. For cities or urban regions for which several climatic data sources are available and for locations for which weather data are not available, the designer shall select available weather data that represent the climate at the construction site. Selected weather data shall be approved by the authority having jurisdiction.

C3.2.1 Surface Exposure. Semi-exterior surfaces separating conditioned spaces from unconditioned spaces shall be simulated as exterior surfaces with no exposure to wind or solar radiation.

C3.3 Purchased Energy Rates. The following rates for purchased energy shall be used to determine the proposed envelope performance factor and the base envelope performance factor:

a. Electricity: 0.1032/kWh

b. Heating: 0.99/therm

Exception: Where approved by the authority having jurisdiction, actual annual rates for purchased energy or state average energy prices published by the Department of Energy's Energy Information Administration shall be permitted. The same rates shall be used for both the proposed envelope performance factor and the base envelope performance factor.

C3.4 Compliance Calculations. The proposed envelope performance factor and base envelope performance factor shall be calculated using the same

a. simulation program,

b. climatic data, and

c. purchased energy rates.

C3.5 Calculation of Proposed Envelope Performance Factor. The simulation model for calculating the proposed envelope performance factor shall be developed in accordance with Sections C3.5.1 through C3.5.7.

C3.5.1 Space Conditioning. All conditioned spaces in the proposed building design shall be simulated as being both heated and cooled, even if no cooling or heating system is being installed. Temperature control setpoints and schedules shall be consistent with those in the building envelope trade-off schedules and loads for the applicable building area type. All semiheated spaces shall be simulated as being heated and not cooled. The heating temperature control setpoint shall be 50°F for all hours.

C3.5.2 Model Geometry and Thermal Zones. The building model shall be divided into thermal zones described as follows:

a. Determine the ratio (R_c) of the floor area to the gross wall area for each unique combination of space-conditioning category and building area type. The index "c" refers to a combination of space-conditioning category and building area type as defined for each surface.

b. Create a perimeter zone for each unique combination of building area type, above-grade-wall orientation, and space-conditioning category. If there is more than one above-grade-wall assembly for a building area type and orientation, each above-grade-wall assembly shall be placed end-to-end in the order it is defined. The area of each perimeter zone shall be the gross wall area of the zone times R_c or 1.25, whichever is smaller.

c. For each unique combination of space-conditioning category and building area type with R_c greater than 1.25, interior zones shall be created and used in the trade-off procedure. The area of the interior zone shall be the total area for the unique combination of space-conditioning category and building area type less the area of the perimeter zones for that combination of space-conditioning category and building area type.

d. Create a below-grade zone for each unique combination of space-conditioning category and building area type associated with below-grade walls. If there is more than one below-grade-wall assembly for a building area type, each below-grade-wall assembly shall be placed end-to-end in the order it is defined. The area of each below-grade zone shall be the gross wall area of the zone times R_c or 1.25, whichever is smaller.

e. The wall height and the height of each thermal zone shall be 15 ft.

f. Roof area and floor area associated with each building area type shall be prorated among all zones of the corresponding building area type in proportion to the zone area of each zone. Roof area and floor area in each zone shall be centered in the horizontal plane of the zone with the same aspect ratio as the horizontal plane of the zone.

g. Slab-on-grade floor perimeter associated with each building area type shall be prorated among perimeter zones of the corresponding building area type in proportion to the area of each zone.

h. Vertical fenestration area shall be assigned to the associated surface as described in Section C1.4. Vertical fenestration shall be centered on the associated surface with the same aspect ratio as the associated surface. Windows with equivalent U-factor, SHGC, and VT that do not include fins may be combined into a single window on the associated surface.

i. Skylight area shall be assigned to the associated surface as described in Section C1.4, prorated among interior zones containing the roof area with which the skylight area is associated, in proportion to the associated roof area. If the total skylight area exceeds the associated roof area in interior zones, the remaining skylight area shall be prorated among perimeter zones containing the roof area with which the skylight area is associated, in proportion to the associated roof area.

j. Each zone shall be modeled as being fully enclosed. Zone boundaries not created as described above shall be modeled as adiabatic interior surfaces.

C3.5.3 Daylight Area and Photosensor Location. Daylight areas and photosensors shall not be modeled in residential zones. In each nonresidential zone, daylight areas and photosensor locations shall be modeled in accordance with the following:

a. For each nonresidential zone associated with vertical fenestration, the daylight area shall be modeled as directly adjacent to the vertical fenestration with a width equal to the width of the vertical fenestration and a depth equal to the head height of the vertical fenestration.

b. In each nonresidential zone associated with skylights, the daylight area under skylights shall be modeled as bounded, in each direction, by the edge of the skylight area plus 10 ft. or the distance to the edge of the zone, whichever is less.

c. For each daylight area associated with vertical fenestration, a photosensor shall be modeled as located at the center of the width of the daylight area, at the depth of the daylight area and at a height of 3 ft.

d. For each daylight area associated with a skylight, a photosensor shall be modeled as located at the center of the horizontal plane of the skylight and at a height of 5 ft.

C3.5.4 Schedules. The schedule types listed in Section C3.1.1(c) shall be required input. The schedules shall be consistent with those in the building envelope trade-off schedules and loads[1] for the applicable building area type.

C3.5.5 Building Envelope. The building envelope shall reflect the information specified in Section C1.

Exception: Where three-year-aged test data for the solar reflectance and three-year-aged thermal emittance of the exterior roof surface are unavailable, the exterior roof surface shall be modeled with a solar reflectance of 0.30 and a thermal emittance of 0.90.

C3.5.5.1 Shading. Manually operated interior shades shall be modeled on all vertical fenestration. Shades shall be modeled to be lowered when the transmitted luminous intensity is greater than 2000 cd/m^2 or the direct solar transmitted energy exceeds 30 Btu/h·ft^2 and then remain lowered for rest of the day. Shades shall be modeled with visible light transmittance of 0.10, visible light reflectance of 0.40, solar transmittance of 0.21, and solar reflectance of 0.23. Permanent shading devices such as fins and overhangs shall be modeled.

C3.5.5.2 Dynamic Glazing. Automatically controlled dynamic glazing is allowed to be modeled. Manually controlled dynamic glazing shall use the average of the minimum and maximum values for both SHGC and VT.

C3.5.5.3 Infiltration. The peak infiltration rate of the building envelope (I_{75Pa}) at a fixed building pressure differential of 0.3 in. H_2O shall be 0.4 cfm/ft^2 exterior building enclosure area. The peak infiltration rate of the building envelope shall be converted to the appropriate units to describe the peak infiltration as a function of exterior wall area as follows:

$$I_{EW} = 0.112 \times I_{75Pa} \times S/A_{EW}$$

where

I_{75Pa} = air leakage rate of the building envelope expressed in cfm/ft^2 at a fixed building pressure differential of 0.3 in. wc, or 1.57 psf.

S = the total area of the envelope air pressure boundary, including the lowest floor, any below-grade walls, above-grade walls, and roof (or ceiling) (including windows and skylights), separating the interior conditioned space from the unconditioned environment measured in square feet (square meters),

I_{EW} = adjusted air leakage rate of the building envelope at a reference wind speed of 10 mph and the above-ground exterior wall area.

A_{EW} = the total above-grade exterior wall area, ft^2

Exception: If the simulation program cannot simulate infiltration as a function of exterior wall area, the peak infiltration of the building envelope shall be

1. Schedules and internal loads by building area type are located at http://sspc901.ashraepcs.org/content.html.

converted to the appropriate units to describe the peak infiltration as a function of floor area as follows:

$$I_{FLR} = 0.112 \times I_{75Pa} \times S/A_{FLR}$$

where

I_{FLR} = adjusted air leakage rate of the building envelope at a reference wind speed of 10 mph and the above-ground exterior wall area.

A_{FLR} = the total gross floor area, ft^2

C3.5.5.3.1 Infiltration Schedule. Infiltration shall be adjusted in accordance with the infiltration schedule in the building envelope trade-off schedules and loads for the applicable building area type.

C3.5.6 Interior Surfaces. Interior surfaces shall be modeled with visible light reflectances of 0.80 for ceilings, 0.50 for walls, and 0.20 for floors. Interior surfaces shall be modeled with a thermal emittance of 0.90.

C3.5.7 Lighting. Lighting power shall be determined using the lighting power density in Table 9.5.1 for the applicable building area type. Lighting power shall be adjusted in accordance with the lighting schedule in the building envelope trade-off schedules and loads for the applicable building area type. Fifty percent (50%) of lighting in daylight areas shall be modeled with continuous daylight dimming controls such that when sufficient daylight is available at the corresponding photosensor, lighting power is reduced to maintain a minimum 50 fc for conditioned spaces and 30 fc for semiheated spaces. The minimum light output for the continuous daylight dimming shall be 6% of peak light output. Power input shall be modeled as 20% of lighting power density at the minimum light output and scaled linearly to 100% of lighting power density at peak light output.

C3.5.8 HVAC Systems. One HVAC system shall be provided for each thermal zone and shall have the following characteristics:

a. Constant-volume fan control

b. Electrically-provided cooling with constant COP equal to the minimum IEER allowed for air-cooled air conditioners of "All Other" heating section type with ≥65,000 Btu/h and <135,000 Btu/h capacity, in accordance with Table 6.8.1-1, divided by 3.412.

c. Gas furnace with constant thermal efficiency equal to the minimum AFUE allowed for gas-fired warm-air furnaces with maximum capacity <225,000 Btu/h, in accordance with Table 6.8.1-5.

d. The ventilation rate for each building area type shall be consistent with the ventilation rate in the building envelope trade-off schedules and loads for the applicable building area type.

e. Outdoor air economizers, except in Climate Zone 1. The high-limit shutoff shall be "Fixed Dry Bulb" type as described in Table 6.5.1.1.3.

f. System design supply air rates shall be based on a supply-air-to-room-air temperature difference of 20°F.

g. System capacities used in the annual simulation shall be 1.5 times the capacities determined by the sizing simulations.

h. Fans shall cycle on whenever the space calls for heating or cooling. The fan energy shall be included in the energy efficiency rating of the equipment, and the fan energy shall not be modeled explicitly.

C3.5.9 Miscellaneous Loads. Miscellaneous loads shall be modeled as included in the building envelope trade-off schedules and loads for the applicable building area type.

C3.5.10 Occupant Density. The occupant density shall be modeled according to the peak occupant density and the occupancy rate schedule in the building envelope trade-off schedules and loads for the applicable building area type.

C3.5.11 Heat Gain from Occupants. The sensible and latent heat gain due to occupants shall be modeled as included in the building envelope trade-off schedules and loads for the applicable building area type.

C3.6 Calculation of Base Envelope Performance Factor. The simulation model for calculating the base envelope performance factor shall modify the simulation model for calculating the proposed envelope performance factor as follows:

a. All opaque assemblies shall be modeled with the maximum U-factor required in Section 5.5.3 for the appropriate class of construction, space-conditioning category, and climate zone. Mass walls and mass floors shall be modeled with HC equal to 7.2 $Btu/ft^2 \cdot °F$. All other opaque assemblies shall be modeled with the same HC as the proposed building design. Mass walls shall be modeled with equal mass on each side of the insulation. All other opaque assemblies shall be modeled with insulation on the exterior.

b. The exterior roof surfaces shall be modeled with a solar reflectance and thermal emittance as required in Section 5.5.3.1.1(a). All other roofs, including roofs exempted from the requirements in Section 5.5.3.1.1, shall be modeled the same as in the proposed design.

c. Fenestration shall be assumed to be flush with the exterior wall or roof. If the fenestration area for new buildings or additions exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. If the fenestration area facing west or east of the proposed building exceeds the area limit set in Section 5.5.4.5, the baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, and 270 degrees, then averaging the results of the four simulations. Fenestration U-factor and SHGC shall be the maximum allowed for the appropriate class of construction, space-conditioning category, and climate zone in

accordance with Section 5.5.4. Where there is no SHGC requirement, the SHGC shall be equal to 0.40 for all vertical fenestration, and 0.55 for skylights. The VT for fenestration in the base envelope design shall be equal to 1.10 times the SHGC.

d. Manually operated interior shades shall be modeled on all vertical fenestration as described in Section C3.5.5.1. Permanent shading devices, such as fins and overhangs, shall not be modeled.

e. Daylight areas and photosensor locations shall be modeled as described in Section C3.5.3 after reducing the fenestration area as described in Section C3.6(c).

(Normative Appendix D is adopted in the District of Columbia.)

NORMATIVE APPENDIX D
CLIMATIC DATA

This normative appendix contains the climatic data necessary to determine building envelope and mechanical requirements for various U.S., Canadian, and international locations. (See Section 5.1.4 for additional information regarding the selection of climatic data.)

TABLE D-1 U.S. and U.S. Territory Climatic Data

State/City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$55 < T_{db} < 69$
District of Columbia (DC)									
R. Reagan Nat'l Airport	38.85 N	77.03 W	66	4047	4391	15	92	76	657

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX E
INFORMATIVE REFERENCES

This appendix contains informative references for the convenience of users of Standard 90.1 and to acknowledge source documents when appropriate. Some documents are also included in Section 12, "Normative References," because there are other citations of those documents within the standard that are normative.

Address/Contact Information

AABC
Associated Air Balance Council
1518 K Street Northwest, Suite 503
Washington, DC 20005
aabchg@aol.com

BLAST
Building Systems Laboratory
University of Illinois
1206 West Green Street
Urbana, IL 61801
www.bso.uiuc.edu/BLAST/index.html

DOE-2
Building Energy Simulation news
http://simulationresearch.lbl.gov/un.html

MICA
Midwest Insulation Contractors Association
16712 Elm Circle
Omaha, NE 68130
www.micainsulation.org

The Green Grid Administration
3855 SW 153rd Drive
Beaverton, Oregon 97006 USA
(T) 503-619-0653
(F) 503-644-6708

IWEC Data
ASHRAE
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
(T) 404-636-8400
(F) 404-321-5478
www.ashrae.org/bookstore

NEBB
National Environmental Balancing Bureau
8575 Grovemont Circle
Gaithersburg, MD 20877
www.nebb.org

SMACNA
Sheet Metal & Air Conditioning Contractors' National Association
4201 Lafayette Center Drive
Chantilly, VA 20151
info@smacna.org
www.smacna.org

TMY2 Data
National Renewable Energy Laboratory
NREL/RReDC
Attn: Pamela Gray-Hann
1617 Cole Blvd., MS-1612
Golden, Colorado, USA 80401
http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

WYEC2 Data
ASHRAE
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
(T) 404-636-8400
(F) 404-321-5478
www.ashrae.org/bookstore

Subsection No.	Reference	Title/Source
3.2 Computer Room Energy	Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011	The Green Grid
3.2 IT Equipment Energy	Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011	The Green Grid
3.2 Power Usage Effectiveness	Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011	The Green Grid
6.4.2	*2013 ASHRAE Handbook—Fundamentals*	ASHRAE
6.4.4.1.1	MICA Insulation Standards—7th Edition	National Commercial and Industrial Insulation Standards
6.4.4.2.1	SMACNA Duct Construction Standards—2005	HVAC Duct Construction Standards, Metal and Flexible
6.4.4.2.2	SMACNA Duct Leakage Test Procedures—2012	HVAC Air Duct Leakage Test Manual Sections 3, 5, and 6
6.8.2.3.1	NEBB Procedural Standards—2013	Procedural Standards for Building Systems Commissioning
6.8.2.3.1	AABC 2002	Associated Air Balance Council, National Standards for Total System Balance
6.8.2.3.1	ASHRAE Standard 111-2008	Measurement, Testing, Adjusting and Balancing of Building HVAC Systems
6.8.2.2	ASHRAE Guideline 4-2008 (RA2013)	Preparation of Operating and Maintenance Documentation for Building Systems
6.8.2.4	ASHRAE Guideline 1.1-2007	HVAC&R Technical Requirements for the Commissioning Process
7.4.1 and 7.5	*2011 ASHRAE Handbook—HVAC Applications*	Chapter 49, Service Water Heating/ASHRAE
11.2.1	DOE-2	Support provided by Lawrence Berkeley National Laboratory at the referenced Web site
11.2.1	BLAST	University of Illinois
11.2.2	IWEC	International Weather for Energy Calculations
11.2.2	TMY 2 Data	Typical Meteorological Year
Appendix B	U.S. Climate Zone Map	Briggs, R.S., R.G. Lucas, and Z.T. Taylor. 2003. Climate classification for building energy codes and standards: Part 1-Development process. ASHRAE Transactions 109(1):109-21.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX F
ADDENDA DESCRIPTION INFORMATION

ANSI/ASHRAE/IES Standard 90.1-2013 incorporates all addenda to ANSI/ASHRAE/IES Standard 90.1-2010. The following table lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE, IES, and ANSI approval dates for each addendum.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
bb (formerly Addendum bb to 90.1-2007)	5. Building Envelope; Appendix A	This addenda modifies the building envelope requirements for opaque assemblies and fenestration in tables 5.5.1 through 5.5.8 and the associated text in section 5.5.4.5. It also updates the NFRC 301 reference and modifies two metal building roof assemblies in Table A2.3.	3/23/2012	4/4/2012	3/23/2012	5/11/2012
bz (formerly Addendum bz to 90.1-2007)	6. Heating, Ventilating, and Air Conditioning	This addendum adds a Section 8.4.2 which specifies requirements for installation of basic electrical metering of major end uses (total electrical energy, HVAC Systems, interior lighting, exterior lighting and receptacle circuits) to provide basic reporting of energy consumption data to building occupant.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
cg (formerly Addendum cg to 90.1-2007)	11. Energy Cost Budget; Appendix G	This addenda modifies the simulation requirements for modeling mandatory automatic daylighting controls as well as automatic lighting controls. It also modifies the simulation requirements for automatic lighting controls in the proposed design, beyond the minimum mandatory requirements. Table G3.2 which provided power adjustment percentages for automatic lighting controls has been deleted and savings through automatic control devices are now required to be modeled in building simulation through schedule adjustments for the proposed design.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
ci (formerly Addendum ci to 90.1-2007)	3. Definitions; 11. Energy Cost Budget; Appendix G	This addenda modifies requirements for the cooling tower in Chapter 11, from two-speed to variable speed. A formula has been specified to calculate the condenser water design supply temperature. Similar revisions have been made to Appendix G for the cooling tower requirements. Definitions for cooling design wet-bulb temperature and heating design wet-bulb temperature have been added to Chapter 3.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
cj (formerly Addendum cj to 90.1-2007)	Appendix G	Creates modeling rules for computer rooms in Appendix G	6/26/2012	6/26/2013	6/28/2013	7/24/2013

*These descriptions may not be complete and are provided for information only.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
cm (formerly Addendum cm to 90.1-2007)	5. Building Envelope	The proposed text clarifies how to interpret the use of dynamic glazing products given the requirements in Addendum bb (envelope requirements).	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dm (previously from 2007)	5. Building Envelope	This addenda modifies section 5.4.3.4. for vestibules. It adds a size limit for large buildings, exemptions for semi heated spaces and elevator lobbies in parking garages	1/26/2013	1/29/2013	2/11/2013	2/12/2013
ds (formerly Addendum ds to 90.1-2007)	5. Building Envelope	This addendum corrects the definitions of primary sidelighted area, secondary sidelighted area, and sidelighting effective area to use the term “vertical fenestration” instead of “window” to clarify that glazed doors and other fenestration products are included as well as windows. Additionally, the definition of daylight area under rooftop monitors is corrected to include the spread of light beyond the width of the rooftop monitor glazing.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
a	10. Other Equipment; 12. Normative References	This addendum specifies that nominal efficiencies for motors are required to be established in accordance with DOE 10 CFR 431 instead of NEMA Standards. It modifies the footnotes to Tables 10.8A, 10.8B, 10.8 C.The corresponding reference for 10 CFR 431 has also been added.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
b	10. Other Equipment 12. Normative References	This addendum requires escalators and moving walks to automatically slow when not conveying passengers. The corresponding reference to ASME A17.1/CSA B44 has also been added to the Normative References.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
c	Appendix G	This addendum adds requirements for laboratory exhaust fans to section G3.1.1, Baseline HVAC System Type and Definition. Lab exhaust fans are required to be modeled as constant horsepower, reflecting constant volume stack discharge with outside air bypass.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
e	Appendix G	This addendum updates language in Section G3.1, part 5 'Building Envelope', to require that existing buildings use the same envelope baseline as new buildings with the exception of fenestration area.	6/27/2012	6/27/2012	6/18/2012	7/26/2012
f	Appendix G	This addendum modifies Section G.3.1, Building Envelope. It specifies the vertical fenestration area for calculating baseline building performance for new buildings and additions.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
g	6. Heating, Ventilating, and Air Conditioning; 12. Normative References	This addendum adds efficiency requirements for commercial refrigerators, freezers and refrigeration equipment. Table 6.8.1L and Table 6.8.1M have been added which specify the energy use limits for refrigerators and freezers. The corresponding references have also been added in Chapter 12.	6/25/2011	6/29/2011	6/30/2011	6/30/2011

*These descriptions may not be complete and are provided for information only.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
h	6. Heating, Ventilating, and Air Conditioning	This addendum modifies the minimum efficiency standards for water to air heat pumps (water loop, ground water and ground loop). The proposed cooling EERs and heating COPs are more stringent than the present values. This addendum also removes the small duct high velocity product class from Table 6.8.1B.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
i	6. Heating, Ventilating, and Air Conditioning	This addendum increases the minimum efficiency standards for SPVAC and SPVHP. It also creates a new product class for SPVAC and SPVHP used in space constrained applications. This new product class only applies to non-weatherized products with cooling capacities <36,000 Btu/h and intended to replace an existing AC.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
j	6. Heating, Ventilating, and Air Conditioning	This addendum modifies notes to Table 8.1 and specifies that nominal efficiencies would be established in accordance with the 10 CFR 431 test procedure for low voltage dry-type transformers. The corresponding references have also been added in Chapter 12.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
k	8. Power; 12. Normative References	This addendum modifies notes to Table 8.1 and specifies that nominal efficiencies would be established in accordance with the 10 CFR 431 test procedure for low voltage dry-type transformers. The corresponding references have also been added in Chapter 12.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
l	6. Heating, Ventilating, and Air Conditioning	This addendum fixes the mistake with 90.1-2010 fan power limitations which required the user to perform calculations for fan bhp even if the simplified nameplate hp option was being used.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
m	9. Lighting	This addendum adds some control requirements for lighting alterations, for interior and exterior applications. It adds a section for submittals and includes loading docks as a tradable surface. It modifies the provisions for additional interior lighting power, which would now be calculated on the basis of controlled wattage.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
n	10. Other Equipment	This addendum clarifies that the total lumens/watt for the entire elevator cab is required to meet the efficiency requirement and it is not required for each individual light source.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
o	5. Building Envelope; 3. Definitions	This addendum adds the definition for sectional garage doors. It also modifies Section 5.4.3.2 (d), fenestration air leakage provisions for doors, to include requirements for glazed sectional garage doors.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
p	5. Building Envelope; 12. Normative References	This addendum modifies Section 5.5.3.1 and requires roof solar reflectance and thermal emittance testing to be in accordance with CRRC-1 Standard. It also modifies Section 12 by adding the reference for CRRC.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
q	5. Building Envelope; 3. Definitions; 12. Normative References	This addendum modifies Section 5.8.2.2, by clarifying the requirements for labeling of fenestration and door products. The corresponding references to NFRC in Chapter 12 have also been updated.	6/27/2012	6/27/2012	6/18/2012	6/28/2012

*These descriptions may not be complete and are provided for information only.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
r	12. Normative References; Appendix G	This addendum clarifies the requirements related to temperature and humidity control in Appendix G and relocates all related wording to the Schedules section of Table3.1. Additionally, clarity is provided for modeling systems that provide occupant thermal comfort via means other than other than directly controlling the air dry bulb and wet-bulb temperature (i.e. radiant cooling/heating, elevated air speed, etc.). It permits the use of ASHRAE Standard 55 for calculation of PMV-PPD. This addendum also updates the Normative References by including a reference to ASHRAE Standard 55-2010.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
s	6. Heating, Ventilating, and Air Conditioning	This addendum modifies the requirement for the static pressure sensor location and the control requirements for set point reset for systems with DDC of individual zones. Insures that savings from previously required static pressure reset will be realized.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
u	6. Heating, Ventilating, and Air Conditioning	This addendum adds new definition as Fan Efficiency Grade (FEG) and requires each fan has a FEG of 67 or higher as defined by AMCA205-10 (Energy Efficiency Classification for Fans)	1/26/2013	1/29/2013	2/11/2013	2/12/2013
v	8. Power	This addendum clarifies the requirement for controlled receptacles in open offices. It also requires the automatically controlled receptacles to be appropriately identified for the users benefit.	1/26/2013	1/29/2013	2/11/2013	2/28/2013
w	3. Definitions; 11. Energy Cost Budget Method; Appendix G	This addendum adds definitions for on-site renewable energy and purchased energy. It clarifies the process for accounting for on-site renewable energy and purchased energy as well as calculating the annual energy costs in the ECB approach and Appendix G.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
y	3. Definitions 10. Other Equipment	This addendum revises the definitions of general purpose electric motors (subtype I &II) based on information from NEMA. It also updates the standard to include the new federal energy efficiency standards used in HVAC equipment, to be in effect from 2015. It adds Table 10.8D which specifies minimum average full-load efficiency for Polyphase Small Electric Motors; and Table 10.8E which specifies minimum average full-load efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run Small Electric Motors.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
z	6. Heating, Ventilating, and Air Conditioning	This addendum relocates the requirements for water economizers into the main economizer section, Section 6.5.1.5.	1/21/2012	1/23/2012	1/18/2012	1/26/2012

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
aa	6. Heating, Ventilating, and Air Conditioning	Prior to this addendum certain controls requirements were only required when the controls were provided by a DDC system. This addendum eliminates that contingency for set point overlap restrictions, humidification and dehumidification controls, VAV fan control set point reset, multiple-zone VAV system ventilation optimization control, hydronic system design and control, and instead specifies how the system must perform. This will in effect require DDC for systems where these controls are needed.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
ad	12. Normative References	Adds reference to specific addenda to AHRI standards 340/360 and 130 being referenced	6/27/2012	6/27/2012	6/18/2012	6/28/2012
ae	12. Normative References	Adds reference to specific addenda to AHRI standards 210/240 and 550/590 being referenced	7/26/2013	7/30/2013	7/29/2013	8/28/2013
af	6. Heating, Ventilating, and Air Conditioning	Modifies heat rejection equipment (cooling tower) requirements to require VSDs on fans, operate all fans at the same speed instead of sequencing them, and require that systems with multiple condenser water pumps operate those pumps in parallel at reduced flow.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
ag	Appendix G	Establishes a method for gaining credit in Appendix G for buildings that undergo whole building air leakage testing to demonstrate that they have an air-tight building.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ah	Appendix G	Sets system sizing requirements in appendix G for humid climates based on humidity ratio instead of SA delta T. Sets baseline system dehumidification requirements.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
ai	Appendix G	Modifies Appendix G to account for 3 prescriptive addenda that were incorporated in to standard 90.1-2010, but did not make it into Appendix G in time for publication. Updates economizer requirements to match addendum cy, establishes baseline transformer efficiency requirements to match addendum o, and establishes path A for centrifugal chiller baselines from addendum m.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
aj	6. Heating, Ventilating, and Air Conditioning	Requires fractional horsepower motors >= 1/22 hp to EC motors or minimum 70% efficient in accordance with DOE 10 CFR 431. Also requires adjustable speed or other method to balance airflow.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
al	Appendix G	Establishes a consistent fuel source for space heating for baseline systems based on climate zone. Establishes a consistent fuel source for service water heating based on building type.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
am	6. Heating, Ventilating, and Air Conditioning	Establishes minimum turndown for boilers and boiler plants with of at least 1,000,000 Btu/h.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
an	Appendix C	Rewrites entire Appendix C to use a simulation based approach for envelope trade-offs.	7/26/2013	7/30/2013	7/29/2013	8/28/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
ap	6. Heating, Ventilating, and Air Conditioning	Adds Power Utilization Effectiveness (PUE) as an alternative compliance methodology for data centers.	1/26/2013	1/29/2013	2/11/2013	5/3/2013
aq	6. Heating, Ventilating, and Air Conditioning; 11. Energy Cost Budget	This addendum makes changes to the requirements for fan control for both constant volume and VAV units including extending the fan part load power requirements down to ¼ HP In addition it defines the requirements for integrated economizer control and defines DX unit capacity staging requirements	6/26/2013	6/26/2013	6/28/2013	7/1/2013
ar	6. Heating, Ventilating, and Air Conditioning	Adds mandatory and prescriptive requirements for walk-in coolers and freezers and refrigerated display cases.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
as	6. Heating, Ventilating, and Air Conditioning	Avoidance of simultaneous heating and cooling at AHU. Requires humidifiers mounted in the airstream to have an automatic control valve shutting off preheat when humidification is not required, and insulation on the humidification system dispersion tube surface.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
at	3. Definitions; 5. Building Envelope; 9. Lighting	Deletes the term clerestory and instead adds roof monitor and clarifies the definition. Changes the references in Chapters 5 and 9 from clerestory to roof monitor.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
au	6. Heating, Ventilating, and Air Conditioning	This addendum modifies Table 6.5.3.1.1B which addresses fan power limitation pressure drop adjustment credits. Deductions are added for systems without any central heating or cooling as well as systems with electric resistance heating. Sound attenuation credit is modified to be available only when there are background noise criteria requirements.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
av	6. Heating, Ventilating, and Air Conditioning	This addendum modifies Section 6.5.1, exception k, applicable to Tier IV data centers, in an attempt to make economizer exceptions more strict and in agreement with ASHRAE TC 9.9	6/26/2013	6/26/2013	6/28/2013	7/24/2013
aw	11. Energy Cost Budget; Appendix G	This addendum updates the reference year for ASHRAE Standard 140 and exempts software used for ECB and Appendix G compliance from having to meet certain sections of ASHRAE Standard 140	1/26/2013	1/29/2013	2/11/2013	2/12/2013
ax	Appendix G	Table G3.1 Part 14 of Appendix G is modified to exclude the condition which permits a building surface, shaded by an adjacent structure, to be simulated as north facing if the simulation program is incapable of simulating shading by adjacent structures.	6/26/2013	6/26/2013	6/28/2013	7/1/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
ay	3. Definitions; 9. Lighting	This addenda modifies daylighting requirements. It modifies definitions for daylight area under skylights, daylight area under roof monitors, primary sidelight area, secondary sidelight area. It modifies the thresholds for applying automatic daylighting control for sidelighting and toplighting, to a wattage basis and provides characteristics for the required photo controls. It modifies Table 9.6.2 to include continuous dimming in secondary sidelighted areas, which is now based on a W level rather than area of the space. It eliminates the need for effective aperture calculation.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
az	6. Heating, Ventilating, and Air Conditioning	This addendum increases the minimum efficiency of open circuit axial fan cooling towers. An additional requirement has been added which states that the minimum efficiency requirements for all types of cooling towers also applies to accessories which affect the thermal performance of the unit. An additional footnote clarifies that the certification requirements do not apply to field erected cooling towers.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
ba	6. Heating, Ventilating, and Air Conditioning	Adds requirements for door switches to disable or reset mechanical heating or cooling when doors are left open.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
bc	9. Lighting	Modifies requirements for automatic lighting control for guestroom type spaces. Exception to this requirement are lighting and switched receptacles controlled by captive key systems.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
bd	9. Lighting	This addenda adds more specific requirements for the functional testing of lighting controls, specifically, occupancy sensors, automatic time switches and daylight controls.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
be	9. Lighting	Minor revisions to Section 9.7.2.2, which addresses the scope of the operating and maintenance manuals required for lighting equipment and controls.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
bf	8. Power	This addenda addresses Section 8.4.2 on automatic receptacle control and increases the spaces where plug shutoff control is required. It also clarifies the application of this requirement for furniture systems, states a labeling requirement to distinguish controlled and uncontrolled receptacles and restricts the use of plug-in devices to comply with this requirement.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
bg	5. Building Envelope	Requirements for low E storm window retrofits.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bh	9. Lighting	Modifies Table 9.6.1 Space-By-Space Lighting Power Density allowance	7/26/2013	7/30/2013	8/12/2013	9/4/2013
bi	6. Heating, Ventilating, and Air Conditioning	Increase SEER and HSPF for air-cooled commercial air conditioners and heat pumps below 65,000 Btu/h. Effective 1/1/2015	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bj	6. Heating, Ventilating, and Air Conditioning	Re-establishes the product class for Small Duct High Velocity (SDHV) air conditioners and heart pumps. Adds efficiency requirements for systems at <65.000 Btuh	6/26/2013	6/26/2013	6/28/2013	7/1/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
bk	6. Heating, Ventilating, and Air Conditioning	Increases cooling efficiency for PTACs	1/26/2013	1/29/2013	2/11/2013	2/12/2013
bl	11. Energy Cost Budget; Appendix G	Provide rules for removing fan energy from efficiency metrics when modeling in ECB or Appendix G.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
bn	8. Power; 10. Other Equipment	Establishes electric and fuel metering requirements	7/26/2013	7/30/2013	7/29/2013	9/4/2013
bo	6. Heating, Ventilating, and Air Conditioning	Requires buildings with SW capacity >= 1million but/h to have average efficiency of at least 90%. Updates Table 7.8 to reflect federal requirements for electric water heaters. Updates the reference standard for swimming pool water heaters to ASHRAE Standard 146.	7/26/2013	7/30/2013	7/29/2013	9/4/2013
bp	6. Heating, Ventilating, and Air Conditioning	Adds efficiency requirements (Btu/h-hp) to Table 6.8.1G for evaporative condensers with ammonia refrigerants	7/26/2013	7/30/2013	7/29/2013	7/31/2013
bq	6. Heating, Ventilating, and Air Conditioning	Improve efficiency of commercial refrigeration systems	1/26/2013	1/29/2013	2/11/2013	2/12/2013
br	10. Other Equipment	Updates motor efficiency tables	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bs	6. Heating, Ventilating, and Air Conditioning	Reduce occupancy threshold for demand controlled ventilation from greater than 40 people per 1000 ft^2 to equal to or greater than 25 people per 1000 ft^2 with exemptions for certain occupancies.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
bt	6. Heating, Ventilating, and Air Conditioning	Reduces the threshold at which energy recovery is required. Relaxed in some climate zones.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
bv	9. Lighting	Reduces the threshold at which skylights and daylighting controls are required for high bay spaces.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bw	5. Building Envelope	Modifies orientation requirements and adds SHGC tradeoff	7/26/2013	7/30/2013	7/29/2013	8/28/2013
bx	9. Lighting	Clarification of exceptions to occupancy sensor requirements	1/26/2013	1/29/2013	2/11/2013	2/12/2013
by	9. Lighting	Improves and enhances lighting controls requirements. Establishes table of lighting controls applicable to each space type. Corrects daylighting threshold.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ca	5. Building Envelope	Adds control requirements for heating systems in vestibules	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cb	6. Heating, Ventilating, and Air Conditioning	This addendum requires night setback 10F heating & 5F cooling and removes exception for systems less than 10,000 cfm min for optimum start	7/26/2013	7/30/2013	7/29/2013	8/28/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
cc	6. Heating, Ventilating, and Air Conditioning	Adds efficiency requirements (Btu/h-hp) to Table 6.8.1G for evaporative condensers with R-507A	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cd	6. Heating, Ventilating, and Air Conditioning	Provides definition for piping to include all accessories in series with pipe such as pumps, valves, strainers, air separators, etc. This is meant to clarify that these accessories need to be insulated.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ce	Appendix G	Establishes a baseline system type for retail occupancies less than 3 stories in Appendix G	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cf	Appendix G	Establishes baseline WWR in Appendix G for strip malls.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ch	6. Heating, Ventilating, and Air Conditioning	Improved air and water cooled chiller efficiencies in Table 6.8.1C. Exempts water cooled positive displacement chillers with leaving condenser temperature >= 115 deg.F. (typically heat reclaim chillers).	6/26/2013	2/26/2013	6/28/2013	7/1/2013
ck	6. Heating, Ventilating, and Air Conditioning	Requires VAV dual maximum damper position when DDC system is present	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cl	6. Heating, Ventilating, and Air Conditioning	Table 6.8.1A and B. Improves IEER requirements for air-cooled air conditioners and heat pumps and EER requirements for water and evaporatively-cooled air-conditioners and heat pumps.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cn	Appendix G	Establishes modeling rules for laboratories with 100% OA in Appendix G	6/26/2013	6/26/2013	6/28/2013	7/1/2013
co	9. Lighting	Comprehensive update of LPDs in Table 9.5.1 - Building Area Method	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cp	5. Building Envelope	Corrects non-residential U-factor and R-value requirements for steel joist floors in CZ3	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cr	9. Lighting	Makes a number of adjustments to Table 9.6.1 Space-by-space LPD	7/26/2013	7/30/2013	7/29/2013	7/31/2013
ct	Appendix G	Identifies heated only storage systems 9 and 10 in Appendix G as being assigned one system per thermal zone.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cv	Appendix G	Establishes baseline system types in Appendix G for Assembly occupancies.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cy	6. Heating, Ventilating, and Air Conditioning	More stringent energy recovery for 24/7 occupancies	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cz	6. Heating, Ventilating, and Air Conditioning	Increases boiler efficiency for residential sized (NAECA covered) equipment, <3,000 Btu/h	7/26/2013	7/30/2013	7/29/2013	7/31/2013
da	5. Building Envelope	Relaxes air leakage requirements for high-speed doors for vehicle access and material transport	7/26/2013	7/30/2013	7/29/2013	8/28/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
db	5. Building Envelope	Corrects residential U-factor and R-value requirements for steel joist floors in CZ3	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dc	9. Lighting	Clarifies automatic lighting and switched receptacle control in guest rooms as applied to individual spaces.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dd	5. Building Envelope	Clarifies roof insulation requirements, differentiating between roof recovering (on top of existing roof covering) and replacement of roof covering.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
de	6. Heating, Ventilating, and Air Conditioning	Relaxes design requirements for waterside economizers for computer rooms	7/26/2013	7/302013	7/29/2013	7/31/2013
dg	5. Building Envelope	Updates reference to ANSI/CRRC-l Standard 2012 (cool roof ratings)	7/26/2013	7/30/2013	7/29/2013	7/31/2013
di	6. Heating, Ventilating, and Air Conditioning	Establishes limits on using electric or fossil fuel to humidify or dehumidify between 30% & 60% RH except certain applications. Requires deadband on humidity controls.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dj	9. Lighting	Additional lighting power allowance for electrical/mechanical rooms provided there is separate control for additional lighting.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dk	9. Lighting	Eliminates the exemption for wattage used in spaces where lighting is specifically designed for those with age-related eye conditions or other medical conditions related to the eye, where special lighting or light levels might be needed.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
dl	9. Lighting	Modifies hotel and motel guest room lighting power density	7/26/2013	7/30/2013	7/29/2013	8/28/2013
dn	6. Heating, Ventilating, and Air Conditioning	Reduces the limits on hot gas bypass as a means of cooling capacity control.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
do	6. Heating, Ventilating, and Air Conditioning	Update references to AHRI 550, AMCA 500, ANSI Z21.10.3 & Z21.47, ASHRAE 90.1 & 62.1, NEMA MG 1, & NFPA 70 &96	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dp	6. Heating, Ventilating, and Air Conditioning	Corrects the definition of walk-in-cooler to be consistent with federal requirements.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dq	6. Heating, Ventilating, and Air Conditioning	Deletes sizing requirements for pipes >24 in.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dr	5. Building Envelope	Clarifies definition of building entrances to exclude electrical room, mechanical rooms, and other utility service entrances.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dt	9. Lighting	Added exceptions for control of exterior lighting integral to signage. Requires certain types of exterior lighting exempt from LPD requirements to be separately controlled.	7/26/2013	7/30/2013	7/29/2013	7/31/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
dv	6. Heating, Ventilating, and Air Conditioning	Establishes chiller and boiler fluid flow isolation requirements so there is no flow through the equipment when not in use.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dw	6. Heating, Ventilating, and Air Conditioning	Revises high limit shutoff for air economizers. Add sensor accuracy requirements.	7/26/2013	7/30/2013	7/29/2013	7/31/2013

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NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.

(Normative Appendix G is adopted in the District of Columbia.)

NORMATIVE APPENDIX G
PERFORMANCE RATING METHOD

G1. GENERAL

G1.1 Performance Rating Method Scope. This building performance rating method is a modification of the Energy Cost Budget (ECB) Method in Section 11 and is intended for use in rating the energy efficiency of building designs that exceed the requirements of this standard. This appendix offers an alternative compliance path for minimum standard compliance per Chapter 1, Section 101.10.6 of Title 12-A DCMR and is provided for those wishing to use the methodology developed for this standard to quantify performance that substantially exceeds the requirements of Standard 90.1. It shall be used for evaluating the performance of all such *proposed designs,* including *alterations* and *additions* to *existing buildings,* except designs with no mechanical systems.

G1.2 Performance Rating.

G1.2.1 Mandatory Provisions. This performance rating method requires conformance with the following provisions:

a. All requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, 10.4, and 11 shall be met. These sections contain the mandatory provisions of the standard and are prerequisites for this rating method.

b. The interior lighting power shall not exceed the interior lighting power allowance determined using either Tables G3.7 or G3.8 and the methodology described in Section 9.5.1 and 9.6.1.

G1.2.2 Performance Rating Calculation. The performance of the proposed design is calculated in accordance with provisions of this appendix using the following formula:

Performance Cost Index =
Proposed building performance/Baseline building performance

Informative Note:

1. Neither the *proposed building performance* nor the *baseline building performance* predictions of actual *energy* consumption or costs for the *proposed design* after *construction*. Actual experience will differ from these calculations due to variations such as occupancy, *building* operation and maintenance, weather, *energy* use not covered by this procedure, changes in energy rates between design of the *building* and occupancy, and the precision of the calculation tool.

2. When using Appendix G, the Performance Cost Index (PCI) shall be less than or equal to the Performance Cost Index Target (PC_{It}) when calculated in accordance with the following:

$$PC_{It} = (BBUEC + (BPF \times BBREC))/BBP$$

Where:

PCI = Performance Cost Index calculated in accordance with Section G1.2.

BBUEC = Baseline Building Unregulated Energy Cost. The portion of the annual energy cost of a baseline building design that is due to unregulated energy use.

BBREC = Baseline Building Regulated Energy Cost. The portion of the annual energy cost of a baseline building design that is due to regulated energy use.

BPF = Building Performance Factor from Table G1.2.2. For building area types not listed in Table G1.2.2 use "All others." Where a building has multiple building area types, the required BPF shall be equal to the area-weighted average of the building area types.

BBP = *Baseline Building Performance*.

Regulated energy cost shall be calculated by multiplying the total energy cost by the ratio of regulated energy use to total energy use for each fuel type. Unregulated energy cost shall be calculated by subtracting regulated energy cost from total energy cost.

3. Neither the proposed building performance nor the baseline building performance are predictions of actual energy consumption or costs for the proposed design after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this procedure, changes in energy rates between design of the building and occupancy, and the precision of the calculation tool.

TABLE G1.2.2 BUILDING PERFORMANCE FACTOR (BPF)

Building Area Types[a]	Climate Zone 4A
Multifamily	0.58
Healthcare/ hospital	0.47
Hotel/motel	0.52
Office	0.48
Restaurant	0.48
Retail	0.45
School	0.39
Warehouse	0.48
All others	0.48

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

G1.2.3 Additions to Existing Buildings. When an addition to an existing building cannot comply by itself, trade-offs will be allowed by modification to one or more of the existing components of the existing building. Modeling of the modified components of the existing building and addition shall employ the procedures of Appendix G; the addition shall not increase the energy consumption of the existing building plus the addition beyond the energy that would be consumed by the existing building plus the addition if the addition alone did comply.

G1.2.4 Alterations of Existing Buildings. Alterations of existing buildings shall comply with the provisions of Section 5, 6, 7, 8, 9, 10, 11, 13 or Appendix G.

G1.3 Documentation Requirements. Simulated performance shall be documented, and documentation shall be submitted to the rating authority. The information shall be submitted in a report and shall include the following:

a. A brief description of the project, the key energy efficiency improvements compared with the requirements in Sections 5 through 11, the simulation program used, the version of the simulation program, and the results of the energy analysis. This summary shall contain the calculated values for the baseline building performance, the proposed building performance, and the percentage improvement

b. An overview of the project that includes: the number of stories (above and below grade), the typical floor size, the uses in the building (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is conditioned space.

c. A list of the energy-related features that are included in the design and on which the performance rating is based. This list shall document all energy features that differ between the models used in the baseline building performance and proposed building performance calculations.

d. A list showing compliance for the proposed design with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, 10.4 and 11 (mandatory provisions).

e. A list identifying those aspects of the proposed design that are less stringent than the requirements of 5.5, 6.5, 7.5, 9.5, and 9.6 (prescriptive provisions).

f. A table with a summary by end use of the energy cost savings in the proposed building performance.

g. A site plan showing all adjacent buildings and topography that may shade the proposed building (with estimated height or number of stories).

h. Building elevations and floor plans (schematic is acceptable).

i. A diagram showing the thermal blocks used in the computer simulation.

j. An explanation of any significant modeling assumptions.

k. Backup calculations and material to support data inputs (*e.g.,* U-factors for building envelope assemblies, NFRC ratings for fenestration, end-uses identified in Table G3.1, "1. Design Model," paragraph [a]).

l. Input and output reports from the simulation program or compliance software including a breakdown of energy use by at least the following components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). The output reports shall also show the amount of unmet load hours for both the proposed design and baseline building design.

m. Purchased energy rates used in the simulations.

n. An explanation of any error messages noted in the simulation program output.

o. For any exceptional calculation methods employed, document the predicted energy savings by energy type, the energy cost savings, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.

p. The reduction in proposed building performance associated with on-site renewable energy.

G2. SIMULATION GENERAL REQUIREMENTS

G2.1 Performance Calculations. The proposed building performance and baseline building performance shall be calculated using the following:

a. The same simulation program.

b. The same weather data.

c. The same energy rates.

G2.2 Simulation Program. The simulation program shall be a computer-based program for the analysis of energy consumption in buildings (a program such as, but not limited to, DOE-2, BLAST, or EnergyPlus). The simulation program shall include calculation methodologies for the building components being modeled. For components that cannot be modeled by the simulation program, the exceptional calculation methods requirements in Section G2.5 shall be used.

G2.2.1 The simulation program shall be approved by the rating authority and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year.

b. Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and

HVAC system operation, defined separately for each day of the week and holidays.

c. Thermal mass effects.

d. Ten or more thermal zones.

e. Part-load performance curves for mechanical equipment.

f. Capacity and efficiency correction curves for mechanical heating and mechanical cooling equipment.

g. Air economizers with integrated control.

h. Baseline building design characteristics specified in Section G3.

G2.2.2 The simulation program shall have the ability to either (1) directly determine the proposed building performance and baseline building performance or (2) produce hourly reports of energy use by an energy source suitable for determining the proposed building performance and baseline building performance using a separate calculation engine.

G2.2.3 The simulation program shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with generally accepted engineering standards and handbooks (for example, *ASHRAE Handbook—Fundamentals*) for both the proposed design and baseline building design.

G2.2.4 The simulation program shall be tested according to ASHRAE Standard 140, except Sections 7 and 8, and the results shall be furnished by the software provider.

G2.3 Climatic Data. The simulation program shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the proposed design is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site. The selected weather data shall be approved by the rating authority.

G2.4 Renewable, Recovered, and Purchased Energy

G2.4.1 On-Site Renewable Energy and Site-Recovered Energy. Site-recovered energy shall not be considered purchased energy and shall be subtracted from the proposed design energy consumption prior to calculating the proposed building performance. On-site renewable energy generated by systems included on the building permit that is used by the building shall be subtracted from the proposed design energy consumption prior to calculating the proposed building performance.

G2.4.2 Annual Energy Costs. The design energy cost and baseline energy cost shall be determined using either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration (EIA) for commercial building customers, but rates from different sources may not be mixed in the same project. Where on-site renewable energy or site-recovered energy is used, the baseline building design shall be based on the energy source used as the backup energy source or the baseline system energy source in that category if no backup energy source has been specified.

Informative Note: The above provision allows users to gain credit for features that yield load management benefits. Where such features are not present, users can simply use state average unit prices from EIA, which are updated annually and readily available on EIA's web site (http://www.eia.gov).

G2.5 Exceptional Calculation Methods. When the simulation program does not model a design, material, or device of the proposed design, an exceptional calculation method shall be used as approved by the rating authority. Where there are multiple designs, materials, or devices that the simulation program does not model, each shall be calculated separately and exceptional savings determined for each. At no time shall the total exceptional savings constitute more than half of the difference between the baseline building performance and the proposed building performance. All applications for approval of an exceptional method shall include the following:

a. Step-by-step documentation of the exceptional calculation method performed detailed enough to reproduce the results.

b. Copies of all spreadsheets used to perform the calculations.

c. A sensitivity analysis of energy consumption when each of the input parameters is varied from half to double the value assumed.

d. The calculations shall be performed on a time step basis consistent with the simulation program used.

e. The performance rating calculated with and without the exceptional calculation method.

G3. CALCULATION OF THE PROPOSED DESIGN AND BASELINE BUILDING PERFORMANCE

G3.1 Building Performance Calculations. The simulation model for calculating the proposed and baseline building performance shall be developed in accordance with the requirements in Table G3.1.

G3.1.1 Baseline HVAC System Type and Description. *HVAC systems* in the *baseline building design* shall comply with the following:

a. *HVAC systems* in the *baseline building design* shall be determined in the following order of priority:

1. The *building* type with the largest *conditioned floor area*.

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance*

No. Proposed Building Performance	Baseline Building Performance
1. Design Model	
a. The simulation model of the *proposed design* shall be consistent with the design documents, including proper accounting of *fenestration* and *opaque building envelope* types and areas; interior lighting power and *controls*; *HVAC system* types, sizes, and *controls*; and *service water-heating systems* and *controls*. All end-use load components within and associated with the *building* shall be modeled, including but not limited to exhaust fans, parking garage *ventilation* fans, snow-melt and freeze-protection *equipment*, façade lighting, swimming *pool* heaters and pumps, elevators and escalators, refrigeration, and cooking. Where the *simulation program* does not specifically model the functionality of the installed *system*, spreadsheets or other documentation of the assumptions shall be used to generate the power *demand* and operating schedule of the *systems*. b. All *conditioned spaces* in the *proposed design* shall be simulated as being both heated and cooled even if no heating or cooling *system* is to be installed. **Exception:** *Spaces* designed with heating only *systems* serving storage rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the *proposed design* shall not be modeled with *mechanical cooling*. c. When the *performance rating method* is applied to *buildings* in which *energy*-related features have not yet been designed (e.g., a *lighting system*), those yet-to-be-designed features shall be described in the *proposed design* exactly as they are defined in the *baseline building design*. Where the *space* classification for a *space* is not known, the *space* shall be categorized as an office *space*.	The *baseline building design* shall be modeled with the same number of *floors* and identical *conditioned floor area* as the *proposed design*. The *baseline building design* shall be developed by modifying the *proposed design* as described in Section G3. Except as specifically instructed, all *building systems* and *equipment* shall be modeled identically in the *proposed design* and *baseline building design*.
2. Additions and *Alterations*	
It is acceptable to predict performance using *building* models that exclude parts of the *existing building* provided that all of the following conditions are met: a. Work to be performed in excluded parts of the *building* shall meet the requirements of Sections 5 through 10. b. Excluded parts of the *building* are served by *HVAC systems* that are entirely separate from those serving parts of the *building* that are included in the *building* model. c. Design *space* temperature and *HVAC system* operating *set points* and schedules on either side of the boundary between included and excluded parts of the *building* are essentially the same. d. If a declining block or similar utility rate is being used in the analysis, and the excluded and included parts of the *building* are on the same utility meter, the rate shall reflect the utility block or rate for the *building* plus the addition.	If the proposed *design* excludes parts of the *existing building*, the *baseline building design* shall exclude them as well. When modeled, unmodified *existing building* components shall follow the same rules as new and modified *building* components.
3. *Space* Use Classification	
Use shall be specified using the *building* type or *space* type lighting classifications in accordance with Section 9.5.1 or 9.6.1. The user shall specify the *space* use classifications using either the *building* type or *space* type categories but shall not combine the two types of categories. More than one *building* type category may be used in a *building* if it is a mixed-use facility. If *space* type categories are used, the user may simplify the placement of the various *space* types within the *building* model, provided that *building* total areas for each space type are accurate.	Same as *proposed design*.

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance (Continued)*

No. Proposed Building Performance	Baseline Building Performance
4. Schedules	
Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat set points*, and *HVAC system* operation shall be used. The schedules shall be typical of the proposed *building* type as determined by the designer and approved by the *rating authority*. **Temperature and Humidity Schedules.** Temperature and humidity *control set points* and schedules as well as *temperature control throttling range* shall be the same for *proposed design* and *baseline building design.* **HVAC Fan Schedules.** Schedules for HVAC fans that provide *outdoor air* for *ventilation* shall run continuously whenever *spaces* are occupied and shall be cycled ON and OFF to meet heating and cooling loads during unoccupied hours. **Exceptions:** 1. Where no heating and/or cooling *system* is to be installed, and a heating or cooling *system* is being simulated only to meet the requirements described in this table, heating and/or cooling *system* fans shall not be simulated as running continuously during occupied hours but shall be cycled ON and OFF to meet heating and cooling loads during all hours. 2. HVAC fans shall remain on during occupied and unoccupied hours in spaces that have health- and safety-mandated minimum ventilation requirements during unoccupied hours. 3. HVAC fans shall remain on during occupied and unoccupied hours in *systems* primarily serving *computer rooms.*	**Same as *proposed design.*** **Exceptions:** 1. *Set points* and schedules for *HVAC systems* that automatically provide occupant thermal comfort via means other than directly controlling the air dry-bulb and wet-bulb temperature may be allowed to differ, provided that equivalent levels of occupant thermal comfort are demonstrated via the methodology in ASHRAE Standard 55, Section 5.3.3, "Elevated Air Speed," or Standard 55, Appendix B, "Computer Program for Calculation of PMV-PPD." 2. Schedules may be allowed to differ between *proposed design* and *baseline building design* when necessary to model nonstandard *efficiency* measures, provided that the revised schedules have been approved by the *rating authority.* Measures that may warrant use of different schedules include but are not limited to *automatic* lighting *controls, automatic* natural *ventilation controls, automatic demand control ventilation controls*, and *automatic controls* that reduce *service water-heating* loads. In no case shall schedules differ where the *controls* are *manual* (e.g., *manual* operation of light switches or *manual* operation of windows).
5. *Building Envelope*	
a. All components of the *building envelope* in the *proposed design* shall be modeled as shown on architectural drawings or as built for *existing building envelopes* per the U-value methodologies provided for in Section 5.4 and associated subsections **Exceptions:** The following *building* elements are permitted to differ from architectural drawings. 1. All uninsulated assemblies (e.g., concrete *floor* beams over parking garages, *roof* parapet) shall be separately modeled using either of the following techniques: a. Separate model of each of these assemblies within the *energy* simulation model. b. Separate calculation of the *U-factor* for each of these assemblies. The *U-factors* of these assemblies are then averaged with larger adjacent surfaces using an area-weighted average method. This average *U-factor* is modeled within the *energy* simulation model. 2. Exterior surfaces whose azimuth *orientation* and tilt differ by less than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers. 3. The exterior *roof* surface shall be modeled using the aged solar *reflectance* and thermal *emittance* determined in accordance with Section 5.5.3.1.1(a). Where aged test data are unavailable, the *roof* surface may be modeled with a *reflectance* of 0.30 and a thermal *emittance* of 0.90.	Equivalent dimensions shall be assumed for each *building envelope* component type as in the *proposed design*; i.e., the total gross area of *walls* shall be the same in the *proposed design* and *baseline building design*. The same shall be true for the areas of roofs, *floors*, and *doors*, and the exposed perimeters of concrete slabs on *grade* shall also be the same in the *proposed design* and *baseline building design*. The following additional requirements shall apply to the modeling of the *baseline building design*: a. ***Orientation.*** The *baseline building performance* shall be generated by simulating the *building* with its actual *orientation* and again after rotating the entire *building* 90, 180, and 270 degrees, then averaging the results. The *building* shall be modeled so that it does not shade itself. **Exceptions:** 1. If it can be demonstrated to the satisfaction of the *rating authority* that the *building orientation* is dictated by site considerations. 2. *Buildings* where the *vertical fenestration area* on each orientation varies by less than 5%. b. ***Opaque* Assemblies.** *Opaque* assemblies used for new *buildings, existing buildings,* or additions shall conform with assemblies detailed in Appendix A and shall match the appropriate assembly maximum *U-factors* in Table G3.4: • Roofs—Insulation entirely above deck (A2.2). • *Above-grade walls—Steel framed* (A3.3). • *Floors—Steel joist* (A5.3) • *Slab-on-grade floors* shall match the *F-factor* for unheated slabs from the same tables. (A-6) • *Opaque door* types shall be of the same type of *construction* as the *proposed design* and conform to the *U-factor* requirements from the same tables (A7). *(Continued on next page)*

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* *(Continued)*

No.	Proposed Building Performance	Baseline Building Performance
5.	***Building Envelope*** **(cont'd)**	
	4. *Manual fenestration* shading devices, such as blinds or shades, shall be modeled or not modeled the same as in the *baseline building design*. Automatically controlled *fenestration* shades or blinds shall be modeled. Permanent shading devices, such as fins, overhangs, and light shelves shall be modeled. 5. Automatically controlled *dynamic glazing* may be modeled. Manually controlled *dynamic glazing* shall use the average of the minimum and maximum *SHGC* and *VT*. b. *Infiltration* shall be modeled using the same methodology, air leakage rate, and adjustments for weather and building operation in both the *proposed design* and the *baseline building design*. These adjustments shall be made for each simulation time step and must account for but not be limited to weather conditions and *HVAC system* operation, including strategies that are intended to positively pressurize the *building*. The air leakage rate of the *building envelope* (I_{75Pa}) at a *fixed building* pressure differential of 0.3 in. of water shall be 0.4 cfm/ft^2. The air leakage rate of the *building envelope* shall be converted to appropriate units for the *simulation program* using one of the methods in Section G3.1.1.4. When whole-*building* air leakage testing, in accordance with ASTM E779, is specified during design and completed after *construction*, the *proposed design* air leakage rate of the *building envelope* shall be as measured	c. ***Vertical Fenestration Areas.*** For *building* area types included in Table G3.1.1-1, *vertical fenestration areas* for new *buildings* and additions shall equal that in Table G3.1.1-1 based on the area of gross *above-grade walls* that separate *conditioned spaces* and *semiheated spaces* from the exterior. Where a *building* has multiple *building* area types, each type shall use the values in the table. The *vertical fenestration* shall be distributed on each face of the *building* in the same proportion as in the *proposed design.* For *building* areas not shown in Table G3.1.1-1, *vertical fenestration areas* for new *buildings* and additions shall equal that in the *proposed design* or 40% of gross *above-grade wall area,* whichever is smaller, and shall be distributed on each face of the building in the same proportions in the *proposed design*. The *fenestration area* for an *existing building* shall equal the existing *fenestration area* prior to the proposed work and shall be distributed on each face of the *building* in the same proportions as the *existing building.* For portions of those tables where there are no *SHGC* requirements, the *SHGC* shall be equal to that determined in accordance with Section C3.6(c). The *VT* shall be equal to that determined in accordance with Section C3.6(c). d. ***Vertical Fenestration*** **Assemblies.** *Fenestration* for new *buildings, existing buildings,* and additions shall comply with the following: • *Fenestration U-factors* shall match the appropriate requirements in Table G3.4 for the applicable glazing percentage for U_{all}. • *Fenestration SHGCs* shall match the appropriate requirements in Table G3.4 using the value for $SHGC_{all}$ for the applicable vertical glazing percentage. • All *vertical fenestration* shall be assumed to be flush with the *exterior wall,* and no shading projections shall be modeled. • *Manual* window shading devices such as blinds or shades are not required to be modeled. e. ***Skylights*** **and Glazed Smoke Vents.** *Skylight* area shall be equal to that in the *proposed design* or 3%, whichever is smaller. If the *skylight* area of the *proposed design* is greater than 3%, baseline skylight area shall be decreased by an identical percentage in all *roof* components in which *skylights* are located to reach 3%. *Skylight orientation* and tilt shall be the same as in the *proposed design. Skylight U-factor* and *SHGC* properties shall match the appropriate requirements in Table G3.4 using the value and the applicable *skylight* percentage. f. ***Roof*** **Solar *Reflectance*** **and Thermal *Emittance*.** The exterior *roof* surfaces shall be modeled using a solar *reflectance* of 0.30 and a thermal *emittance* of 0.90. g. **Roof Albedo.** All *roof* surfaces shall be modeled with a reflectivity of 0.30.

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* *(Continued)*

No. Proposed Building Performance	Baseline Building Performance
6. Lighting	
Lighting power in the *proposed design* shall be determined as follows: a. Where a complete *lighting system* exists, the actual lighting power for each *thermal block* shall be used in the model. b. Where a *lighting system* has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where lighting neither exists nor is submitted with design documents, lighting shall comply with but not exceed the requirements of Section 9. Lighting power shall be determined in accordance with the *Building* Area Method. d. *Lighting system* power shall include all *lighting system* components shown or provided for on the plans (including *lamps* and *ballasts* and task and furniture-mounted *fixtures*). **Exception:** For multifamily *dwelling units,* hotel/motel guest rooms, and other *spaces* in which *lighting systems* are connected via receptacles and are not shown or provided for on *building* plans, assume identical lighting power for the *proposed design* and *baseline building design* in the simulations. e. Lighting power for parking garages and *building* façades shall be modeled. f. For lighting *controls*, at a minimum, the proposed design shall contain the mandatory *automatic* lighting *controls* specified in Section 9.4.1 (e.g., *automatic* daylight responsive *controls*, occupancy sensors, programmable *controls*, etc.). These *controls* shall be modeled in accordance with (g) and (h). g. *Automatic* daylighting responsive controls shall be modeled directly in the *proposed design* or through schedule adjustments determined by a separate daylighting analysis approved by the *rating authority.* Modeling and schedule adjustments shall separately account for *primary sidelighted areas, secondary sidelighted areas*, and toplighted areas. h. Other *automatic* lighting *controls* included in the *proposed design* shall be modeled directly in the *building* simulation by reducing the lighting schedule each hour by the occupancy sensor reduction factors in Table G3.7 for the applicable *space* type. This reduction shall be taken only for lighting controlled by the occupancy sensors. Credit for other programmable lighting *control* in *buildings* less than 5000 ft^2 can be taken by reducing the lighting schedule each hour by 10%.	Interior lighting power in the *baseline building design* shall be determined using the values in Table G3.7. Lighting shall be modeled having the *automatic* shutoff *controls* in *buildings* >5000 ft^2 and occupancy sensors in employee lunch and break rooms, conference/meeting rooms, and classrooms (not including shop classrooms, laboratory classrooms, and preschool through 12th-grade classrooms). These *controls* shall be reflected in the *baseline building design* lighting schedules. No additional *automatic* lighting *controls,* e.g., *automatic controls* for daylight utilization and occupancy sensors in *space* types not listed above, shall be modeled in the *baseline building design*. Exterior lighting in areas identified as "Tradable Surfaces" in Table G3.6 shall be modeled with the baseline lighting power shown in Table G3.6. Other exterior lighting shall be modeled the same in the *baseline building design* as in the *proposed design*.
7. Thermal Blocks—*HVAC Zones* Designed	
Where *HVAC zones* are defined on HVAC design drawings, each *HVAC zone* shall be modeled as a separate *thermal block*. **Exception:** Different *HVAC zones* may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied, provided that all of the following conditions are met: 1. The *space* use classification is the same throughout the *thermal block.* 2. All *HVAC zones* in the *thermal block* that are adjacent to glazed *exterior walls* and glazed *semiexterior walls* face the same *orientation* or their orientations vary by less than 45 degrees. 3. All of the zones are served by the same *HVAC system* or by the same kind of *HVAC system.*	Same as *proposed design.*

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* *(Continued)*

No. Proposed Building Performance	Baseline Building Performance
8. Thermal Blocks—*HVAC Zones* Not Designed	
Where the *HVAC zones* and *systems* have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and *space* temperature schedules, and in combination with the following guidelines: a. Separate *thermal blocks* shall be assumed for interior and perimeter *spaces*. Interior *spaces* shall be those located greater than 15 ft from an *exterior wall* or *semiexterior wall*. Perimeter *spaces* shall be those located within 15 ft of an *exterior wall* or *semiexterior wall.* A separate thermal zone does not need to be modeled for areas adjacent to *semiexterior walls* that separate *semiheated space* from *conditioned space*. b. Separate *thermal blocks* shall be assumed for *spaces* adjacent to glazed *exterior walls* or glazed *semiexterior walls*; a separate zone shall be provided for each *orientation*, except that orientations that differ by less than 45 degrees may be considered to be the same *orientation*. Each zone shall include all *floor* area that is 15 ft or less from a glazed perimeter *wall*, except that *floor* area within 15 ft of glazed perimeter *walls* having more than one *orientation* shall be divided proportionately between zones. c. Separate *thermal blocks* shall be assumed for *spaces* having *floors* that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. d. Separate *thermal blocks* shall be assumed for *spaces* having exterior ceiling or *roof* assemblies from zones that do not share these features.	Same as *proposed design.*
9. *Thermal Blocks*—Multifamily *Residential Buildings*	
Residential spaces shall be modeled using at least one *thermal block* per *dwelling unit*, except that those units facing the same orientations may be combined into one *thermal block*. Corner units and units with *roof* or *floor* loads shall only be combined with units sharing these features.	Same as *proposed design.*
10. *HVAC Systems*	
The *HVAC system* type and all related performance parameters in the *proposed design*, such as *equipment* capacities and efficiencies, shall be determined as follows: a. Where a complete *HVAC system* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where an *HVAC system* has been designed and submitted with design documents, the HVAC model shall be consistent with design documents. Mechanical *equipment* efficiencies shall be adjusted from actual *design conditions* to the standard rating conditions specified in Section 6.4.1 if required by the simulation model. Where *efficiency* ratings include supply fan *energy*, the *efficiency* rating shall be adjusted to remove the supply fan *energy* from the *efficiency* rating in the *baseline building design*. The equations in Section G3.1.2.1 shall not be used in the *proposed design*. The *proposed design HVAC system* shall be modeled using *manufacturers*' full- and part-load data for the *HVAC system* without fan power. c. Where no heating *system* exists or no heating *system* has been submitted with design documents, the *system* type shall be the same *system* as modeled in the *baseline building design* and shall comply with but not exceed the requirements of Section 6. d. Where no cooling *system* exists or no cooling *system* has been submitted with design documents, the cooling *system* type shall be the same as modeled in the *baseline building design* and shall comply with the requirements of Section 6. **Exception:** Spaces using baseline HVAC system types 9 and 10.	The *HVAC systems* in the *baseline building design* shall be of the type and description specified in Section G3.1.1, shall meet the general *HVAC system* requirements specified in Section G3.1.2, and shall meet any *system*-specific requirements in Section G3.1.3 that are applicable to the baseline *HVAC system* types. If the *proposed design* includes humidification then the *baseline building design* shall use adiabatic humidification. **Exception:** If the proposed *building* humidification *system* complies with Section 6.5.2.4 then the *baseline building design* shall use nonadiabatic humidification. For *systems* serving *computer rooms*, the *baseline building design* shall not have *reheat* for the purpose of dehumidification. *Fossil fuel systems* shall be modeled using natural gas as their *fuel* source. **Exception:** For *fossil fuel systems* where natural gas is not available for the proposed *building* site as determined by the *rating authority*, the baseline *HVAC system*s shall be modeled using propane as their *fuel*.

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* *(Continued)*

No.	Proposed Building Performance	Baseline Building Performance
11.	***Service Water-Heating Systems***	
	The *service water-heating system* type and all related performance parameters, such as *equipment* capacities and efficiencies, in the *proposed design* shall be determined as follows:	The *service water-heating system* in the *baseline building design* shall be as specified in Table G3.1.1-2 and conform with the following conditions:
	a. Where a complete *service water-heating system* exists, the *proposed design* shall reflect the actual *system* type using actual component capacities and efficiencies.	a. Where a complete *service water-heating system* exists or a new *service water-heating system* has been specified, one *service water-heating system* shall be modeled for each *building* area type in the proposed *building*. Each *system* shall be sized according to the provisions of Section 7.4.1, and the *equipment* shall match the minimum *efficiency* requirements in Section 7.4.2.
	b. Where a *service water-heating system* has been designed and submitted with design documents, the *service water-heating model* shall be consistent with design documents.	
	c. Where no *service water-heating system* exists or has been designed and submitted with design documents but the *building* will have *service water-heating* loads, a *service water-heating system* shall be modeled that matches the *system* type in the *baseline building design*, serves the same *water-heating* loads, and shall comply with but not exceed the requirements of Section 7.	b. Where no *service water-heating system* exists or has been specified but the *building* will have *service water-heating* loads, one *service water-heating system* shall be modeled for each anticipated *building* area type in the *proposed design*. Each *system* shall meet the minimum *efficiency* requirements of Section 7.4.2 and be modeled identically to the *proposed design*.
	d. For *buildings* that will have no *service water-heating* loads, no *service water-heating system* shall be modeled.	c. For *buildings* that will have no *service water-heating* loads, no *service water-heating* shall be modeled.
	e. Where a combined *system* has been specified to meet both *space* heating and *service water-heating* loads, the *proposed design* shall reflect the actual *system* type using actual component capacities and efficiencies.	d. Where a combined *system* has been specified to meet both *space* heating and *service water-heating* loads, the baseline *building system* shall use separate *systems* meeting the minimum *efficiency* requirements applicable to each *system* individually.
		e. For large, 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery *systems* described in Section 6.5.6.2, a *system* meeting the requirements of that section shall be included in the *baseline building design* regardless of the exceptions to Section 6.5.6.2.
		Exception: If a condenser heat recovery *system* meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a *system* in the actual *building* shall be met as a prescriptive requirement in accordance with Section 6.5.6.2, and no heat recovery *system* shall be included in the *proposed design* or *baseline building design*.
		f. *Service water-heating energy* consumption shall be calculated explicitly based upon the volume of *service water heating* required and the entering makeup water and the leaving *service water-heating* temperatures. Entering water temperatures shall be estimated based upon the location. Leaving temperatures shall be based upon the end-use requirements.
		g. Where recirculation pumps are used to ensure prompt availability of *service water-heating* at the end use, the *energy* consumption of such pumps shall be calculated explicitly.

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TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* *(Continued)*

No. Proposed Building Performance	Baseline Building Performance
11. *Service Water-Heating Systems* (cont.)	
	h. *Service* water loads and usage shall be the same for both the *proposed design* and *baseline building design* and shall be documented by the calculation procedures described in Section 7.2.1. **Exceptions:** 1. *Service water-heating* use can be demonstrated to be reduced by documented water conservation measures that reduce the physical volume of *service* water required. Examples include low-flow shower heads. Such reduction shall be demonstrated by calculations. 2. *Service water-heating energy* consumption can be demonstrated to be reduced by reducing the required temperature of *service* mixed water, by increasing the temperature, or by increasing the temperature of the entering makeup water. Examples include alternative sanitizing technologies for dishwashing and heat recovery to entering makeup water. Such reduction shall be demonstrated by calculations. 3. *Service water heating* use can be demonstrated to be reduced by reducing the hot fraction of mixed water to achieve required operational temperature. Examples include shower or laundry heat recovery to incoming cold-water supply, reducing the hot-water fraction required to meet required mixed-water temperature. Such reduction shall be demonstrated by calculations. i. Gas storage *water heaters* shall be modeled using natural gas as their *fuel*. Where natural gas is not available for the proposed *building* site, as determined by the *rating authority,* gas storage *water heaters* shall be modeled using propane as their *fuel*.
12. Receptacle and Other Loads	
Receptacle and *process loads*, such as those for office and other *equipment*, shall be estimated based on the *building area type* or *space* type category and shall be assumed to be identical in the *proposed design* and *baseline building design*, except as specifically approved by the *rating authority* only when quantifying performance that exceeds the requirements of Standard 90.1 but not when the *Performance Rating Method* is used as an alternative path for minimum standard compliance in accordance with Section 4.2.1.1. These loads shall always be included in simulations of the *building*. These loads shall be included when calculating the *proposed building performance* and the *baseline building performance* as required by Section G1.2.1. a. Where power and other *systems* covered by Sections 8 and 10 have been designed and submitted with design documents, those *systems* shall be determined in accordance with Sections 8 and 10. b. Where power and other *systems* covered by Sections 8 and 10 have not been submitted with design documents, those *systems* shall comply with but not exceed the requirements of those sections.	Motors shall have the *efficiency* ratings found in Table G3.9.1. Other *systems* covered by Section 10 and miscellaneous loads shall be modeled as identical to those in the *proposed design*, including schedules of operation and *control* of the *equipment*. *Energy* used for cooking *equipment*, receptacle loads, computers, medical or laboratory *equipment*, and manufacturing and industrial process *equipment* not specifically identified in the standard power and *energy* rating or capacity of the *equipment* shall be identical between the *proposed building performance* and the *baseline building performance*. When quantifying performance that exceeds the requirements of Standard 90.1 (but not when using the *Performance Rating Method* as an alternative path for minimum standard compliance per Section 4.2.1.1), variations of the power requirements, schedules, or *control* sequences of the *equipment* modeled in the *baseline building design* from those in the *proposed design* shall be approved by the *rating authority* based on documentation that the *equipment* installed in the *proposed design* represents a significant verifiable departure from documented current conventional practice. The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline *building equipment* different from that installed in the *proposed design*. Occupancy and occupancy schedules shall not be changed.

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* *(Continued)*

No. Proposed Building Performance	Baseline Building Performance
13. Modeling Limitations to the *Simulation Program*	
If the *simulation program* cannot model a component or system included in the *proposed design* explicitly, substitute a thermodynamically similar component model that can approximate the expected performance of the component that cannot be modeled explicitly.	Same as *proposed design*.
14. Exterior Conditions	
a. **Shading by Adjacent Structures and Terrain.** The effect that structures and significant vegetation or topographical features have on the amount of solar radiation being received by a structure shall be adequately reflected in the computer analysis. All elements whose effective height is greater than their distance from a proposed *building* and whose width facing the proposed *building* is greater than one-third that of the proposed *building* shall be accounted for in the analysis. b. **Ground Temperatures for *Below-Grade Wall* and Basement *Floor* Heat-Loss Calculations.** It is acceptable to use either an annual average ground temperature or monthly average ground temperatures for calculation of heat loss through *below-grade walls* and basement *floors*. c. **Water Main Temperatures for *Service Water-Heating* Calculations.** It is acceptable to use either an annual water main supply temperature or monthly average water main supply temperatures for calculating *service water heating*. If annual or monthly water main supply temperatures are not available from the local water utility, annual average ground temperatures may be used.	Same as *proposed design*.
15. Distribution *Transformers*	
Low-voltage dry-type distribution *transformers* shall be modeled if the *transformers* in the *proposed design* exceed the *efficiency* required in Table 8.4.4.	Low-voltage dry-type distribution *transformers* shall be modeled only if the *proposed design transformers* exceed the *efficiency* requirements of Table 8.4.4. If modeled, the *efficiency* requirements from Table 8.4.4 shall be used. The ratio of the capacity to peak electrical load of the *transformer* shall be the same as the ratio in the *proposed design*.

TABLE G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

No. Proposed Building Performance	Baseline Building Performance
16. Elevators	
Where the *proposed design* includes elevators, the elevator motor, *ventilation* fan, and light load shall be included in the model. The cab *ventilation* fan and lights shall be modeled with the same schedule as the elevator motor.	Where the *proposed design* includes elevators, the *baseline building design* shall be modeled to include the elevator cab motor, *ventilation* fans, and lighting power. The elevator peak motor power shall be calculated as follows: $\text{bhp} = (\text{Weight of Car} + \text{Rated Load} - \text{Counterweight}) \times \text{Speed of Car}/(33{,}000 \times h_{mechanical})$ $P_m = \text{bhp} \times 746/h_{motor}$ where Weight of Car = the *proposed design* elevator car weight, lb Rated Load = the *proposed design* elevator load at which to operate, lb Counterweight of Car = the elevator car counterweight, from Table G3.9.2, lb Speed of Car = the speed of the proposed elevator, ft/min $h_{mechanical}$ = the mechanical *efficiency* of the elevator from Table G3.9.2 h_{motor} = the motor *efficiency* from Table G3.9.2 P_m = peak elevator motor power, W The elevator motor use shall be modeled with the same schedule as the *proposed design*. When included in the *proposed design*, the baseline elevator cab *ventilation* fan shall be 0.33 W/cfm and the *lighting power density* shall be 3.14 W/ft^2; both operate continuously.
17. Refrigeration	
The *proposed design* shall be modeled using the actual *equipment* capacities and efficiencies.	Where refrigeration *equipment* is specified in the *proposed design* and listed in Tables G3.10.1 and G3.10.2, the *baseline building design* shall be modeled as specified in Tables G3.10.1 and G3.10.2 using the actual *equipment* capacities. If the refrigeration *equipment* is not listed in Tables G3.10.1 and G3.10.2, the *baseline building design* shall be modeled the same as the *proposed design*.

2. Number of *floors* (including *floors* above grade and below *grade* but not including *floors* solely devoted to parking).
3. *Gross conditioned floor area*.
4. Climate zone as specified in Table G3.1.1-3, which shall conform with the *system* descriptions in Table G3.1.1-4. For *Systems* 1, 2, 3, 4, 9, 10, 11, 12, and 13, each *thermal block* shall be modeled with its own *HVAC system*. For *Systems* 5, 6, 7, and 8, each *floor* shall be modeled with a separate *HVAC system*. *Floors* with identical *thermal blocks* can be grouped for modeling purposes.

b. Use additional *system* types for nonpredominant conditions (i.e., *residential*/*nonresidential* or heating source) if those conditions apply to more than 20,000 ft^2 of *conditioned floor area*.

c. If the baseline *HVAC system* type is 5, 6, 7, 8, 9, 10, 11, 12, or 13, use separate *single-zone systems* conforming with the requirements of *system* 3 or *system* 4 (depending on *building* heating source) for any *spaces* that have occupancy or *process loads* or schedules that differ significantly from the rest of the *building*. Peak thermal loads that differ by 10 Btu/h·ft^2 or more from the average of other *spaces* served by the *system*, or schedules that differ by more than 40 equivalent full-load hours per week from other *spaces* served by the *system,* are considered to differ significantly. Examples where this exception may be applicable include but are not limited to natatoriums and continually occupied security areas. This exception does not apply to *computer rooms*.

d. For laboratory *spaces* in a *building* having a total laboratory exhaust rate greater than 15,000 cfm, use a single *system* of type 5 or 7 serving only those *spaces*. The lab exhaust fan shall be modeled as constant horsepower reflecting constant-volume stack discharge with *outdoor air* bypass.

TABLE G3.1.1-1 Baseline Building Vertical Fenestration Percentage of Gross Above-Grade-Wall Area

Building Area Types[a]	Baseline Building Gross Above-Grade-Wall Area
Grocery Store	7%
Healthcare (outpatient)	21%
Hospital	27%
Hotel/motel (≤75 rooms)	24%
Hotel/motel (>75 rooms)	34%
Office (≤5000 ft^2)	19%
Office (5000 to 50,000 ft^2)	31%
Office (>50,000 ft^2)	40%
Restaurant (quick service)	34%
Restaurant (full service)	24%
Retail (stand alone)	11%
Retail (strip mall)	20%
School (primary)	22%
School (secondary and university)	22%
Warehouse (nonrefrigerated)	6%

TABLE G3.1.1-2 Baseline *Service Water-Heating System*

Building **Area Type**	**Baseline Heating Method**	***Building*** **Area Type**	**Baseline Heating Method**
Automotive facility	Gas storage *water heater*	Performing arts theater	Gas storage *water heater*
Convenience store	*Electric resistance water heater*	Police station	*Electric resistance* storage *water heater*
Convention center	*Electric resistance* storage *water heater*	Post office	*Electric resistance* storage *water heater*
Courthouse	*Electric resistance* storage *water heater*	Religious *facility*	*Electric resistance* storage *water heater*
Dining: Bar lounge/leisure	Gas storage *water heater*	Retail	*Electric resistance* storage *water heater*
Dining: Cafeteria/fast food	Gas storage *water heater*	School/university	Gas storage *water heater*
Dining: Family	Gas storage *water heater*	Sports arena	Gas storage *water heater*
Dormitory	Gas storage *water heater*	Town hall	*Electric resistance* storage *water heater*
Exercise center	Gas storage *water heater*	Transportation	*Electric resistance* storage *water heater*
Fire station	Gas storage *water heater*	Warehouse	*Electric resistance* storage *water heater*
Grocery store	Gas storage *water heater*	Workshop	*Electric resistance* storage *water heater*
Gymnasium	Gas storage *water heater*	All others	Gas storage *water heater*
Health-care clinic	*Electric resistance* storage *water heater*		
Hospital and outpatient surgery center	Gas storage *water heater*		
Hotel	Gas storage *water heater*		
Library	*Electric resistance* storage *water heater*		
Manufacturing facility	Gas storage *water heater*		
Motel	Gas storage *water heater*		
Motion picture theater	*Electric resistance* storage *water heater*		
Multifamily	Gas storage *water heater*		
Museum	*Electric resistance* storage *water heater*		
Office	*Electric resistance* storage *water heater*		
Parking garage	*Electric resistance* storage *water heater*		
Penitentiary	Gas storage *water heater*		

e. Thermal zones designed with heating-only *systems* in the *proposed design* serving storage rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the *proposed design* shall use *system* type 9 or 10 in the *baseline building design*.

f. If the baseline *HVAC system* type is 9 or 10, all *spaces* that are mechanically cooled in the *proposed design* shall be assigned to a separate baseline *system* determined by using the area and heating source of the mechanically *cooled spaces*.

g. *Computer rooms* in *buildings* with a total *computer room* peak cooling load >3,000,000 Btu/h or a total *computer room* peak cooling load >600,000 Btu/h where the baseline *HVAC system* type is 7 or 8 shall use *System* 11. All other *computer rooms* shall use *System* 3 or 4.

h. For hospitals, depending on *building* type, use *System* 5 or 7 in all climate zones.

G3.1.1.1 Purchased Heat. For systems using purchased hot water or steam, the heating source shall be modeled as purchased hot water or steam in both the proposed design and baseline building designs. Hot water or steam costs shall be based on actual utility rates, and on-site boilers, electric heat, and furnaces shall not be modeled in the baseline building design

G3.1.1.2 Purchased Chilled Water. For systems using purchased chilled water, the cooling source shall be modeled as purchased chilled water in both the proposed design and baseline building designs. Purchased chilled water costs shall be based on actual utility rates, and on-site chillers and direct expansion equipment shall not be modeled in the baseline building design.

G3.1.1.3 Baseline HVAC System Requirements for Systems Utilizing Purchased Chilled Water and/or Purchased Heat. If the proposed design uses purchased chilled water and/or purchased heat, the following modifications to the baseline HVAC Ssystem types in Table G3.1.1-4 shall be used:

G3.1.1.3.1 Purchased Heat Only. If the proposed design uses purchased heat, but does not use purchased chilled water, then Tables G3.1.1-3 and G3.1.1-4 shall be used to select the baseline HVAC system type and purchased heat shall be substituted for the heating type in Table G3.1.1-4. The same heating source shall be used in the proposed design and baseline building design.

G3.1.1.3.2 Purchased Chilled Water Only. If the proposed design uses purchased chilled water but does not use purchased heat, then Tables G3.1.1-3 and G3.1.1-4 shall be used to select the baseline HVAC system type, with the modifications listed below:

a. Purchased chilled water shall be substituted for the cooling types in Table G3.1.1-4.

b. System 1 and 2 shall be constant-volume fan-coil units with fossil fuel boilers.

c. System 3 and 4 shall be constant-volume single-zone air handlers with fossil fuel furnaces.

d. System 7 shall be used in place of System 5.

e. System 8 shall be used in place of System 6.

TABLE G3.1.1-3 Baseline HVAC System Types

Building **Type, Number of *Floors*, and Gross Conditioned Floor Area**	**Climate Zones 3B, 3C, and 4 to 8**	**Climate Zones 0 to 3A**
Residential	*System* 1—PTAC	*System* 2—*PTHP*
Public assembly <120,000 ft^2	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Public assembly ≥120,000 ft^2	*System* 12—SZ-CV-HW	*System* 13—SZ-CV-ER
Heated-only storage	*System* 9—Heating and *ventilation*	*System* 10—Heating and *ventilation*
Retail and 2 *floors* or fewer	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Other residential and 3 *floors* or fewer and <25,000 ft^2	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Other residential and 4 or 5 *floors* and <25,000 ft^2 or 5 *floors* or fewer and 25,000 ft^2 to 150,000 ft^2	*System* 5—Packaged *VAV* with *reheat*	*System* 6—Packaged *VAV* with PFP boxes
Other residential and more than 5 *floors* or >150,000 ft^2	*System* 7—*VAV* with *reheat*	*System* 8—*VAV* with PFP boxes

Notes:

1. *Residential building* types include dormitory, hotel, motel, and multifamily. *Residential space* types include guest rooms, living quarters, private living *space*, and sleeping quarters. Other *building* and *space* types are considered *nonresidential*.
2. Where attributes make a *building* eligible for more than one baseline *system* type, use the predominant condition to determine the *system* type for the entire *building* except as noted in Section G3.1.1.
3. For laboratory *spaces* in a *building* having a total laboratory exhaust rate greater than 15,000 cfm, use a single *system* of type 5 or 7 serving only those *spaces*.
4. For hospitals, depending on *building* type, use *System* 5 or 7 in all climate zones.
5. Public assembly *building* types include houses of worship, auditoriums, movie theaters, performance theaters, concert halls, arenas, enclosed stadiums, ice rinks, gymnasiums, convention centers, exhibition centers, and natatoriums.

G3.1.1.3.3 Purchased Chilled Water and Purchased Heat. If the proposed design uses purchased chilled water and purchased heat, then Tables G3.1.1-3 and G3.1.1-4 shall be used to select the baseline HVAC system type, with the following modifications:

a. Purchased heat and purchased chilled water shall be substituted for the heating types and cooling types in Table G3.1.1-4.

b. System 1 shall be constant-volume fan-coil units.

c. System 3 shall be constant-volume single-zone air handlers.

d. System 7 shall be used in place of System 5.

G3.1.1.3.4 On-Site Distribution Pumps. All on-site distribution pumps shall be modeled in both the proposed design and base building design.

G3.1.1.4 Modeling Building Envelope Infiltration. The air leakage rate of the building envelope (I_{75Pa}) at a pressure differential of 0.3 in. of water shall be converted to appropriate units for the simulation program using one of the following formulas:

For methods describing air leakage as a function of floor area,

$$I_{FLR} = 0.112 \times I_{75Pa} \times S/A_{FLR}$$

For methods describing air leakage as a function of the area of above-grade walls that separate conditioned spaces and semiheated spaces from the exterior,

$$I_{AGW} = 0.112 \times I_{75Pa} \times S/A_{AGW}$$

When using the measured air leakage rate of the building envelope at a pressure differential of 0.3 in. of water for the proposed design, the air leakage rate shall be calculated as follows:

$$I_{75Pa} = Q/S$$

where

I_{75Pa} = air leakage rate of the building envelope cfm/ft^2 at a fixed building pressure differential of 0.3 in. of water, or 1.57 psf.

Q = volume of air in cfm flowing through the building envelope when subjected to a pressure differential of 0.3 in. of water, or 1.57 psf, in accordance with ASTM E779.

S = total area of the building envelope (ft^2), including the lowest floor, any below-grade walls or above-grade walls, and roof (including vertical fenestration and skylights).

I_{FLR} = adjusted air leakage rate of the *building envelope* (cfm/ft^2) at a reference wind speed of 10 mph and relative to the *gross floor area.*

A_{FLR} = gross floor area, ft^2.

TABLE G3.1.1-4 Baseline *System* Descriptions

***System* No.**	***System* Type**	**Fan *Control***	**Cooling Type[a]**	**Heating Type[a]**
1. *PTAC*	*Packaged terminal air conditioner*	Constant volume	Direct expansion	Hot-water *fossil fuel boiler*
2. *PTHP*	Packaged terminal heat pump	Constant volume	Direct expansion	Electric heat pump
3. PSZ-AC	Packaged rooftop air conditioner	Constant volume	Direct expansion	*Fossil fuel* furnace
4. PSZ-HP	Packaged rooftop heat pump	Constant volume	Direct expansion	Electric heat pump
5. Packaged *VAV* with *reheat*	Packaged rooftop *VAV* with *reheat*	VAV	Direct expansion	Hot-water *fossil fuel boiler*
6. Packaged *VAV* with PFP boxes	Packaged rooftop *VAV* with parallel fan power boxes and *reheat*	VAV	Direct expansion	Electric resistance
7. *VAV* with *reheat*	*VAV* with *reheat*	VAV	Chilled water	Hot-water *fossil fuel boiler*
8. *VAV* with PFP boxes	*VAV* with parallel fan-powered boxes and *reheat*	VAV	Chilled water	Electric resistance
9. Heating and *ventilation*	Warm air furnace, gas fired	Constant volume	None	*Fossil fuel* furnace
10. Heating and *ventilation*	Warm air furnace, electric	Constant volume	None	Electric resistance
11. SZ–*VAV*	Single-zone *VAV*	VAV	Chilled water	See note (b).
12. SZ-CV-HW	Single-zone system	Constant volume	Chilled water	Hot-water *fossil fuel boiler*
13. SZ-CV-ER	Single-zone system	Constant volume	Chilled water	Electric resistance

Notes:

a. For purchased chilled water and purchased heat, see G3.1.1.3.

b. For Climate Zones 0 through 3A, the heating type shall be *electric resistance*. For all other climate zones, the heating type shall be hot-water fossil-*fuel boiler.*

I_{AGW} = adjusted air leakage rate of the *building envelope* (cfm/ft^2) at a reference wind speed of 10 mph and relative to the area of the *above-grade walls* of the *building envelope.*

A_{AGW} = total area of *above-grade walls* of the *building envelope*, ft^2.

Exceptions: A multizone airflow model alternative method to modeling building envelope air leakage may be used provided the following criteria are met:

1. Where the calculations are made independently of the energy simulation program, the proposed method must comply with Section G2.5.
2. The method for converting the air leakage rate of the building envelope at 0.3 in. of water, or 1.57 psf, to the appropriate units for the simulation program is fully documented and submitted to the rating authority for approval.

G3.1.2 General Baseline HVAC System Requirements. HVAC systems in the baseline building design shall conform with the general provisions in this section.

G3.1.2.1 Equipment Efficiencies. All HVAC equipment in the baseline building design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with Tables G.3.5.1 through G.3.5.6. Chillers shall use Path A efficiencies as shown in Table 6.8.1-3. Where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy. For Baseline HVAC Systems 1, 2, 3, 4, 5, and 6, calculate the minimum $COP_{nfcooling}$ and $COP_{nfheating}$ using the equation for the applicable performance rating as indicated in Tables 6.8.1-1 through 6.8.1-4.

Where a full- and part-load efficiency rating is provided in Tables 6.8.1-1 through 6.8.1-4, the full-load equation below shall be used:

$$COP_{nfcooling} = 7.84E\text{-}8 \times EER \times Q + 0.338 \times EER$$

$$COP_{nfcooling} = -0.0076 \times SEER^2 + 0.3796 \times SEER$$

$$COP_{nfheating} = 1.48E\text{-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$$

(applies to heat-pump heating efficiency only)

$$COP_{nfheating} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$$

where $COP_{nfcooling}$ and $COP_{nfheating}$ are the packaged HVAC equipment cooling and heating energy efficiency, respectively, to be used in the baseline building design, which excludes supply fan power, and Q is the AHRI-rated cooling capacity in Btu. EER, SEER, COP, and HSPF shall be at AHRI test conditions. Fan energy shall be modeled separately according to Section G3.1.2.9.

G3.1.2.2 Equipment Capacities. The equipment capacities (i.e., system coil capacities) for the baseline building design shall be based on sizing runs for each orientation (per Table G3.1, No. 5a) and shall be oversized by 15% for cooling and 25% for heating, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating.

G3.1.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine baseline equipment capacities shall be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.

G3.1.2.3 Unmet Loads. Unmet load hours for the proposed design or baseline building designs shall not exceed 300 (of the 8760 hours simulated). Alternatively, unmet load hours exceeding these limits shall be permitted to be accepted upon approval of the rating authority provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

G3.1.2.4 Fan System Operation. Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. Supply, return, and/or exhaust fans will remain on during occupied and unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.

Exception: For *Systems* 6 and 8, only the *terminal*-unit fan and *reheat* coil shall be energized to meet heating *set point* during unoccupied hours.

G3.1.2.5 Ventilation. Minimum ventilation system outdoor air intake flow shall be the same for the proposed design and baseline building design.

Exceptions:

1. When modeling demand-control ventilation in the proposed design in systems with outdoor air capacity less than or equal to 3,000 cfm serving areas with an average design capacity of 100 people per 1,000 ft^2 or less.
2. When designing systems in accordance with Standard 62.1, Section 6.2, "Ventilation Rate Procedure," reduced ventilation airflow rates may be calculated for each HVAC zone in the proposed design with a zone air distribution effectiveness (E_z) > 1.0 as defined by Standard 62.1, in Table 6-2. Baseline ventilation airflow rates in those zones shall be calculated using the proposed design Ventilation Rate Procedure calculation with the following change only. Zone air distribution effectiveness shall be changed to (E_z) = 1.0 in each zone having a zone air distribution effectiveness (E_z) > 1.0. Proposed design and baseline building design Ventilation Rate Procedure calculations, as described in Standard 62.1, shall be submitted to the rating authority to claim credit for this exception.

3. Where the minimum outdoor air intake flow in the proposed design is provided in excess of the amount required by the building code or the rating authority, then the baseline building design shall be modeled to reflect the greater of that required by either the rating authority or the building code and will be less than the proposed design.

4. For baseline systems serving only laboratory spaces that are prohibited from recirculating return air by code or accreditation standards, the baseline system shall be modeled as 100% outdoor air.

G3.1.2.6 Economizers. Air economizers shall not be included in baseline HVAC Systems 1, 2, 9, and 10. Air economizers shall be included in baseline HVAC Systems 3 through 8, and 11, 12, and 13 based on climate as specified in Table G3.1.2.6.

Exception: Economizers shall not be included for systems meeting one or more of the exceptions listed below.

1. Systems that include gas-phase air cleaning to meet the requirements of Section 6.1.2 in Standard 62.1. This exception shall be used only if the system in the proposed design does not match the building design.

2. Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems. This exception shall only be used if the system in the proposed design does not use an economizer. If the exception is used, an economizer shall not be included in the baseline building design.

3. Systems that serve computer rooms complying with Section G3.1.2.6.1.

TABLE G3.1.2.6 Climate Conditions under which Economizers are Included for Comfort Cooling for Baseline *Systems* 3 through 8 and 11, 12, and 13

Climate Zone	Conditions
0A, 0B, 1A, 1B, 2A, 3A, 4A	NR
Others	Economizer Included

Note: NR means that there is no conditioned *building floor* area for which economizers are included for the type of zone and climate.

G3.1.2.6.1 Computer Room Economizers. Systems that serve computer rooms that are HVAC System 3 or 4 shall not have an economizer. Systems that serve computer rooms that are HVAC System 11 shall include an integrated fluid economizer meeting the requirements of Section 6.5.1.2 in the baseline building design.

G3.1.2.7 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb fixed switch with setpoint temperatures in accordance with the values in Table G3.1.2.7.

TABLE G3.1.2.7 Economizer High-Limit Shutoff Temperature

Climate Zone	Dry-Bulb Temperature *Set Point*
2B, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	75°F
5A, 6A	70°F

G3.1.2.8 Design Airflow Rates

G3.1.2.8.1 Baseline All System Types Except System Types 9 and 10. System design supply airflow rates for the baseline building design shall be based on a supply-air-to-room temperature set-point difference of 20°F or the *minimum outdoor airflow* rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. For systems with multiple zone thermostat set-points, use the design set point that will result in the lowest supply air cooling set point or highest supply air heating set point. If return or relief fans are specified in the proposed design, the baseline building design shall also be modeled with fans serving the same functions and sized for the baseline system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.

Exceptions:

1. For systems serving laboratory spaces, airflow rate shall be based on a supply-air-to-room-temperature set-point difference of 17°F or the required ventilation air or makeup air, whichever is greater.

2. If the proposed design HVAC system airflow rate based on latent loads is greater than the design airflow rate based on sensible loads, then the same supply-air-to-room-air humidity ratio difference (gr/lb) used to calculate the proposed design airflow shall be used to calculate design airflow rates for the baseline building design.

G3.1.2.8.2 Baseline System Types 9 and 10. System design supply airflow rates for the baseline building design shall be based on the temperature difference between a supply air temperature setpoint of 105°F and the design space heating temperature setpoint, the *minimum outdoor airflow* rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. If the proposed design includes a fan sized and controlled to provide non-mechanical cooling, the baseline building design shall

include a separate fan to provide non-mechanical cooling, sized and controlled the same as the proposed design.

G3.1.2.9 System Fan Power. System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:

For Systems 1 and 2,

$$P_{fan} = \text{CFMs} \times 0.3$$

For Systems 3 through 8, and 11, 12, and 13,

$$P_{fan} = \text{bhp} \times 746/\text{fan motor efficiency}$$

For Systems 9 and 10 (supply fan),

$$P_{fan} = \text{CFMs} \times 0.3$$

For Systems 9 and 10 (nonmechanical cooling fan if required by Section G3.1.2.8.2)

$$P_{fan} = \text{CFM}_{nmc} \times 0.054$$

where

P_{fan} = electric power to fan motor, W

bhp = brake horsepower of baseline fan motor from Table G3.1.2.9

fan motor *efficiency* = the *efficiency* from Table G3.9.1 for the next motor size greater than the bhp using a totally enclosed fan cooled motor at 1800 rpm

CFMs = the baseline system maximum design supply fan airflow rate, cfm

CFM_{nmc} = the baseline non-*mechanical cooling* fan airflow, cfm

TABLE G3.1.2.9 Baseline *Fan Brake Horsepower*

Baseline Fan Motor Brake Horsepower		
Constant Volume *Systems* 3 to 4	**Variable Volume *Systems* 5 to 8**	**Variable Volume *System* 11**
$\text{CFM}_s \times 0.00094 + A$	$\text{CFM}_s \times 0.0013 + A$	$\text{CFM}_s \times 0.00062 + A$

Notes:

1. Where A is calculated according to Section 6.5.3.1.1 using the pressure-drop adjustment from the *proposed design* and the design flow rate of the baseline *building system.*
2. Do not include pressure-drop adjustments for evaporative coolers or heat recovery devices that are not required in the baseline *building system* by Section G3.1.2.10.

G3.1.2.9.1 The calculated *system* fan power shall be distributed to supply, return, exhaust, and relief fans in the same proportion as the *proposed design.*

G3.1.2.10 Exhaust Air Energy Recovery. Individual fan *systems* that have both a design supply air capacity of 5000 cfm or greater and have a minimum design *outdoor air* supply of 70% or greater shall have an *energy* recovery *system* with at least 50% *enthalpy recovery ratio*. Fifty percent *enthalpy recovery ratio* shall mean a change in the enthalpy of the *outdoor air* supply equal to 50% of the difference between the *outdoor air* and return air at *design conditions.* Provision shall be made to bypass or *control* the heat recovery *system* to permit *air economizer* operation, where applicable.

Exception: If any of these exceptions apply, exhaust air energy recovery shall not be included in the *baseline building design.*

a. Systems serving spaces that are not cooled and that are heated to less than 60°F.
b. Systems exhausting toxic, flammable, or corrosive fumes or paint or dust. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.
c. Commercial kitchen hoods (grease) classified as Type 1 by NFPA 96. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.
d. Heating systems in climate zones 0 through 3.
e. Cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8.
f. Where the largest exhaust source is less than 75% of the design *outdoor air* flow. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.
g. Systems requiring dehumidification that employ energy recovery in series with the cooling coil. This exception shall only be used if exhaust air energy recovery and series-style energy recovery coils are not used in the *proposed design.*

G3.1.3 System-Specific Baseline HVAC System Requirements. Baseline HVAC systems shall conform with provisions in this section, where applicable, to the specified baseline system types as indicated in section headings.

G3.1.3.1 Heat Pumps (Systems 2 and 4). Electric air-source heat pumps shall be modeled with electric auxiliary heat and an outdoor air thermostat. The systems shall be controlled to energize auxiliary heat only when the outdoor air temperature is less than 40°F. The air-source heat pump shall be modeled to continue to operate while auxiliary heat is energized.

G3.1.3.2 Type and Number of Boilers (Systems 1, 5, and 7). The boiler plant shall use the same fuel as the proposed design and shall be natural draft, except as noted in Section G3.1.1.1. The baseline building design boiler plant shall be modeled as having a single boiler if the baseline building design plant serves a conditioned floor area of 15,000 ft^2 or less and as having two equally sized boilers for plants serving more than 15,000 ft^2. Boilers shall be staged as required by the load.

G3.1.3.3 Hot-Water Supply Temperature (Systems 1, 5, 7, and 12). Hot-water design supply temperature shall be modeled as 180°F and design return temperature as 130°F.

G3.1.3.4 Hot-Water Supply Temperature Reset (Systems 1, 5, 7, 11, and 12). Hot-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 180°F at 20°F and below, 150°F at 50°F and above, and ramped linearly between 180°F and 150°F at temperatures between 20°F and 50°F.

Exception: Systems served by purchased heat.

G3.1.3.5 Hot-Water Pumps. The baseline building design hot-water pump power shall be 19 W/gpm. The pumping system shall be modeled as primary-only with continuous variable flow and a minimum of 25% of the design flow rate. Hot-water systems serving 120,000 ft^2 or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft^2 shall be modeled as riding the pump curve.

Exception: The pump power for systems using purchased heat shall be 14 W/gpm.

G3.1.3.6 Piping Losses (Systems 1, 5, 7, 8, and 11). Piping losses shall not be modeled in either the proposed design or baseline building design for hot-water, chilled-water, or steam piping.

G3.1.3.7 Type and Number of Chillers (Systems 7, 8, 11, 12, and 13). Electric chillers shall be used in the baseline building design regardless of the cooling energy source, e.g., direct fired absorption or absorption from purchased steam. The baseline building design's chiller plant shall be modeled with chillers having the number and type as indicated in Table G3.1.3.7 as a function of building peak cooling load.

Exception: Systems using purchased chilled water shall be modeled in accordance with Section G3.1.1.3.

TABLE G3.1.3.7 Type and Number of Chillers

Building Peak Cooling Load	Number and Type of Chiller(s)
≤300 tons	1 water-cooled screw chiller
>300 tons, <600 tons	2 water-cooled screw chillers sized equally
≥600 tons	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

G3.1.3.8 Chilled-Water Design Supply Temperature (Systems 7, 8, 11, 12, and 13). Chilled-water design supply temperature shall be modeled at 44°F and return water temperature at 56°F.

G3.1.3.9 Chilled-Water Supply Temperature Reset (Systems 7, 8, 11, 12, and 13). Chilled-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 44°F at 80°F and above, 54°F at 60°F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F.

Exceptions:

1. If the baseline chilled-water system serves a computer room HVAC system, the supply chilled-water temperature shall be reset higher based on the HVAC system requiring the most cooling; i.e., the chilled-water setpoint is reset higher until one cooling-coil valve is nearly wide open. The maximum reset chilled-water supply temperature shall be 54°F.
2. Systems served by purchased chilled water.

G3.1.3.10 Chilled-Water Pumps (Systems 7, 8, and 11). Chilled-water *systems* shall be modeled as primary/secondary *systems* with constant-flow primary loop and variable-flow secondary loop. For *systems* with cooling capacity of 300 tons or more, the secondary pump shall be modeled with variable-speed drives and a minimum flow of 25% of the design flow rate. For *systems* with less than 300 tons cooling capacity, the secondary pump shall be modeled as riding the pump curve. The baseline *building* constant-volume primary pump power shall be modeled as 9 W/gpm, and the variable-flow secondary pump power shall be modeled as 210 W/gpm at *design conditions.* For *computer room systems* using *System* 11 with an integrated *fluid economizer*, the *baseline building design* primary chilled-water pump power shall be increased by 3 W/gpm for flow associated with the *fluid economizer.*

Exception: For *systems* using purchased chilled water, the *building* distribution pump shall be modeled with variable-speed drive, a minimum flow of 25% of the design flow rate, and a pump power of 16 W/gpm.

G3.1.3.11 Heat Rejection (Systems 7, 8, 9, 12, and 13). The heat rejection device shall be an axial fan open circuit cooling tower with variable-speed fan control and shall have an efficiency of 38.2 gpm/hp at the conditions specified in Table 6.8.1-7. Condenser water design supply temperature shall be calculated using the cooling tower approach to the 0.4% evaporation design wet-bulb temperature as generated by the formula below, with a design temperature rise of 5.6°C.

$$\text{Approach}_{10°F\ Range} = 25.72 - (0.24 \times \text{WB})$$

where WB is the 0.4% evaporation design wet-bulb temperature in °F; valid for wet bulbs from 55°F to 90°F. The tower shall be controlled to maintain a leaving water temperature, where weather permits, per Table G3.1.3.11, floating up to the design leaving water temperature for the cooling tower. The baseline building design condenser-water pump power shall be 19 W/gpm and modeled as constant volume. For computer room systems using System 11 with an integrated water-side economizer, the baseline building design condenser water-pump power shall be increased by 3 W/gpm

for flow associated with the water-side economizer. Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller.

TABLE G3.1.3.11 Heat-Rejection Leaving Water Temperature

Climate Zone	Leaving Water Temperature
5B, 5C, 6B, 8	65°F
0B, 1B, 2B, 3B, 3C, 4B, 4C, 5A, 6A, 7	70°F
3A, 4A	75°F
0A, 1A, 2A	80°F

G3.1.3.12 Supply Air Temperature Reset (Systems 5 through 8). The air temperature for cooling shall be reset higher by 5°F under the minimum cooling load conditions.

G3.1.3.13 VAV Minimum Flow Setpoints (Systems 5 and 7). Minimum volume setpoints for VAV reheat boxes shall be 30% of zone peak airflow, the *minimum outdoor airflow* rate or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger.

Exception: Systems serving laboratory spaces shall reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak airflow, the *minimum outdoor airflow* rate, or the airflow rate required to comply with applicable codes or accreditation standards.

G3.1.3.14 Fan Power (Systems 6 and 8). Fans in parallel *VAV* fan-powered boxes shall run as the first stage of heating before the *reheat* coil is energized. Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design primary air (from the VAV air-handling unit) flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to 30% of peak design primary airflow rate or the rate required to meet the minimum outdoor air ventilation requirement, whichever is larger. The supply air temperature setpoint shall be constant at the design condition.

G3.1.3.15 VAV Fan Part-Load Performance (Systems 5 through 8 and 11). VAV system supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table G3.1.3.15.

TABLE G3.1.3.15 Part-Load Performance for *VAV* Fan *Systems*

Method 1—Part-Load Fan Power Data

Fan Part-Load Ratio	Fraction of Full -Load Power
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	083
1.00	1.00

Method 2—Part-Load Fan Power Equation

$$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$$

where

P_{fan} = fraction of full-load fan power.

PLR_{fan} = fan part-load ratio (current cfm/design cfm).

G3.1.3.16 Computer Room Equipment Schedules. Computer room equipment schedules shall be modeled as a constant fraction of the peak design load per the following monthly schedule:

Month 1, 5, 9—25%
Month 2, 6, 10—50%
Month 3, 7, 11—75%
Month 4, 8, 12—100%

G3.1.3.17 System 11 Supply Air Temperature and Fan Control. Minimum volume setpoint shall be 50% of the maximum design airflow rate, the minimum ventilation outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger.

Fan volume shall be reset from 100% airflow at 100% cooling load to minimum airflow at 50% cooling load. Supply air temperature setpoint shall be reset from minimum supply air temperature at 50% cooling load and above to space temperature at 0% cooling load. In heating mode, supply air temperature shall be modulated to maintain space temperature, and fan volume shall be fixed at the minimum airflow.

TABLE G3.4 *Performance Rating Method Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum		Assembly Maximum		Assembly Maximum	
Roofs						
Insulation entirely above deck	U-0.063		U-0.063		U-0.218	
Walls, Above-Grade						
Steel-framed	U-0.124		U-0.064		U-0.124	
Wall, Below-Grade						
Below-grade wall	C-1.140		C-1.140		C-1.140	
Floors						
Steel-joist	U-0.052		U-0.038		U-0.069	
Slab-on-Grade Floors						
Unheated	F-0.730		F-0.730		F-0.730	
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. *SHGC***	**Assembly Max. U**	**Assembly Max. *SHGC***	**Assembly Max. U**	**Assembly Max. *SHGC***
Vertical Glazing, % of *Wall*						
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-1.22	$SHGC_{all}$-NR
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-1.22	$SHGC_{all}$-NR
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-1.22	$SHGC_{all}$-NR
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-0.57	$SHGC_{all}$-0.39	U_{all}-1.22	$SHGC_{all}$-NR
Skylight* All, % of *Roof						
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-0.58	$SHGC_{all}$-0.36	U_{all}-1.36	$SHGC_{all}$-NR
2.1% +	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-0.58	$SHGC_{all}$-0.19	U_{all}-1.36	$SHGC_{all}$-NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), NR = no (insulation) requirement.

a. Exception to Section A3.1.3.1 applies.

TABLE G3.5.1 *Performance Rating Method* Air Conditioners

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure
Air conditioners, air-cooled	<65,000 Btu/h	All	Single-package	9.7 *SEER*	ARI 210/240
	≥65,000 Btu/h and <135,000 Btu/h		Split-*system* and single-package	10.1 *EER*	ARI 340/360
	≥135,000 Btu/h and <240,000 Btu/h			9.5 *EER*	
	≥240,000 Btu/h and <760,000 Btu/h			9.3 *EER* 9.4 *IEER*	
	≥760,000 Btu/h			9.0 *EER* 9.1 *IEER*	

TABLE G3.5.2 *Performance Rating Method* Electrically Operated Unitary and Applied Heat Pumps—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure
Air-cooled (cooling mode)	<65,000 Btu/h	All	Single package	9.7 *SEER*	ARI 210/240
	≥65,000 Btu/h and <135,000 Btu/h		Split-*system* and single-package	9.9 *EER*	ARI 340/360
	≥135,000 Btu/h and <240,000 Btu/h			9.1 *EER*	
	≥240,000 Btu/h			8.8 *EER* 8.9 *IEER*	
Air-cooled (heating mode)	<65,000 Btu/h (cooling capacity)	All	Single-package	6.6 *HSPF*	ARI 210/240
	≥65,000 Btu/h and <135,000 Btu/h (cooling capacity)		47°F db/43°F wb *outdoor air*	3.2 COP_H	ARI 340/360
			17°F db/15°F wb *outdoor air*	2.2 COP_H	
	≥135,000 Btu/h (cooling capacity)		47°F db/43°F wb *outdoor air*	3.1 COP_H	
			17°F db/15°F wb *outdoor air*	2.0 COP_H	

TABLE G3.5.3 *Performance Rating Method* Water Chilling Packages—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure
Water-cooled, electrically operated, positive displacement (rotary screw and scroll)	<150 tons	*kW*/ton	0.790 FL 0.676 *IPLV*.IP	ARI 550/590
	≥150 tons and <300 tons		0.718 FL 0.629 *IPLV*.IP	
	≥300 tons		0.639 FL 0.572 *IPLV*.IP	
Water-cooled, electrically operated, centrifugal	<150 tons	*kW*/ton	0.703 FL 0.670 *IPLV*.IP	ARI 550/590
	≥150 tons and <300 tons		0.634 FL 0.596 *IPLV*.IP	
	≥300 tons		0.576 FL 0.549 *IPLV*.IP	

TABLE G3.5.4 Performance Rating Method Electrically Operated Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
PTAC (Cooling Mode)	All Capacities	95°F db Outdoor air	12.5 – (0.213 × Cap/1000)EER	ARI 310/380
PTHP (Cooling Mode)	All Capacities	95°F db Outdoor air	12.3 – (0.213 × Cap/1000)EER	ARI 310/380
PTHP (Heating Mode)	All Capacities		3.2 – (0.026 × Cap/1000)COP	ARI 310/380

TABLE G3.5.5 Warm-Air Furnaces and Unit Heaters

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
Warm Air Furnace, Gas-Fired	<225,000 Btu/h		78% AFUE or 80% E_t	DOE 10 CFR Part 430 or ANSI Z21.47
	⩾225,000 Btu/h	Maximum Capacity	80% E_c	ANSI Z21.47
Warm Air Unit Heaters, Gas-Fired	All Capacities	Maximum Capacity	80% E_c	ANSI Z83.8

TABLE G3.5.6 Gas-Fired *Boilers*—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure
Boilers, gas-fired	<300,000 Btu/h	Hot water	80% *AFUE*	DOE 10 CFR Part 430
	≥300,000 Btu/h and ≤2,500,000 Btu/h	Maximum capacity	75% E_t	DOE 10 CFR Part 431
	>2,500,000 Btu/h	Hot water	80% E_c	

TABLE G3.6 ***Lighting Power Densities*** **for** ***Building*** **Exterior**

Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.)	**Uncovered Parking Areas**	
	Parking Lots and drives	0.15 W/ft^2
	Building Grounds	
	Walkways less than 10 feet wide	1.0 W/linear foot
	Walkways 10 feet wide or greater Plaza areas Special Feature Areas	0.2 W/ft^2
	Stairways	1.0 W/ft^2
	Building Entrances and Exits	
	Main entries	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width
	Canopies and Overhangs	
	Canopies (free standing and attached and overhangs)	1.25 W/ft^2
	Outdoor Sales	
	Open areas (including vehicle sales lots)	0.5 W/ft^2
	Street frontage for vehicle sales lots in addition to "open area" allowance	20 W/linear foot
Non-Tradable 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 Façades	0.2 W/ft^2 for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
	Automated teller machines and night depositories	270 W per location plus 90 W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	1.25 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
	Drive-up windows at fast food restaurants	400 W per drive-through
	Parking near 24-hour retail entrances	800 W per main entry

TABLE G3.7 *Performance Rating Method Lighting Power Density* Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method

Common *Space* Types[a]	*Lighting Power Density*, W/ft^2	Occupancy Sensor Reduction[b]
Audience Seating Area		
Auditorium	0.90	10%
Convention center	0.70	10%
Exercise center	0.30	10%
Gymnasium	0.40	10%
Motion picture theater	1.20	10%
Penitentiary	0.70	10%
Performing arts theater	2.60	10%
Religious facility	1.70	10%
In a sports arena	0.40	10%
Transportation facility	0.50	10%
All other audience seating area	0.90	10%
Atrium		
≤40 ft in height	0.0375 per foot in total height	10%
>40 ft in height	0.50 + 0.025 per foot in total height	10%
Banking Activity Area	1.50	10%
Breakroom (See Lounge/Breakroom)		
Classroom/Lecture Hall/Training Room		
Penitentiary	1.30	None
Preschool through 12th grade, laboratory, and shop classrooms	1.40	30%
All other classroom/lecture hall/training room	1.40	None
Conference/Meeting/Multipurpose Room	1.30	None
Confinement Cells	0.90	10%
Copy/Print Room	0.90	10%
Corridor		
Facility for the visually impaired (and used primarily by residents)	1.15	25%
Hospital	1.00	25%
Manufacturing facility	0.50	25%
All other corridor	0.50	25%
Courtroom	1.90	10%
Computer Room	2.14	35%

TABLE G3.7 *Performance Rating Method Lighting Power Density* Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method *(Continued)*

Common *Space* Types[a]	*Lighting Power Density*, W/ft^2	Occupancy Sensor Reduction[b]
Dining Area		
Penitentiary	1.30	35%
Facility for the visually impaired (and used primarily by residents)	3.32	35%
Bar/lounge or leisure dining	1.40	35%
Cafeteria or fast food dining	0.90	35%
Family dining	2.10	35%
All other dining area	0.90	35%
Electrical/Mechanical Room	1.50	30%
Emergency Vehicle Garage	0.80	10%
Food Preparation Area	1.20	30%
Guest Room	1.14	45%
Judges Chambers	1.30	30%
Laboratory		
In or as a classroom	1.40	None
All other laboratory	1.40	10%
Laundry/Washing Area	0.60	10%
Loading Dock, Interior	0.59	10%
Lobby		
Facility for the visually impaired (and used primarily by residents)	2.26	25%
Elevator	0.80	25%
Hotel	1.10	25%
Motion picture theater	1.10	25%
Performing arts theater	3.30	25%
All other lobby	1.30	25%
Locker Room	0.60	25%
Lounge/Breakroom		
Healthcare facility	0.80	None
All other lounge/breakroom	1.20	None
Office		
Enclosed	1.10	30%
Open plan	1.10	15%[c]
Parking Area, Interior	0.20	15%
Pharmacy Area	1.20	10%
Restroom		
Facility for the visually impaired (and used primarily by residents)	1.52	45%
All other restroom	0.90	45%

TABLE G3.7 *Performance Rating Method Lighting Power Density* Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method *(Continued)*

Common *Space* Types[a]	***Lighting Power Density*, W/ft^2**	**Occupancy Sensor Reduction[b]**
Sales Area	1.70	15%
Seating Area, General	0.68	10%
Stairwell	0.60	75%
Storage Room		
Hospital	0.90	45%
≥50 ft^2	0.80	45%
<50 ft^2	0.80	45%
Vehicular Maintenance Area	0.70	10%
Workshop	1.90	10%
***Building* Type Specific *Space* Types[a]**	***Lighting Power Density*, W/ft^2**	**Occupancy Sensor Reduction[b]**
Assisted Living Facility		
Chapel (used primarily by residents)	2.77	10%
Recreation room (used primarily by residents)	3.02	10%
Automotive (See "Vehicular Maintenance Area")		10%
Convention Center—Exhibit *Space*	1.30	35%
Dormitory—Living Quarters	1.11	10%
Fire Station—Sleeping Quarters	0.30	10%
Gymnasium/Fitness Center		
Exercise area	0.90	35%
Playing area	1.40	35%
Healthcare Facility		
Emergency room	2.70	10%
Exam/treatment room	1.50	10%
Medical supply room	1.40	45%
Nursery	0.60	10%
Nurse's station	1.00	10%
Operating room	2.20	10%
Patient room	0.70	10%
Physical therapy room	0.90	10%
Recovery room	0.80	10%
Library		
Reading area	1.20	15%
Stacks	1.70	15%

TABLE G3.7 *Performance Rating Method Lighting Power Density* Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method *(Continued)*

***Building* Type Specific *Space* Types**[a]	***Lighting Power Density*, W/ft²**	**Occupancy Sensor Reduction**[b]
Manufacturing Facility		
Detailed manufacturing area	2.10	10%
Equipment room	1.20	10%
Extra-high bay area (>50 ft *floor*-to-ceiling height)	1.32	10%
High bay area (25 to 50 ft *floor*-to-ceiling height)	1.70	10%
Low bay area (<25 ft *floor*-to-ceiling height)	1.20	10%
Museum		
General exhibition area	1.00	10%
Restoration room	1.70	10%
Post Office—Sorting Area	1.20	10%
Religious Facility		
Fellowship hall	0.90	10%
Worship/pulpit/choir area	2.40	10%
Retail Facilities		
Dressing/fitting room	0.89	10%
Mall concourse	1.70	10%
Sports Arena—Playing Area		
Class I facility	4.61	10%
Class II facility	3.01	10%
Class III facility	2.26	10%
Class IV facility	1.50	10%
Transportation Facility		
Baggage/carousel area	1.00	10%
Airport concourse	0.60	10%
Terminal ticket counter	1.50	10%
Warehouse—Storage Area		
Medium to bulky, palletized items	0.90	45%
Smaller, hand-carried items	1.40	45%

a. In cases where both a common *space* type and a *building* area specific *space* type are listed, the *building* area specific *space* type shall apply.
b. For *manual*-ON or partial-auto-ON occupancy sensors, the occupancy sensor reduction factor shall be multiplied by 1.25.
c. For occupancy sensors controlling individual workstation lighting, occupancy sensor reduction factor shall be 30%.

TABLE G3.8 *Performance Rating Method Lighting Power Densities* Using the *Building* Area Method

Building Area Type	LPD (W/ft^2)
Automotive facility	0.90
Convention center	1.20
Courthouse	1.20
Dining: bar lounge/leisure	1.30
Dining: cafeteria/fast food	1.40
Dining: family	1.60
Dormitory	1.00
Exercise center	1.00
Fire station	1.00
Gymnasium	1.10
Health-care clinic	1.00
Hospital	1.20
Hotel	1.09
Library	1.30
Manufacturing facility	1.17
Motion picture theater	1.20
Multifamily	0.70
Museum	1.10
Office	1.00
Parking garage	0.30
Penitentiary	1.00
Performing arts theater	1.60
Police station	1.00
Post office	1.10
Religious building	1.30
Retail	1.50
School/university	1.20
Sports arena	1.10
Town hall	1.10
Transportation	1.00
Warehouse	0.80
Workshop	1.40

TABLE G3.9.1 *Performance Rating Method* Motor *Efficiency* Requirements

Motor Horsepower	Minimum Nominal Full-Load *Efficiency*, %
1.0	82.5
1.5	84.0
2.0	84.0
3.0	87.5
5.0	87.5
7.5	89.5
10.0	89.5
15.0	91.0
20.0	91.0
25.0	92.4
30.0	92.4
40.0	93.0
50.0	93.0
60.0	93.6
75.0	94.1
100.0	94.5
125.0	94.5
150.0	95.0
200.0	95.0

TABLE G3.9.2 *Performance Rating Method* Baseline Elevator Motor

Number of Stories (Including Basement)	Motor Type	Counterweight	Mechanical *Efficiency*	Motor Efficiency[a]
≤4	Hydraulic	None	58%	Table G3.9.3
>4	Traction	*Proposed design* counterweight, if not specified use weight of the car plus 40% of the rated load	64%	Table G3.9.1

a. Use the efficiency for the next motor size greater than the calculated bhp.

TABLE G3.9.3 *Performance Rating Method* Hydraulic Elevator Motor *Efficiency*

Horsepower	Full-Load *Efficiency*
10	72%
20	75%
30	78%
40	78%
100	80%

TABLE G3.10.1 *Performance Rating Method* Commercial Refrigerators and Freezers

Equipment Type	Application	*Energy* Use Limits, kWh/day	Test Procedure
Refrigerator with solid *doors*	Holding temperature	$0.125 \times V + 2.76$	AHRI 1200
Refrigerator with transparent *doors*		$0.172 \times V + 4.77$	
Freezers with solid *doors*		$0.398 \times V + 2.28$	
Freezers with transparent *doors*		$0.94 \times V + 5.10$	
Refrigerators/freezers with solid *doors*		$0.12 \times V + 4.77$	
Commercial refrigerators	Pulldown	$0.181 \times V + 5.01$	

Note: *V* is the chiller or frozen compartment volume (ft^3) as defined in Association of Home Appliance Manufacturers Standard HRF-1.

TABLE G3.10.2 *Performance Rating Method* Commercial Refrigeration

***Equipment* Type**

***Equipment* Class**[a]	**Family Code**	**Operating Mode**	**Rating Temperature**	***Energy* Use Limits,**[b,c] **kWh/day**	**Test Procedure**
VOP.RC.M	Vertical open	Remote condensing	Medium temperature	1.01 × TDA + 4.07	AHRI 1200
SVO.RC.M	Semivertical open	Remote condensing	Medium temperature	1.01 × TDA + 3.18	
HZO.RC.M	Horizontal open	Remote condensing	Medium temperature	0.51 × TDA + 2.88	
VOP.RC.L	Vertical open	Remote condensing	Low temperature	2.84 × TDA + 6.85	
HZO.RC.L	Horizontal open	Remote condensing	Low temperature	0.68 × TDA + 6.88	
VCT.RC.M	Vertical transparent *door*	Remote condensing	Medium temperature	0.48 × TDA + 1.95	
VCT.RC.L	Vertical transparent *door*	Remote condensing	Low temperature	1.03 × TDA + 2.61	
SOC.RC.M	*Service* over counter	Remote condensing	Medium temperature	0.62 × TDA + 0.11	
VOP.*SC*.M	Vertical open	Self-contained	Medium temperature	2.34 × TDA + 4.71	
SVO.*SC*.M	Semivertical open	Self-contained	Medium temperature	2.23 × TDA + 4.59	
HZO.*SC*.M	Horizontal open	Self-contained	Medium temperature	1.14 × TDA + 5.55	
HZO.*SC*.L	Horizontal open	Self-contained	Low temperature	2.63 × TDA + 7.08	
VCT.*SC*.I	Vertical transparent *door*	Self-contained	Ice cream	1.63 × TDA + 3.29	
VCS.*SC*.I	Vertical solid *door*	Self-contained	Ice cream	0.55 × *V* + 0.88	
HCT.*SC*.I	Horizontal transparent *door*	Self-contained	Ice cream	1.33 × TDA + 0.43	
SVO.RC.L	Semivertical open	Remote condensing	Low temperature	2.84 × TDA + 6.85	
VOP.RC.I	Vertical open	Remote condensing	Ice cream	3.6 × TDA + 8.7	
SVO.RC.I	Semivertical open	Remote condensing	Ice cream	3.6 × TDA + 8.7	
HZO.RC.I	Horizontal open	Remote condensing	Ice cream	0.87 × TDA + 8.74	
VCT.RC.I	Vertical transparent *door*	Remote condensing	Ice cream	1.2 × TDA + 3.05	

TABLE G3.10.2 *Performance Rating Method* Commercial Refrigeration *(Continued)*

***Equipment* Type**

***Equipment* Class**[a]	**Family Code**	**Operating Mode**	**Rating Temperature**	***Energy* Use Limits,**[b,c] **kWh/day**	**Test Procedure**
HCT.RC.M	Horizontal transparent *door*	Remote condensing	Medium temperature	0.39 × TDA + 0.13	AHRI 1200
HCT.RC.L	Horizontal transparent *door*	Remote condensing	Low temperature	0.81 × TDA + 0.26	
HCT.RC.I	Horizontal transparent *door*	Remote condensing	Ice cream	0.95 × TDA + 0.31	
VCS.RC.M	Vertical solid *door*	Remote condensing	Medium temperature	0.16 × *V* + 0.26	
VCS.RC.L	Vertical solid *door*	Remote condensing	Low temperature	0.33 × *V* + 0.54	
VCS.RC.I	Vertical solid *door*	Remote condensing	Ice cream	0.39 × *V* + 0.63	
HCS.RC.M	Horizontal solid *door*	Remote condensing	Medium temperature	0.16 × *V* + 0.26	
HCS.RC.L	Horizontal solid *door*	Remote condensing	Low temperature	0.33 × *V* + 0.54	
HCS.RC.I	Horizontal solid *door*	Remote condensing	Ice cream	0.39 × *V* + 0.63	
SOC.RC.L	*Service* over counter	Remote condensing	Low temperature	1.3 × TDA + 0.22	
SOC.RC.I	*Service* over counter	Remote condensing	Ice cream	1.52 × TDA + 0.26	
VOP.*SC*.L	Vertical open	Self contained	Low temperature	5.87 × TDA + 11.82	
VOP.*SC*.I	Vertical open	Self-contained	Ice cream	7.45 × TDA + 15.02	
SVO.*SC*.L	Semivertical open	Self-contained	Low temperature	5.59 × TDA + 11.51	
SVO.*SC*.I	Semivertical open	Self-contained	Ice cream	7.11 × TDA + 14.63	
HZO.*SC*.I	Horizontal open	Self-contained	Ice cream	3.35 × TDA + 9.0	
SOC.*SC*.I	*Service* over counter	Self-contained	Ice cream	2.13 × TDA + 0.36	
HCS.*SC*.I	Horizontal solid *door*	Self-contained	Ice cream	0.55 × *V* + 0.88	

a. *Equipment* class designations consist of a combination (in sequential order separated by periods [AAA].[BB].[C]) of the following: (AAA) An *equipment* family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical transparent *doors*, VCS = vertical solid *doors*, HCT = horizontal transparent *doors*, HCS = horizontal solid *doors*, and SOC = *service* over counter); (BB) An operating mode code (RC = remote condensing and *SC* = self-contained); and (C) A rating temperature code (M = medium temperature [38°F], L = low temperature [0°F], or I = ice cream temperature [15°F]). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" *equipment* class.

b. V is the volume of the case (ft^3) as measured in AHRI Standard 1200, Appendix C.

c. TDA is the total display area of the case (ft^2) as measured in AHRI Standard 1200, Appendix D.

APPENDIX Z
NET-ZERO ENERGY COMPLIANCE PATH

Z1. GENERAL. Appendix Z is intended to be an optional alternative compliance path for projects to comply with the energy conservation code-commercial provisions.

The design of a *net-zero energy building* shall be achieved through the use of three complementary approaches, to be employed to the maximum extent feasible, in the following order:

1. Reducing building energy demand for heating, cooling, lighting and ventilation through the use of passive design and improved envelope performance techniques.
2. Reducing total building energy demand through the installation of high-efficiency mechanical systems, hot water systems, power systems, lighting, and process equipment.
3. Supplying remaining building energy needs from renewable sources of energy.

Appendix Z draws on existing requirements outlined in the *Energy Conservation Code—Commercial Provisions.* Additional minimum performance requirements for building thermal energy performance and airtightness testing have been set to ensure new construction achieves a high degree of energy conservation.

Z1.1 Definitions. In addition to definitions contained in Chapter 2 of the *Building Code* and in Section 3.2 of the *Energy Conservation Code—Commercial Provisions*, the following definitions shall apply to projects opting to use Appendix Z:

Airtightness. The rate of air leakage through the building envelope, measured in cubic feet per minute per square foot of building envelope (cfm/ft^2_{env}), at 0.0109 psig (75 Pa) of pressure differential.

Annual cooling demand. The total amount of thermal energy required to cool a building over the course of a year, measured in thousands of British thermal units per square foot of interior conditioned floor area, per year ($kBtu/ft^2_{iCFA}/yr$).

Annual heating demand. The total amount of thermal energy required to heat a building over the course of a year, measured in thousands of British thermal units per square foot of interior conditioned floor area, per year ($kBtu/sf_{iCFA}/yr$).

Energy Use Intensity (EUI). The annual energy use of the building expressed in kBtu divided by square feet ($kBtu/ft^2$).

Low-carbon neighborhood thermal energy system. A district-scale energy system that uses acceptable sources of renewable energy per Section Z3.2 to produce steam, hot water, or chilled water for the purposes of providing for building heating, cooling, and/or domestic hot water needs.

Net-zero energy building. A highly energy-efficient building that produces on-site, or procures through the construction of new renewable energy generation, enough energy to meet or exceed the annual energy consumption of its operations.

Renewable energy microgrid. (As defined by the U.S. Department of Energy) A group of interconnected loads and distributed renewable energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid.

Zero Energy Performance Index (zEPI). A scale representing the ratio of the energy performance of a proposed design or an existing building compared to the mean energy performance of the building stock from the benchmark year of 2000 (Commercial Buildings Energy Consumption Survey, US Department of Energy, 2003 Average).

Z1.2 Scope and Intent. The provisions of Appendix Z regulate the design, construction, commissioning and operation of buildings and their associated building sites for compliance with the *Energy Conservation Code—Commercial Provisions*. The intent of this Appendix is the reduction of energy use to achieve net-zero performance.

Z1.3 Administration and Enforcement. Administration and enforcement of Appendix Z shall be governed by Chapter 1 of the *Building Code*, 12-A DCMR.

Z1.4 Application. The provisions of Appendix Z shall apply to each project that is new construction, or classified as a Level 3 alteration under the *Existing Building Code*, and for which this compliance path option has been chosen.

Z1.5 Compliance. Compliance with Appendix Z requires that the building and its site comply with the provisions of Sections Z2, Z3, Z4, and Z5.

Z2. MINIMUM PERFORMANCE REQUIREMENTS. Minimum performance requirements for building energy use intensity have been set to ensure maximum energy efficiency prior to adding renewable energy generation. The building and its site shall be designed and constructed to meet the mandatory prescriptive requirements in Sections Z2.1, Z.2, Z.3, Z.4, and Z.5.

Z2.1 Building Energy Use Intensity. Applicant shall submit, with the building permit application, *permit documents* with data and calculations sufficient to ascertain compliance with the net-zero energy performance target for buildings and their sites, using predictive modeling. Predictive modeling shall use a source energy unit of measurement, expressed in $kBtu/ft^2/yr$, based on the use of the *Zero Energy Performance Index (zEPI*) as outlined in section Z2.1.1. In a mixed-use building, all uses shall be included in demonstrating compli-

ance, and an area-weighted calculation method shall be used to account for each use.

Z2.1.1 Zero Energy Performance Index, zEPI. Building design shall demonstrate a zEPI of 30 or lower as determined in accordance with Equation 1.

$$zEPI = 50.4 \times (EUIp/EUI) \quad \text{(Equation 1)}$$

Where:

EUIp = The annual energy use of the building in source kBtu/ft^2, for the proposed design of the building and its site, calculated in accordance with Section Z2.1.2, not taking into account any on-site or off-site renewable energy.

EUI = The annual energy use of the building in source kBtu/ft^2 for a baseline building and its site, calculated in accordance with Section Z2.1.2, not taking into account any on-site or off-site renewable energy.

Z2.1.2 Annual Energy Use Indices. The EUIp of the building and building site, and the EUI, shall be calculated in accordance with Appendix G to ASHRAE 90.1-2016, as modified by Sections Z2.1.2.1 and Z2.1.2.2, and *approved* modeling guidelines published by the *Department* in *administrative bulletins*. The annual energy use shall include all energy used for the building systems and its anticipated occupancies.

Z2.1.2.1 Additional Modeling Rules and Procedures. Modeling inputs shall be in accordance with the *COMNet Rules and Procedures Manual.*

Z2.1.2.2 Electricity. In calculating the annual energy use indices, consistent units shall be used for electric energy use, converting the electric energy use, measured at the utility meter or metered point of delivery from kWh to kBtu. KWh shall be converted to kBtu by multiplying the annual electric energy use, in kWh, by 3.412 kBtu/kWh. and multiplying the result by the dimensionless conversion factor found in Table Z2.1.2.2.

TABLE Z2.1.2.2 ELECTRICITY GENERATION ENERGY CONVERSION FACTOR BASED ON EPA eGRID SUB-REGION

eGRID 2010 SUB-REGION ACRONYM	eGRID 2010 SUB-REGION NAME	CONVERSION FACTOR
RFCE	RFC East	3.28

Z2.2 Building Thermal Energy Performance. Building thermal energy performance shall comply with Sections Z2.2.1 through Z2.2.2.

Z2.2.1 Annual Heating Demand. Building design shall demonstrate a maximum *annual heating demand* of 4.2 kBtu/ft^2 $_{iCFA}$/yr (4.8×10^4 kJ/m^2 $_{iCFA}$/yr).

Z2.2.2 Annual Cooling Demand. Building design shall demonstrate a maximum *annual cooling demand* of 6.4 kBtu/ft^2 $_{iCFA}$/yr (7.3×10^4 kJ/m^2 $_{iCFA}$/yr).

Z2.3 Multiple Buildings on a Site. Where there is more than one building on a site, each building shall comply with Sections Z2.2.1 and Z2.2.2 or the combined demands of all the buildings on the site shall comply with Sections Z2.2.1 and Z2.2.2.

Z2.3.1 Assignment of Energy to Multiple Buildings on a Site. For building sites employing district energy systems and with multiple buildings, the energy use associated with the building site shall be assigned to each building proportionally to the gross floor area of each building as a fraction of the total gross floor area of all buildings on the building site. Where energy is derived from either renewable or waste energy, or both sources, either located on the building site, within individual buildings, or on individual buildings and delivered to multiple buildings, the energy so derived shall be assigned on a proportional basis to the buildings served, based on each served building gross floor area. Energy delivered from renewable or waste energy sources located on or within a building shall be assigned to that building.

Exception: Where it can be shown that energy to be used at the building site is associated with a specific building, that energy use shall be assigned to that specific building.

Z2.4 Registered Design Professional in Responsible Charge of Building Energy Simulation. Where the *applicant* chooses to utilize Appendix Z as the path of compliance with the *Energy Conservation Code—Commercial Provisions*, the owner shall engage the services of, and designate on the building permit application, a registered design professional who shall act as the registered design professional in responsible charge of building energy simulation. Building energy simulation services engaged by the registered design professional shall be certified by an *approved* accrediting entity as determined by the *code official*. As authorized by the *code official*, the owner is allowed to designate a substitute registered design professional who shall perform the duties required of the original registered design professional in responsible charge of building energy simulation. The owner shall notify the *code official*, in writing, whenever the registered design professional in responsible charge of building energy simulation is changed or is unable to continue to perform his or her duties.

Z2.5 Building Commissioning. All systems shall be commissioned in accordance with this section and the *Energy Conservation Code—Commercial Provisions*. Energy systems commissioning and completion shall be performed for the following systems and their associated controls:

- Building envelope;
- HVAC (both mechanical and passive systems as well as HVAC controls);
- Lighting, daylighting, and lighting control systems;

- Domestic hot water systems; and
- Renewable energy systems.

Z2.6 Airtightness Testing. A whole building pressurization testing shall be conducted in accordance with Section 11.3.1.2.4(a) of the *Energy Conservation Code – Commercial Provisions* to measure the airtightness of the building envelope. The owner shall verify that the airtightness specified in the final approved predictive energy model is achieved in the field by providing the *code official* with a copy of the test results before the final *Certificate of Occupancy* is issued.

Z3. RENEWABLE ENERGY. The building and building site shall be provided with renewable energy equal to the EUI_P on an annual basis and calculated in accordance with Section Z2.1.1. Sources of renewable energy shall comply with Sections Z3.1 through Z3.3.

Z3.1 On-site Combustion. On-site combustion of fossil fuels shall not be permitted for the provision of thermal energy to the building except as specified by the *code official.*

Z3.2 Acceptable Sources of Renewable Energy. Acceptable sources of on-site renewable energy to be used on the building site include:

- Photovoltaic panels.
- Solar thermal systems.
- Wind turbines.
- Biogas.

No other source of on-site renewable energy is acceptable for building design, unless the rationale for its selection is approved by the *code official*.

Z3.3 On-site Renewable Energy. Renewable energy shall be generated on-site wherever feasible. Before procuring off-site renewable energy, a project must demonstrate one of the following:

1. A minimum of 5% of the total building energy consumption shall first be met by an acceptable source of renewable energy installed on the building roof or site.
2. For projects generating onsite renewable energy through solar photovoltaic systems, a minimum of 25% of total site area, including building footprint, shall be allocated for photovoltaic array and energy production.

Exception: Where there is not adequate solar access as determined by Chapter 13 of the *Energy Conservation Code—Commercial Provisions.*

Z3.4 Procurement of Off-site Renewable Energy. The procurement of off-site renewable energy is acceptable only where the energy is procured from a qualified electricity supplier providing energy from Tier 1 renewable sources meeting the minimum percentages of the District of Columbia Renewable Portfolio Standard. Acceptable methods for the procurement of off-site renewable energy include any of the following or as approved by the *code official*:

- Owner shall provide the *code official* with documentation of a signed, legally-binding contract to procure off-site renewable energy through a power purchase agreement for a minimum period of 5 years for electricity generation from, solar or wind-generation facilities that are located within the District of Columbia, Maryland, or Virginia. The owner remains subject to, and must comply with, the District of Columbia's Renewable Portfolio Standard.
- Connection to a *renewable energy microgrid*.
- Connection to a *low-carbon neighborhood thermal energy system*.

Z4. ENERGY METERING, MONITORING AND REPORTING.

Z4.1 Scope. The provisions of this Section Z4 shall apply to all projects that opted for Appendix Z as a path of code compliance.

Z4.2 Purpose. The purpose of Section Z4 is to provide requirements that will ensure that buildings are constructed or altered in a way that will provide the capability for their energy use, production and reclamation to be measured, monitored and reported. This includes the design of energy distribution systems so as to isolate load types, the installation of meters, devices and a data acquisition system, and the installation of energy displays and other appropriate reporting mechanisms.

Z4.3 Energy Metering. All forms of energy delivered to the building and building site or produced on the building site or in the building, shall be metered and all energy load types measured.

Z4.4 Ventilation Flow Rate. In addition to requirements outlined in the *Energy Conservation Code—Commercial Provisions*, all centrally ventilated building systems shall be designed to enable the collection of real-time and historical ventilation flow rate data.

Z4.5 Grid Integration. In places where equipment constraints in the distribution network render net metering impossible, onsite storage options shall be considered.

Z5. ENERGY REPORTING. Owners of buildings that used Appendix Z as a path for code compliance shall comply with this section.

Z5.1 Post Occupancy Measurement and Reporting.

Z5.1.1 Owners of buildings that use Appendix Z as a path for code compliance shall annually benchmark and report their energy and water performance using the Energy Star® Portfolio Manager tool, including renewable energy generation and green power usage, pursuant to rules in *20 DCMR 3513,* regardless of square footage.

Z5.1.2 Energy Star Portfolio Manager Account. The *owner* of a *building* that used Appendix Z as a path for compliance with the *Energy Conservation Code—Commercial*

Provisions shall create an Energy Star® Portfolio Manager account and property record on the U.S. Environmental Protection Agency's benchmarking website, and share the property with the District of Columbia's Department of Energy and Environment. The *code official* is authorized to require proof of compliance with Section Z5.3.1 and proof that all utilities have been linked to the account.

Z5.2 Performance Verification. Within 24 months of occupancy, the owner or owner's representative shall submit documentation to the *code official* demonstrating 12 continuous months of operation with no less than 90% occupancy where the energy consumed by the building and building site as measured in accordance with Section Z4 are equal to or less than the renewable energy associated with the building and building site in accordance with Section Z3. Documentation shall be in a form acceptable to the *code official.*

Z5.2.1 Normalization for abnormal conditions. At the discretion of the *code official*, the owner or owner's representative may submit documentation demonstrating that abnormal weather or occupancy conditions during the compliance period are responsible for the variance between the energy consumed by the energy and energy site and the renewable energy associated with the building and building site and that the building would comply with Z5.2 under normal conditions.

Z6. NORMATIVE REFERENCES

Section numbers indicate where the reference occurs in Appendix Z.

Standard Reference number	Title	Referenced in code section number
U.S. Army Corps of Engineers **441 G Street NW, Washington, DC 20314-1000**		
Version 3: 2012-05-11	Air Leakage Test Protocol for Building Envelopes	Appendix Z, Z2.6
Passive House Institute US (PHIUS) **116 W Illinois Street, #5e, Chicago, IL 60654**		
Version 1.03 July 27 2016	Passive Building Standard for North America	Appendix Z, Z.1
RESNET **P.O Box 4561, Oceanside, CA 92052** www.resnet.us		
August 16, 2010	*COMNET Rules and Procedures Manual*	Appendix Z, Z2.1.2.1

DC ENERGY CONSERVATION CODE—RESIDENTIAL PROVISIONS

TABLE OF CONTENTS

CHAPTER 1 [RE]

SCOPE AND ADMINISTRATION

PART 1—SCOPE AND APPLICATION

SECTION R101
SCOPE AND GENERAL REQUIREMENTS

R101.1 General. Administration and enforcement of the *Energy Conservation Code—Residential Provisions* shall be governed by Chapter 1 of the *Building Code*, Title 12-A DCMR.

R101.2 Scope. The scope of the *Energy Conservation Code—Residential Provisions* shall be as defined in Chapter 1 of Title 12-A DCMR.

CHAPTER 2 [RE]

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 *Building Code*, *Fire Code*, *Fuel Gas Code*, *Mechanical Code*, *Plumbing Code* or the *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, retrofit or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a building, electrical, gas, mechanical or plumbing system that involves an extension, addition or change to the arrangement, type or purpose of the original installation that requires a permit.

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

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

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 SITE. A continguous 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 provide 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 ($Btu/h \cdot ft^2 \cdot °F$) [$W/(m^2 \cdot K)$].

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

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

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

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

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

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

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

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

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.

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.

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

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

ERI REFERENCE DESIGN. A version of the rated design that meets the minimum requirements of the 2006 *International Energy Conservation Code.*

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

FENESTRATION. Products classified as either *vertical fenestration* or *skylights*.

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

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

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. LED, compact fluorescent lamps (CFLs), 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.
3. 40 lumens per watt for lamps 15 watts or less.

HISTORIC BUILDING. Any building or structure that is one or more of the following:

1. Listed, or certified as eligible for listing by the State Historic Preservation Officer or the Keeper of the National Register of Historic Places, in the National Register of Historic Places.
2. Designated as historic under an applicable state or local law.
3. Certified as a contributing resource within a National Register-listed, state-designated or locally designated historic district.

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.

INSULATED SIDING. A type of continuous insulation with manufacturer-installed insulating material as an integral part of the cladding product having a minimum *R*-value of R-2.

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 where 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 where the 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").

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

RATED DESIGN. A description of the proposed *building* used to determine the energy rating index.

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 for the purpose of its maintenance or to correct damage.

REROOFING. The process of recovering or replacing an existing *roof covering*. See "Roof recover" and "Roof replacement."

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

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

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

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

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

***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 ($h \cdot ft^2 \cdot °F/Btu$) [$(m^2 \cdot K)/W$].

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.

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.

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.

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 set point.

***U*-FACTOR (THERMAL TRANSMITTANCE).** The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films ($Btu/h \cdot ft^2 \cdot °F$) [$W/(m^2 \cdot K)$].

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.

VERTICAL FENESTRATION. Windows (fixed or moveable), opaque doors, glazed doors, glazed block and combination opaque/glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of a least 60 degrees (1.05 rad) from horizontal.

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.

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 [RE]

GENERAL REQUIREMENTS

SECTION R301
DISTRICT OF COLUMBIA CLIMATE ZONE

R301.1 General. The District of Columbia, Virginia and Maryland are located in *Climate Zone* 4A in accordance with Figure R301.1.

SECTION R302
DESIGN CONDITIONS

R302.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be not greater than 72°F (22°C) for heating and not less than 75°F (24°C) for cooling.

SECTION R303
MATERIALS, SYSTEMS AND EQUIPMENT

R303.1 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.

R303.1.1 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. Alternatively, the insulation installers shall provide a certification listing the type, manufacturer and *R*-value of insulation installed in each element of the *building thermal envelope*. For blown or sprayed insulation (fiberglass and cellulose), the initial installed thickness, settled thickness, settled *R*-value, installed density, coverage area and number of bags installed shall be *listed* on the certification. For sprayed polyurethane foam (SPF) insulation, the installed thickness of the areas covered and *R*-value of installed thickness shall be *listed* on the certification. For insulated siding, the *R*-value shall be labeled on the product's package and shall be *listed* on the certification. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

R303.1.1.1 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 m^2) throughout the attic space. The markers shall be affixed to the trusses or joists and marked with the minimum initial installed thickness with numbers not less than 1 inch (25 mm) in height. Each marker shall face the attic access opening. Spray polyurethane foam thickness and installed *R*-value shall be *listed* on certification provided by the insulation installer.

R303.1.2 Insulation mark installation. Insulating materials shall be installed such that the manufacturer's *R*-value mark is readily observable upon inspection.

R303.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100.

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

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

Products lacking such a *labeled U*-factor shall be assigned a default *U*-factor from Table R303.1.3(1) or R303.1.3(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 R303.1.3(3).

R303.1.4 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 $h \cdot ft^2 \cdot °F/Btu$ at a mean temperature of 75°F (24°C).

R303.1.4.1 Insulated siding. The thermal resistance (*R*-value) of insulated siding shall be determined in accordance with ASTM C 1363. Installation for testing shall be in accordance with the manufacturer's instructions.

R303.2 Installation. Materials, systems and equipment shall be installed in accordance with the manufacturer's instructions and the *Building Code* or *Residential Code*, as applicable.

R303.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawlspace walls and the perimeter of slab-on-grade floors shall have a rigid, opaque and weather-resistant protective covering to prevent the degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend not less than 6 inches (153 mm) below grade.

R303.3 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.

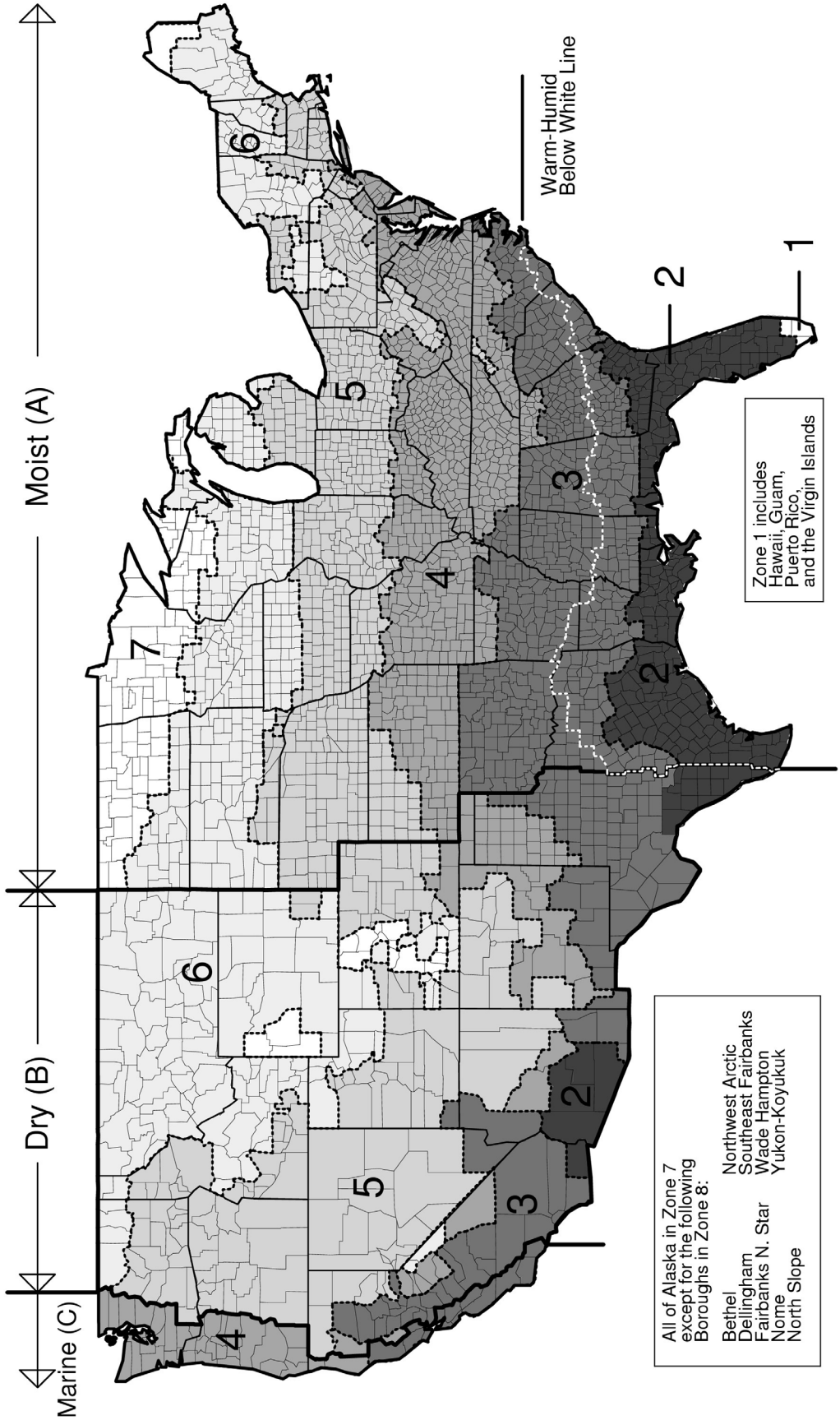

FIGURE R301.1
CLIMATE ZONES

TABLE R303.1.3(1)
DEFAULT GLAZED FENESTRATION *U*-FACTORS

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 R303.1.3(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 R303.1.3(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 [RE]

RESIDENTIAL ENERGY EFFICIENCY

SECTION R401
GENERAL

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

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401 through R405.
2. Section R406.

R401.3 Certificate (Mandatory). For new construction and Level 3-*alteration* projects, an *approved* permanent certificate shall be completed by the builder or registered design professional and posted on a wall in the space where the furnace is located, a utility room or an *approved* location inside the building. Where located on an electrical panel, the certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label or other required labels. The certificate shall list the predominant *R*-values of insulation installed in or on ceiling/roof, walls, foundation (slab, basement wall, crawlspace wall and 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.

SECTION R402
BUILDING THERMAL ENVELOPE

R402.1 General (Prescriptive). The *building thermal envelope* shall meet the requirements of Sections R402.1.2 through R402.1.5.

Exception: The following low-energy buildings, or portions thereof, separated from the remainder of the building by building thermal envelope assemblies complying with this section shall be exempt from the building thermal envelope provisions of Section R402.

1. Those with a peak design rate of energy usage less than 3.4 Btu/h · ft^2 (10.7 W/m^2) or 1.0 watt/ft^2 of floor area for space-conditioning purposes.
2. Those that do not contain conditioned space.

R402.1.1 [Reserved]

R402.1.2 Insulation and fenestration criteria. The *building thermal envelope* shall meet the requirements of Table R402.1.2.

R402.1.3 *R*-value computation. Insulation material used in layers, such as framing cavity insulation, or continuous insulation shall be summed to compute the corresponding 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. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table R402.1.2, the manufacturer's labeled *R*-value for insulated siding shall be reduced by R-0.6.

R402.1.4 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table R402.1.4 shall be permitted as an alternative to the *R*-value in Table R402.1.2.

TABLE R402.1.4
EQUIVALENT *U*-FACTORS[a]

Fenestration U-Factor	0.30 *U*-Factor
Skylight U-Factor	0.55 *U*-Factor
Ceiling U-Factor	0.026 v-Factor
Wood Frame Wall U-Factor	0.045 *U*-Factor
Mass Wall U-Factor	0.060 *U*-Factor
Frame Floor U-Factor	0.033 *U*-Factor
Elevated Slab	0.066 *U*-Factor
Mass Floor U-Factor	0.058 *U*-Factor
Basement Wall U-Factor	0.045 *U*-Factor
Conditioned Crawlspace Wall U-Factor	0.045 *U*-Factor

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.

R402.1.5 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 R402.1.4 (multiplied by the same assembly area as in the proposed building), the building shall be considered in compliance with Table R402.1.2. 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.

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 R402.2.13.

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

Fenestration *U*-Factor[b]	0.30 *U*-Factor
Skylight[b] *U*-Factor	0.55 *U*-Factor
Glazed Fenestration SHGC[b]	0.40 Solar Heat Gain Coefficient (SHGC)
Ceiling	R-49
Wood Frame Wall and Rim Joists	R-19 in cavity + R-5 continuous on the exterior, **or** R-13 in cavity + R-10 continuous on the exterior, **or** R-15 continuous
Mass Wall[c]	R-15 continuous on the exterior, or R-20 continuous on the interior
Frame Floor	R-25 + R-5 continuous
Elevated Slab	R-15 continuous
Basement Wall	R-19 cavity + R-5 continuous on the exterior, **or** R-13 in cavity + R-10 continuous on the exterior, **or** R-15 continuous
Slab on Grade[d]	R-10 perimeter insulation for a depth of 2 ft.
Conditioned Crawlspace Wall	R-19 cavity + R-5 continuous on the exterior, **or** R-13 in cavity + R-10 continuous on the exterior, **or** R-15 continuous

For SI: 1 foot = 304.8 mm.

a. *R*-values are minimums. *U*-factors and SHGC are maximums. When insulation is installed in a cavity which 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.

b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.

c. The second *R*-value applies when more than half the insulation is on the interior of the mass wall.

d. R-5 shall be added to the required slab edge *R*-values for heated slab.

R402.2.1 Ceilings with attic spaces. Where Section R402.1.2 would require R-49 insulation in the ceiling but the depth of the roof rafters does not allow R-49, the ceiling insulation value may be reduced to R-38. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

R402.2.2 [Reserved]

R402.2.3 Eave baffle. For air-permeable insulation in vented attics utilizing eave vents, 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 may be any solid material.

R402.2.4 Access hatches and doors. Access doors from conditioned spaces to unconditioned spaces such as attics and crawl spaces shall be weatherstripped 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.

Exception: Vertical doors that provide access from conditioned to unconditioned spaces shall be permitted to meet the fenestration requirements of Table R402.1.2.

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, or any other walls having a heat capacity greater than or equal to 6 Btu/ft^2 × °F (123 kJ/m^2 × K).

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 R402.1.4. The calculation of the *U*-factor for a steel-frame envelope assembly shall use a series-parallel path calculation method.

R402.2.7 Walls with partial structural sheathing. Where Section R402.1.2 would require continuous insulation on exterior walls and structural sheathing covers 40 percent or less of the gross area of all exterior walls, the continuous insulation *R*-value shall be permitted to be reduced by an amount necessary to result in a consistent

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″ on center	
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-19 + 5	R-15 continuous or R-13 + 12.2 or R-15 + 11.8 or R-19 + 11.2 or R-21 + 10.9 or R-25 + 10.5
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″ on center	
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-19 + 5	R-15 continuous or R-13 + 11.1 or R-15 + 10.4 or R-19 + 9.7 or R-21 + 9.2 or R-25 + 8.7
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
R-25 + 5	R-15 + 15

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.

total sheathing thickness, but not more than R-3, on areas of the walls covered by structural sheathing. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

R402.2.8 Floors. Floor framing-cavity insulation shall be installed to maintain permanent contact with the underside of the subfloor decking.

Exception: The floor framing-cavity insulation shall be permitted to be in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing where combined with insulation that meets or exceeds the minimum wood frame wall *R*-value in Table 402.1.2 and that extends from the bottom to the top of all perimeter floor framing members.

R402.2.9 [Reserved]

R402.2.10 Slab-on-grade floors. Slab-on-grade floors with a floor surface less than 30 inches (762 mm) below grade shall be insulated in accordance with Table R402.1.2. 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 R402.1.2 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 not less than 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.

R402.2.11 Crawl space walls. As an alternative to insulating floors over crawl spaces, crawl space walls may 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 underside of the floor, including the band joist area, 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 *Building Code* or *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 not less than 6 inches (153 mm) up the stem wall and shall be attached to the stem wall.

R402.2.12 Masonry veneer. Insulation shall not be required on the horizontal portion of the foundation that supports a masonry veneer.

R402.2.13 Sunroom insulation. *Sunrooms* enclosing conditioned space shall meet the insulation 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 R402.3.5.

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.

Dynamic glazing shall be permitted to satisfy the SHGC requirements of Table R402.1.2 provided the ratio of the higher to lower labeled SHGC is greater than or equal to 2.4, and the *dynamic glazing* is automatically controlled to modulate the amount of solar gain into the space in multiple

steps. *Dynamic glazing* shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not dynamic glazing shall not be permitted.

Exception: *Dynamic glazing* is not required to comply with this section when both the lower and higher labeled SHGC already comply with the requirements of Table R402.1.2.

R402.3.3 Glazed fenestration exemption. Up to 15 square feet (1.4 m^2) of glazed fenestration per dwelling unit shall be permitted to be exempt from *U*-factor and SHGC requirements in Section R402.1.2. This exemption shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the Total UA alternative in Section R402.1.5.

R402.3.4 Opaque door exemption. One side-hinged opaque door assembly up to 24 square feet (2.22 m^2) in area is exempted from the *U*-factor requirement in Section R402.1.2. This exemption shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

R402.3.5 Sunroom fenestration. *Sunrooms* enclosing *conditioned space* shall meet the fenestration requirements of this code.

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 R402.4.5.

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 Air leakage testing. Each *dwelling unit* shall comply with Table R402.4.1.2. Testing shall be conducted in accordance with ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). Testing shall be conducted by an *approved* third party. A written report of the results of the test shall be signed by the *approved* third party conducting the test and provided to the *code official* before issuance of the certificate of occupancy or final inspection. Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope*. *Approved* sampling protocols approved by the code official may be used.

R402.4.2 Fireplaces. New wood-burning fireplaces shall have tight-fitting flue dampers or doors, and outdoor combustion air. Where using tight-fitting doors on factory-built fireplaces listed and labeled in accordance with UL 127, the doors shall be tested and listed for the fireplace. Where using tight-fitting doors on masonry fireplaces, the doors shall be listed and labeled in accordance with UL 907.

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/m^2), and swinging doors no more than 0.5 cfm per square foot (2.6 L/s/m^2), 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 Fuel burning appliances and equipment. For new construction, all new fuel burning appliances and equipment located inside the building envelope must be sealed combustion.

Existing buildings undertaking a Level 3 *alteration* at 80% of aggregate area must comply with one of the following:

1. New equipment and appliances shall be sealed combustion.
2. Locate open combustion appliances and equipment outside the building thermal envelope or enclosed in a room, isolated from the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table R402.1.2, where the walls, floors and ceilings shall meet not less than the basement wall *R*-value requirement. The door into the room shall be fully gasketed and any water lines and ducts in the room insulated in accordance with Section R403. The combustion air duct shall be insulated where it passes through conditioned space to a minimum of R-8.

In an existing building Level 3 *alteration* at 80 percent of aggregate area that contains open combustion equipment or appliances, a "worst-case testing of atmospheric venting systems" shall be conducted by an *approved* party in accordance with Appendix RA. Testing reports shall be provided to the *code official*. If the building fails the test in accordance with Appendix RA, the existing equipment must comply with either option 1 or 2.

Exceptions:

1. Power-vented equipment and appliances.
2. Fireplaces and stoves complying with Section R402.4.2 and Section R1006 of the *Residential Code*.

R402.4.5 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 E 283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
General requirements	A continuous six-sided air barrier shall be installed in the building envelope. The 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. All ceiling, wall, floor and slab insulation shall achieve Grade I installation per the RESNET Standards or, alternatively, Grade II for surfaces that contain a layer of continuous, air impermeable insulation > R5.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed. Access openings, drop down stairs or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. Knee walls shall be sealed.	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance of not less than R-3 per inch. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
Windows, skylights and doors	The space between window/door jambs and framing, and skylights and framing shall be sealed. Doors adjacent to unconditioned space or ambient conditions shall be made substantially air-tight with weather stripping or equivalent gasket.	Continuous exterior insulation shall continue over window and door headers. Skylight and window chases through unconditioned attic space must be insulated to exterior wall values per table 402.1.2.
Rim joists	Rim joists shall include continuous air barrier.	Rim joists shall be insulated per Table 402.1.2.
Floors (including above garage and cantilevered floors)	The air barrier shall be installed at any exposed edge of insulation.	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extends from the bottom to the top of all perimeter floor framing members.
Crawl space walls	Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.	Where provided instead of floor insulation, insulation shall be permanently attached to the crawlspace walls.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.	Duct shafts or chases next to exterior or unconditioned space shall be insulated.
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.	Walls next to unconditioned garage space shall be insulated.
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be sealed to the drywall.	Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated.
Plumbing and wiring	Seal any plumbing or wiring that penetrates the building envelope.	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	The air barrier installed at exterior walls adjacent to showers and tubs shall separate them from the showers and tubs.	Exterior walls adjacent to showers and tubs shall be insulated.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air-sealed boxes shall be installed.	
Common wall separating dwelling units	Air barrier is installed in common wall between dwelling units.	
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.	
Concealed sprinklers	When required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.	
Fireplace	An air barrier shall be installed on fireplace walls.	

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

TABLE R402.4.1.2
MAXIMUM ALLOWED AIR LEAKAGE RATES

	New construction	Level 3 Alteration affecting 80% or more of the aggregate work of the building (Gut Rehabilitation)
Single family detached, two family attached (duplex), townhouses, flats	3 ACH50	3 ACH50
Dwelling units in Multifamily buildings 3 stories and less	.30 CFM50/SF enclosure area of each unit or 3 ACH50	.30 CFM50/SF enclosure area of each unit or 3 ACH50

R402.5 Maximum fenestration *U*-factor and SHGC (Mandatory). The area-weighted average maximum fenestration *U*-factor permitted using tradeoffs from Section R402.1.5 or R406 shall be 0.40 for vertical fenestration, and 0.75 for skylights.

R402.6 Cool roof requirements. Roof coverings for roof slopes less than or equal to two units vertical in 12 units horizontal (17 percent slope or less) for buildings and covered parking shall conform to this section. A minimum of 75 percent of the entire roof surface not used for roof penetrations, renewable energy power systems (e.g., photovoltaics or solar thermal collectors), harvesting systems for rainwater to be used on-site, or green roofing systems shall be covered with products that comply with one or both of the following:

1. Have a 3-year-aged Solar Reflective Index (SRI) of not less than 64.
2. Comply with the criteria for roof products as defined in "ENERGY STAR® Program Requirements, Product Specification for Roof Products, Eligibility Criteria."

Exceptions:

1. Building projects where an annual energy analysis simulation demonstrates that the total annual building energy consumption with the proposed roof is 2 percent less than it would be with a roof having a three-year-aged SRI of 64.
2. Roofs used to shade or cover parking and roofs over semi-heated spaces or used as outdoor recreation space by the occupants of the building shall be permitted to be either landscaped or have a minimum initial SRI of 29. A default SRI value of 35 for new concrete without added color pigment is allowed to be used in lieu of measurements.
3. Terraces on setbacks comprising less than 25 percent of the area of the largest floor plate in the building.
4. Green roofs shall be permitted to comprise part or all of the 75 percent required area coverage.

R402.6.1 Solar Reflective Index. Initial and aged values of the SRI shall be calculated in accordance with ASTM E1980 for medium-speed wind conditions, using a convection coefficient of [2.1 BTU/(h · ft^2 · °F)] or the metric equivalent [12 W/(m^2 · K)]. The SRI shall be based upon solar reflectance as measured in accordance with ASTM E1918 or ASTM C1549, and the thermal emittance as measured in accordance with ASTM E408 or ASTM C1371. For roofing products, the values for solar reflectance and thermal emittance shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the Cool Roof Rating Council CRRC-1 Product Rating Program, and shall be labeled and certified by the manufacturer.

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. The thermostat controlling the primary heating or cooling system of the dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points 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 by the manufacturer with a heating temperature set point no higher than 70°F (21°C) and a cooling temperature set point no lower than 78°F (26°C).

R403.1.2 Heat pump supplementary heat (Mandatory). 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 Hot water boiler outdoor temperature setback. Hot water boilers that supply heat to the building through one- or two-pipe heating systems shall have an outdoor setback control that lowers the boiler water temperature based on the outdoor temperature.

R403.3 Ducts. Ducts and air handlers shall be in accordance with Sections R403.3.1 through R403.3.5.

R403.3.1 Insulation (Mandatory). Supply and return ducts outside of the *building thermal envelope* shall be insulated to not less than R-8.

Exception: Where ducts are less than 3 inches (76 mm) in diameter, not less than R-6 is allowed.

R403.3.2 Sealing (Mandatory). Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply

with either the *Mechanical Code* or *Residential Code*, as applicable.

Exceptions:

1. Air-impermeable spray foam products shall be permitted to be applied without additional joint seals.
2. For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), additional closure systems shall not be required for continuously welded joints and seams, and locking-type joints and seams of other than the snap-lock and button-lock types.

R403.3.2.1 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.

Exception: ENERGY STAR-certified heating and cooling systems are deemed to be compliant.

R403.3.3 Duct testing (Mandatory). Testing shall be conducted by an *approved* third party. A written report of the result of the test shall be signed by the party conducting the test and provided to the code official before issuance of the certificate of occupancy or final inspection. Ducts shall be pressure tested to determine air leakage by one of the following methods:

1. Rough-in test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. All registers shall be taped or otherwise sealed during the test.
2. Postconstruction test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Exception:

1. Where the ducts and air handlers are located entirely within the building thermal envelope.
2. Where ducts from an existing heating and cooling system are extended to an addition, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces.

R403.3.4 Duct leakage (Prescriptive). The total leakage of the ducts, where measured in accordance with Section R403.3.3, shall be as follows:

1. Rough-in test: The total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m^2) of conditioned floor area where the air handler is installed at the time of the test. Where the air handler is not installed at the time of the test, the total leakage shall be less than or equal to 3 cubic feet per minute (85 L/min) per 100 square feet (9.29 m^2) of conditioned floor area.
2. Postconstruction test: Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m^2) of conditioned floor area.

R403.3.5 Building cavities (Mandatory). Building framing cavities shall not be used as ducts or plenums.

R403.4 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.

R403.4.1 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.

R403.5 Service hot water systems. Energy conservation measures for service hot water systems shall be in accordance with Sections R403.5.1 through R403.5.4.

R403.5.1 Heated water circulation and temperature maintenance systems (Mandatory). Heated water circulation systems shall be in accordance with Section R403.5.1.1. Heat trace temperature maintenance systems shall be in accordance with Section R403.5.1.2. Automatic controls, temperature sensors and pumps shall be accessible. Manual controls shall be readily accessible.

R403.5.1.1 Circulation systems. Heated water circulation systems shall be provided with a circulation pump. The system return pipe shall be a dedicated return pipe or a cold water supply pipe. Gravity and thermosyphon circulation systems shall be prohibited. Controls for circulating hot water system pumps shall start the pump based on the identification of a demand for hot water within the occupancy. The controls shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.

R403.5.1.2 Heat trace systems. Electric heat trace systems shall comply with IEEE 515.1 or UL 515. Controls for such systems shall automatically adjust the energy input to the heat tracing to maintain the desired water temperature in the piping in accordance with the times when heated water is used in the occupancy.

R403.5.2 Demand recirculation systems. A water distribution system having one or more recirculation pumps that pump water from a heated water supply pipe back to the heated water source through a cold water supply pipe shall be a *demand recirculation water system*. Pumps shall have controls that comply with both of the following:

1. The control shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sensing the flow of hot or tempered water to a fixture fitting or appliance.
2. The control shall limit the temperature of the water entering the cold water piping to 104ºF (40ºC).

R403.5.3 Hot water pipe insulation (Mandatory). Insulate hot water pipe with a thermal resistance (*R*-value) of not less than R-3.

R403.5.4 [Reserved]

R403.6 Mechanical ventilation (Mandatory). The building shall be provided with ventilation that meets the requirements of the *Residential Code* or the *Mechanical Code*, as applicable. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

R403.6.1 Mechanical ventilation system fan efficacy. Mechanical ventilation system fans shall meet the efficacy requirements of Table R403.6.1 or be certified to the most current version of ENERGY STAR.

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

R403.7 Equipment sizing and efficiency rating (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. 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. If available equipment cannot satisfy the latent and sensible loads calculated while complying with ACCA Manual S, the next larger size may be selected.

Exceptions:

1. Where the new cooling equipment utilizes multistage technology or variable refrigerant flow technology.
2. Where the new heating and/or cooling equipment is 1.5 tons or less.
3. Where ductwork is being extended from an existing equipment into an addition.
4. Where there is a replacement in kind of an existing system, as long as the Btus of the new system are equivalent or smaller to the new equipment and the building thermal envelope is not being altered.

R403.8 Systems serving multiple dwelling units (Mandatory). Systems serving multiple dwelling units shall comply with Sections 6 and 7 of the *Energy Conservation Code—Residential Provisions* in lieu of Section R403.

Exception: Accessory Dwelling Unit (ADU) and *flats* are exempt.

R403.9 Snow melt and ice 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 (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 (4.8°C).

R403.10 Pools and permanent spa energy consumption (Mandatory). The energy consumption of pools and permanent spas shall be in accordance with Sections R403.10.1 through R403.10.3.

R403.10.1 Heaters. The electric power to heaters shall be controlled by a readily *accessible* on-off switch that is an integral part of the heater mounted on the exterior of the heater, or external to and within 3 feet (914 mm) of the heater. Operation of such switch shall not change the setting of the heater thermostat. Such switches shall be in addition to a circuit breaker for the power to the heater. Gas-fired heaters shall not be equipped with continuously burning ignition pilots.

R403.10.2 Time switches. Time switches or other control methods that can automatically turn off and on according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

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

R403.10.3 Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a permanent, operable vapor-retardant cover or other *approved* vapor-retardant means.

Exception: Where more than 70 percent of the energy for heating, computed over an operation season, is from site-recovered energy, such as from a heat pump or solar energy source, covers or other vapor-retardant means shall not be required.

TABLE R403.6.1
WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM FAN EFFICACY[a]

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 or utility room	10	1.4 cfm/watt	< 90
Bathroom or utility room	90	2.8 cfm/watt	Any

For SI: 1 cfm = 28.3 L/min.

a. When tested in accordance with HVI Standard 916.

R403.11 Portable spas (Mandatory). The energy consumption of electric-powered portable spas shall be controlled by the requirements of APSP-14.

R403.12 Residential pools and permanent residential spas. Residential swimming pools and permanent residential spas that are accessory to detached one- and two-family dwellings and townhouses three stories or less in height above grade plane and that are available only to the household and its guests shall be in accordance with APSP-15.

SECTION R404
ELECTRICAL POWER AND LIGHTING SYSTEMS

R404.1 Lighting equipment (Mandatory). Not less than 85 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 85 percent of the permanently installed lighting fixtures shall contain only *high-efficacy lamps*. *High efficacy lamps* are either LED, compact fluorescent lamps (CFLs), 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.
3. 40 lumens per watt for lamps 15 watts or less.

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

SECTION R405
SIMULATED PERFORMANCE ALTERNATIVE (PERFORMANCE)

R405.1 Requirements. New buildings shall comply with at least one of the following:

1. Enhanced HVAC performance in accordance with Section R405.2.
2. Enhanced building envelope in accordance with Section R405.3.
3. Enhanced air leakage and heat recovery ventilation in accordance with Section R405.4.
4. Enhanced water heating system in accordance with Section R405.5.

Exception: *Alterations* are exempt from Section R405.

R405.2 Efficient heating and cooling systems. All heating and cooling equipment shall meet the minimum efficiency requirements of Table R405.2.

TABLE R405.2
MINIMUM EFFICIENCY FOR HEATING AND COOLING EQUIPMENT

EQUIPMENT TYPE	EFFICIENCY
Split and Packaged Air Conditioners	≥ 15 SEER[a]
Split and Packaged Air Source Heat Pumps	≥ 15 SEER[a], ≥ 9.0 HSPF[b]
Gas-fired Furnace	≥ 90% AFUE[c] and Furnace Fan Efficiency ≤ 2.0%
Gas-fired Boiler	≥ 90% AFUE[c]
Ground Source Heat Pump	≥ 17.1 EER[d] and ≥ 3.6 COP[e]

a. SEER – Seasonal Energy Efficiency Ratio
b. HSPF – Heating Seasonal Performance Factor
c. AFUE – Annual Fuel Utilization Efficiency
d. EER – Energy Efficiency Ratio
e. COP – Coefficient of Performance

R405.3 Enhanced building thermal envelope. *Building thermal envelope* shall comply with Table R405.3 in addition to Table R402.1.2.

TABLE R405.3
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

Fenestration	Windows = 0.24 *U*-Factor ENERGY STAR Compliant Doors
Skylight *U*-factor	0.45 *U*-Factor
Glazed Fenestration SHGC	0.40 Solar Heat Gain Coefficient (SHGC)
Ceiling	R60
Mass Wall	*U*-factor less than or equal to .035 or R-19 cavity + R-10 continuous, or R-13 in cavity + R-15 continuous, or R-25 continuous
Wood Frame	*U*-factor less than or equal to .035 or R-19 cavity + R-10 continuous, or R-13 in cavity + R-15 continuous, or R-25 continuous
Metal Frame Wall	*U*-factor less than or equal to .035
Continuous Slab Insulation	R-10 continuous

R405.4 Enhanced air leakage and heat recovery ventilation. Buildings shall meet the minimum air leakage requirements of Table R405.4 and install a heat or energy recovery ventilation system.

TABLE R405.4
AIR LEAKAGE TESTING REQUIREMENTS

	NEW CONSTRUCTION
Single family detached, two family attached (duplex), townhouses, flats	2 ACH50
Dwelling units in Multifamily buildings 3 stories and less	.25 CFM50/SF enclosure area of each unit or 2 ACH50

R405.5 Efficient appliances and water heating. All refrigerators, freezers, dishwashers, clothes washers, and ceiling fans must be ENERGY STAR Qualified, and water heater(s) shall meet the minimum efficiency requirements of Table R405.5.

TABLE R405.5
MINIMUM EFFICIENCY FOR WATER HEATERS

EQUIPMENT TYPE	EFFICIENCY
Gas Storage Water Heaters	≥ 0.90 Energy Factor (EF)
Tankless Water Heaters	≥ 0.95 Energy Factor (EF) with electronic ignition
Electric Water Heaters	≥ 2.2 Energy Factor (EF)

SECTION R406
ENERGY RATING INDEX COMPLIANCE ALTERNATIVE

R406.1 Scope. This section establishes criteria for compliance using an Energy Rating Index (ERI) analysis.

R406.2 Mandatory requirements. Compliance with this section requires that the provisions identified in Sections R401 through R404 labeled as "mandatory" be met. The building thermal envelope shall be greater than or equal to Table R406.2.

TABLE R406.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

Fenestration *U*-factor[b]	0.35 *U*-Factor
Skylight[b] *U*-factor	0.60 *U*-Factor
Glazed Fenestration SHGC[b]	No Requirement
Ceiling	R-38
Wood Frame Wall	R-13
Mass Wall	R-5 exterior continuous or R-10 interior continuous
Frame Floor	R-19
Mass Floor	R-15
Basement Wall	R-10 continuous or R-13 in cavity
Slab[c] *R*-value & Depth	R-10 for the first 2 feet
Conditioned Crawlspace Wall	R-10 continuous or R-13 in cavity

For SI: 1 foot = 304.8 mm.

a. *R*-values are minimums. *U*-factors and SHGC are maximums. When insulation is installed in a cavity which 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.

b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.

c. R-5 shall be added to the required slab edge *R*-values for heated slabs.

R406.3 Energy Rating Index. The Energy Rating Index (ERI) shall be a numerical integer value that is based on a linear scale constructed such that the *ERI reference design* has an Index value of 100 and a *residential building* that uses no net purchased energy has an Index value of 0. Each integer value on the scale shall represent 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 shall consider all energy used in the *residential building*.

R406.3.1 ERI reference design. The *ERI reference design* shall be configured such that it meets the minimum requirements of the 2006 *International Energy Conservation Code* prescriptive requirements.

The proposed *residential building* shall be shown to have an annual total normalized modified load less than or equal to the annual total loads of the *ERI reference design*.

R406.4 ERI-based compliance. Compliance based on an ERI analysis requires that the *rated design* be shown to have an ERI less than or equal to 54 when compared to the *ERI reference design*.

R406.4.1 Renewable energy. The use of renewable energy is not allowed to meet the minimum requirement of 54 as listed in Section R406.4.

R406.5 Verification by approved agency. Verification of compliance with Section R406 shall be completed by an *approved* third party.

R406.6 Documentation. Documentation of the software used to determine the ERI and the parameters for the residential building shall be in accordance with Sections R406.6.1 through R406.6.3.

R406.6.1 Compliance software tools. Documentation verifying that the methods and accuracy of the compliance software tools conform to the provisions of this section shall be provided to the *code official*.

R406.6.2 Compliance report. Compliance software tools shall generate a report that documents that the ERI of the *rated design* complies with Sections R406.3 and R406.4. The compliance documentation shall include the following information:

1. Address or other identification of the residential building.
2. An inspection checklist documenting the building component characteristics of the *rated design*. The inspection checklist shall show results for both the *ERI reference design* and the *rated design*, and shall document all inputs entered by the user necessary to reproduce the results.
3. Name of individual completing the compliance report.
4. Name and version of the compliance software tool.

Exception: Multiple orientations. Where an otherwise identical building model is offered in multiple orientations, compliance for any orientation shall be permitted by documenting that the building meets the performance requirements in each of the four (north, east, south and west) cardinal orientations.

R406.6.3 Additional documentation. The *code official* shall be permitted to require the following documents:

1. Documentation of the building component characteristics of the *ERI reference design*.

2. A certification signed by the builder providing the building component characteristics of the *rated design.*

3. Documentation of the actual values used in the software calculations for the *rated design*.

R406.7 Calculation software tools. Calculation software, where used, shall be in accordance with Sections R406.7.1 through R406.7.3.

R406.7.1 Minimum capabilities. Calculation procedures used to comply with this section shall be software tools capable of calculating the ERI as described in Section R406.3, and shall include the following capabilities:

1. Computer generation of the *ERI reference design* using only the input for the *rated design*.

   The calculation procedure shall not allow the user to directly modify the building component characteristics of the *ERI reference design*.

2. Calculation of whole building, as a single *zone*, sizing for the heating and cooling equipment in the *ERI reference design* residence in accordance with Section R403.7.

3. Calculations that account for the effects of indoor and outdoor temperatures and part-load ratios on the performance of heating, ventilating and air-conditioning equipment based on climate and equipment sizing.

4. Printed *code official* inspection checklist listing each of the *rated design* component characteristics determined by the analysis to provide compliance, along with their respective performance ratings.

R406.7.2 Specific approval. Performance analysis tools meeting the applicable sections of Section R406 shall be *approved*. Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall approve tools for a specified application or limited scope.

R406.7.3 Input values. When calculations require input values not specified by Sections R402, R403, R404 and R405, those input values shall be taken from an approved source.

CHAPTER 5 [RE]

EXISTING BUILDINGS

SECTION R501 GENERAL

R501.1 Scope. The scope and intent of this chapter shall be governed by Section 101.10 of the *Building Code*, Title 12-A DCMR.

R501.1.1 Additions, alterations or repairs: General. Additions, alterations or repairs to an existing building, building system or portion thereof shall comply with Section R502, R503 or R504. Unaltered portions of the existing building or building system shall not be required to comply with this code.

SECTION R502 ADDITIONS

R502.1 General. Additions to an existing building, building system or portion thereof shall conform to the provisions of this code as those provisions relate to new construction without requiring the unaltered portion of the existing building or building system to comply with this code. Additions shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code where the addition alone complies, where the existing building and addition comply with this code as a single building, or where the building with the addition uses no more energy than the existing building. Additions shall be in accordance with Section R502.1.1 or R502.1.2.

R502.1.1 Prescriptive compliance. Additions shall comply with Sections R502.1.1.1 through R502.1.1.4.

R502.1.1.1 Building envelope. New building envelope assemblies that are part of the addition shall comply with Sections R402.1, R402.2, R402.3.1 through R402.3.5, and R402.4.

Exception: Where nonconditioned space is changed to conditioned space, the building envelope of the addition shall comply where the UA, as determined in Section 402.1.5, of the existing building and the addition, and any alterations that are part of the project, is less than or equal to UA generated for the existing building.

R502.1.1.2 Heating and cooling systems. New heating, cooling and duct systems that are part of the addition shall comply with Sections R403.1, R403.2, R403.3, R403.5 and R403.6.

Exception: Where ducts from an existing heating and cooling system are extended to an addition, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces shall not be required to be tested in accordance with Section R403.3.3.

R502.1.1.3 Service hot water systems. New service hot water systems that are part of the addition shall comply with Section R403.5.

R502.1.1.4 Lighting. New lighting systems that are part of the addition shall comply with Section R404.1.

R502.1.2 Existing plus addition compliance (Energy Rating Index compliance alternative). The addition shall be deemed to comply where the annual site energy use of the addition and the existing building, and any alterations that are part of the project, is less than or equal to the annual site energy use of the existing building when modeled in accordance with Section R406. The addition and any alterations that are part of the project shall comply with Section R406 in its entirety.

SECTION R503 ALTERATIONS

R503.1 General. *Alterations* to any building or structure shall comply with the requirements of the code for new construction. *Alterations* shall be such that the existing building or structure is no less conforming to the provisions of this code than the existing building or structure was prior to the *alteration*.

Alterations to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portions of the existing building or building system to comply with this code. Alterations shall not create an unsafe or hazardous condition or overload existing building systems. *Alterations* shall be such that the existing building or structure uses no more energy than the existing building or structure prior to the *alteration*. Alterations to existing buildings shall comply with Sections R503.1.1 through R503.2.

R503.1.1 Building envelope. Building envelope assemblies that are part of the alteration shall comply with Section R402.1.2 or R402.1.4, Sections R402.2.1 through R402.2.13, R402.3.1, R402.3.2, R402.4.1.1, R402.4.3 and R402.4.5.

Exception: The following alterations need not comply with the requirements for new construction provided the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.
2. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation.
3. Construction where the existing roof, wall or floor cavity is not exposed.
4. Roof recover.
5. 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.

6. Surface-applied window film installed on existing single pane fenestration assemblies to reduce solar heat gain provided the code does not require the glazing or fenestration assembly to be replaced.

R503.1.1.1 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 as provided in Table R402.1.2.

R503.1.1.2 Additional insulation requirements for *Level 3 alterations* affecting 80 percent or more of the aggregate area of the building. Existing exterior wall, ceiling, and floor assemblies that are not part of the scope of work of the *alteration* but are in an existing building undertaking a *Level 3 alteration* affecting 80 percent or more of the aggregate area of the building are required to comply with the following minimum insulation requirements:

1. Existing exterior walls shall be insulated to a minimum of R-7.5 continuous insulation or R-13 cavity insulation. Air permeable cavity insulation shall also be sufficient to fill the cavity.
2. Existing ceilings must be insulated to R-49 or have the cavity filled with insulation to the maximum extent possible.
3. Existing floors must be insulated to R-25 or have the cavity filled with insulation to the maximum extent possible.

Exception: Existing exterior walls where space constraints would make it impractical to meet this section without substantial reconfiguration of interior spaces or features.

R503.1.1.3 Air leakage testing. *Level 3 alterations* affecting 80 percent or more of the aggregate area of the building must comply with air leakage requirements and procedures in accordance with Section R402.4.1.2.

R503.1.2 Heating and cooling systems. New heating, cooling and duct systems that are part of the alteration shall comply with Sections R403.1, R403.2, R403.3 R403.4, R403.6, and R403.7.

Exception: Where ducts from an existing heating and cooling system are extended, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces shall not be required to be tested in accordance with Section R403.3.3.

R503.1.3 Service hot water systems. New service hot water systems that are part of the alteration shall comply with Section R403.5.

R503.1.4 Lighting. New lighting fixtures that are part of the alteration shall comply with Section R404.

R503.2 Change in space conditioning. Any nonconditioned or low-energy space, as defined in Section R402.1 that is altered to become *conditioned space* shall be required to be brought into full compliance with this code.

SECTION R504
REPAIRS

R504.1 General. Buildings, structures and parts thereof shall be repaired in compliance with Section R501.3 and this section. Work on nondamaged components necessary for the required *repair* of damaged components shall be considered part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter. Routine maintenance required by Section R501.3, ordinary repairs exempt from *permit*, and abatement of wear due to normal service conditions shall not be subject to the requirements for *repairs* in this section.

R504.2 Application. For the purposes of this code, the following shall be considered repairs:

1. Glass-only replacements in an existing sash and frame.
2. Roof repairs.
3. Repairs where only the bulb and/or ballast within the existing luminaires in a space are replaced provided that the replacement does not increase the installed interior lighting power.

SECTION R505
CHANGE OF OCCUPANCY OR USE

R505.1 General. 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.

R505.2 General. Any space that is converted to a dwelling unit or portion thereof from another use or occupancy shall comply with this code.

Exception: Where the simulated performance option in Section R405 is used to comply with this section, the annual energy cost of the proposed design is permitted to be 110 percent of the annual energy cost otherwise allowed by Section R405.3.

CHAPTER 6 [RE]

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.

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/A C440—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—2011	Residential Load Calculation Eighth Edition	R403.7
Manual S—13	Residential Equipment Selection	R403.7

APSP

The Association of Pool and Spa Professionals
2111 Eisenhower Avenue
Alexandria, VA 22314

Standard reference number	Title	Referenced in code section number
APSP 14—11	American National Standard for Portable Electric Spa Energy Efficiency	R403.10.1, 403.11
APSP 15a—2013	American National Standard for Residential Swimming Pool and Spa Energy Efficiency	R403.12

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—2013	ASHRAE Handbook of Fundamentals	R402.1.5, Table R405.5.2(1)
ASHRAE 193—2010	Method of Test for Determining the Airtightness of HVAC Equipment	R403.3.2.1

ASTM

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

Standard reference number	Title	Referenced in code section number
C 1363—11	Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus	R303.1.4.1
C1371—04a	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers	R402.6
C1549—09	Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer	R402.6
E 283—04	Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen	R402.4.4
E408—71 (2008)	Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques	R402.6
E 779—10	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization	R402.4.1.2
E 1827—11	Standard Test Methods for Determining Airtightness of Building Using an Orifice Blower Door.	R402.4.1.2
E1918—06	Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field	R402.6
E1980—11	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces	R402.6

CSA

CSA Group
8501 East Pleasant Valley
Cleveland, OH 44131-5575

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
CSA 55.1—2012	Test Method for measuring efficiency and pressure loss of drain water heat recovery units.	R403.5.4
CSA 55.2—2012	Drain water heat recover units	R403.5.4

DASMA

Door and Access Systems Manufacturers Association
1300 Sumner Avenue
Cleveland, OH 44115-2851

Standard reference number	Title	Referenced in code section number
105—92(R2004)—13	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors	R303.1.3

EPA

Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

Standard reference number	Title	Referenced in code section number
ENERGY STAR	Energy Star Program Requirements, Product Specification for Roof Products, Eligibility Criteria, version 2.2 (October 2010)	R402.6

ICC

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

Standard reference number	Title	Referenced in code section number
IBC—15	International Building Code®	R201.3, R303.2, R402.1.1, R501.4
ICC 400—12	Standard on the Design and Construction of Log Structures	Table R402.5.1.1
IECC—15	International Energy Conservation Code®	R101.4.1, 403.8
IECC—09	2009 International Energy Conservation Code®	R406.2
ECC—06	2006 International Energy Conservation Code®	R202, R406.3.1
IFC—15	International Fire Code®	R201.3, R501.4
IFGC—15	International Fuel Gas Code®	R201.3, R501.4
IMC—15	International Mechanical Code®	R201.3, R403.3.2, R403.6, R501.4
IPC—15	International Plumbing Code®	R201.3, R501.4
IPSDC—15	International Private Sewage Disposal Code®	501.4
IPMC—15	International Property Maintenance Code®	501.4
IRC—15	International Residential Code®	R201.3, R303.2, R402.1.1, R402.2.11, R403.3.2, R403.6, R501.4

IEEE

The Institute of Electrical and Electronic Engineers, Inc.
3 Park Avenue
New York, NY 1016-5997

Standard reference number	Title	Referenced in code section number
515.1—2012	IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Commercial Applications	R403.5.1.2

NFPA

National Fire Protection Association.
1 Batterymarch Park
Quincy, MA 02169-7471

Standard reference number	Title	Referenced in code section number
70—14	National Electrical Code	R501.4

NFRC

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

Standard reference number	Title	Referenced in code section number
100—2009	Procedure for Determining Fenestration Products *U*-factors—Second Edition	R303.1.3
200—2009	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence—Second Edition	R303.1.3
400—2009	Procedure for Determining Fenestration Product Air Leakage—Second Edition	R402.4.3

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062

Standard reference number	Title	Referenced in code section number
127—11	Standard for Factory Built Fireplaces	R402.4.2
515—11	Electrical Resistance Heat Tracing for Commercial and Industrial Applications including revisions through November 30, 2011	R403.5.1.2

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	R303.1.4

WDMA

Window and Door Manufacturers Association
2025 M Street, NW Suite 800
Washington, DC 20036-3309

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

APPENDIX RA

RECOMMENDED PROCEDURE FOR WORST-CASE TESTING OF ATMOSPHERIC VENTING SYSTEMS

(This appendix is informative and is not part of the code.)

SECTION RA101
SCOPE

RA101.1 General. This appendix is intended to provide guidelines for worst-case testing of atmospheric venting systems. Worst-case testing is recommended to identify problems that weaken draft and restrict combustion air.

SECTION RA201
GENERAL DEFINITIONS

COMBUSTION APPLIANCE ZONE (CAZ). A contiguous air volume within a building that contains a Category I or II atmospherically vented appliance or a Category III or IV direct-vent or integral vent appliance drawing combustion air from inside the building or dwelling unit. The CAZ includes, but is not limited to, a mechanical closet, a mechanical room, or the main body of a house or dwelling unit.

DRAFT. The pressure difference existing between the *appliance* or any component part and the atmosphere that causes a continuous flow of air and products of *combustion* through the gas passages of the *appliance* to the atmosphere.

Mechanical or induced draft. The pressure difference created by the action of a fan, blower or ejector that is located between the *appliance* and the *chimney* or vent termination.

Natural draft. The pressure difference created by a vent or *chimney* because of its height and the temperature difference between the *flue* gases and the atmosphere.

SPILLAGE. Combustion gases emerging from an appliance or venting system into the combustion appliance zone during burner operation.

SECTION RA301
TESTING PROCEDURE

RA301.1 Worst-case testing of atmospheric venting systems. Buildings or dwelling units containing a Category I or II atmospherically vented appliance; or a Category III or IV direct-vent or integral vent appliance drawing combustion air from inside of the building or dwelling unit, shall have the Combustion Appliance Zone (CAZ) tested for spillage, acceptable draft and carbon monoxide (CO) in accordance with this section. 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 creation of all penetrations of the *building thermal* envelope and prior to final inspection.

Exception: Buildings or dwelling units containing only Category III or IV direct-vent or integral vent appliances that do not draw combustion air from inside of the building or dwelling unit.

The enumerated test procedure as follows shall be complied with during testing:

1. Set combustion appliances to the pilot setting or turn off the service disconnects for combustion appliances. Close exterior doors and windows and the fireplace damper. With the building or dwelling unit in this configuration, measure and record the baseline ambient pressure inside the building or dwelling unit CAZ. Compare the baseline ambient pressure of the CAZ to that of the outside ambient pressure and record the difference (Pa).
2. Establish worst case by turning on the clothes dryer and all exhaust fans. Close all interior doors that make the CAZ pressure more negative. Turn on the air handler, where present, and leave on if, as a result, the pressure in the CAZ becomes more negative. Check interior door positions again, closing only the interior doors that make the CAZ pressure more negative. Measure net change in pressure from the CAZ to outdoor ambient pressure, correcting for the base ambient pressure inside the home. Record "worst case depressurization" pressure and compare to Table RA301.1(1).

   Where CAZ depressurization limits are exceeded under worst-case conditions in accordance with Table A301.1(1), additional combustion air shall be provided or other modifications to building air-leakage performance or exhaust appliances such that depressurization is brought within the limits prescribed in Table RA301.1(1).
3. Measure worst-case spillage, acceptable draft and carbon monoxide (CO) by firing the fuel-fired appliance with the smallest Btu capacity first.
   a. Test for spillage at the draft diverter with a mirror or smoke puffer. An appliance that continues to spill flue gases for more than 60 seconds fails the spillage test.
   b. Test for CO measuring undiluted flue gases in the throat or flue of the appliance using a digital gauge in parts per million (ppm) at the 10-minute mark. Record CO ppm readings to be compared with Table

RA301.1(3) upon completion of Step 4. Where the spillage test fails under worst case, go to Step 4.

c. Where spillage ends within 60 seconds, test for acceptable draft in the connector not less than 1 foot (305 mm), but not more than 2 feet (610 mm) downstream of the draft diverter. Record draft pressure and compare to Table RA301.1(2).

d. Fire all other connected appliances simultaneously and test again at the draft diverter of each appliance for spillage, CO and acceptable draft using procedures 3a through 3c.

4. Measure spillage, acceptable draft, and carbon monoxide (CO) under natural conditions—without *clothes dryer* and exhaust fans on—in accordance with the procedure outlined in Step 3, measuring the net change in pressure from worst case condition in Step 3 to natural in the CAZ to confirm the worst case depressurization taken in Step 2. Repeat the process for each appliance, allowing each vent system to cool between tests.
5. Monitor indoor ambient CO in the breathing zone continuously during testing, and abort the test where indoor ambient CO exceeds 35 ppm by turning off the appliance, ventilating the space, and evacuating the building. The CO problem shall be corrected prior to completing combustion safety diagnostics.
6. Make recommendations based on test results and the retrofit action prescribed in Table RA301.1(3).

TABLE RA301.1(1)
CAZ DEPRESSURIZATION LIMITS

VENTING CONDITION	LIMIT (Pa)
Category I, atmospherically vented water heater	–2.0
Category I or II atmospherically vented boiler or furnace common-vented with a Category I atmospherically vented water heater	–3.0
Category I or II atmospherically vented boiler or furnace, equipped with a flue damper, and common vented with a Category I atmospherically vented water heater	–5.0
Category I or II atmospherically vented boiler or furnace alone	
Category I or II atmospherically vented, fan-assisted boiler or furnace common vented with a Category I atmospherically vented water heater	
Decorative vented, gas appliance	
Power-vented or induced-draft boiler or furnace alone, or fan-assisted water heater alone	–15.0
Category IV direct-vented appliances and sealed combustion appliances	–50.0

For SI: 6894.76 Pa = 1.0 psi.

TABLE RA301.1(2)
ACCEPTABLE DRAFT TEST CORRECTION

OUTSIDE TEMPERATURE (°F)	MINIMUM DRAFT PRESSURE REQUIRED (Pa)
< 10	–2.5
10 – 90	(Outside Temperature ÷ 40) – 2.75
> 90	–0.5

For SI: 6894.76 Pa = 1.0 psi.

TABLE RA301.1(3)
ACCEPTABLE DRAFT TEST CORRECTION

CARBON MONOXIDE LEVEL (ppm)	AND OR	SPILLAGE AND ACCEPTABLE DRAFT TEST RESULTS	RETROFIT ACTION
0 – 25	and	Passes	Proceed with work
25 < × ≤ 100	and	Passes	Recommend that CO problem be resolved
25 < × ≤ 100	and	Fails in worst case only	Recommend an appliance service call and repairs to resolve the problem
100 < × ≤ 400	or	Fails under natural conditions	**Stop!** Work shall not proceed until appliance is serviced and problem resolved
> 400	and	Passes	**Stop!** Work shall not proceed until appliance is serviced and problem resolved
> 400	and	Fails under any condition	**Emergency!** Shut off fuel to appliance and call for service immediately

APPENDIX RB

SOLAR-READY PROVISIONS

SECTION RB101
SCOPE

RB101.1 General. These provisions shall be applicable for new construction and Level 3 *alteration* affecting 80 percent or more of the aggregate area of the building.

SECTION RB102
DEFINITIONS

RB102.1 General. For purposes of this appendix, the following terms are defined as follows:

SOLAR-READY ZONE. A section or sections of the roof or building overhang designated and reserved for the future installation of a solar photovoltaic or solar thermal system.

SECTION RB103
SOLAR-READY ZONE

RB103.1 General. A *residential building* with a roof area of 600 square feet (55.74 m^2) or more oriented between 110 degrees and 270 degrees of true north shall comply with Sections RB103.2 through RB103.8.

Exceptions:

1. *Residential buildings* with a permanently installed on-site renewable energy system with a size of not less than 2 kilowatts (KW) per *dwelling unit*.
2. A building with a *solar-ready zone* that is shaded for more than 70 percent of daylight hours annually.

RB103.2 Construction document requirements for solar-ready zone. *Construction documents* shall indicate the solar-ready zone.

RB103.3 Solar-ready zone. The total *solar-ready zone* shall be not less than 300 square feet (27.87 m^2) exclusive of mandatory access or set back areas as required by the *Fire Code*. *Residential buildings* with a total floor area less than or equal to 2,000 square feet (185.8 m^2) per dwelling shall have a *solar-ready zone* of not less than 150 square feet (13.94 m^2). The *solar-ready zone* shall be composed of areas not less than 5 feet (1524 mm) in width and not less than 80 square feet (7.44 m^2) exclusive of access or set back areas as required by the *Fire Code*.

RB103.4 Obstructions. *Solar-ready zones* shall be free from obstructions, including but not limited to vents, chimneys, and roof-mounted equipment.

RB103.5 Roof load documentation. The structural design loads for roof dead load and roof live load shall be clearly indicated on the *construction documents*.

RB103.6 Interconnection pathway. *Construction documents* shall indicate pathways for routing of conduit or plumbing from the solar-ready zone to the electrical service panel or service hot water system.

RB103.7 Electrical service reserved space. The main electrical service panel shall have a reserved space to allow installation of a dual pole circuit breaker for future solar electric installation and shall be labeled "For Future Solar Electric." The reserved space shall be positioned at the opposite (load) end from the input feeder location or main circuit location.

RB103.8 Construction documentation certificate. A permanent certificate, indicating the *solar-ready zone* and other requirements of this section, shall be posted near the electrical distribution panel, water heater or other conspicuous location by the builder or *registered design professional*.

RB103.9 Shading. The *solar-ready zone* shall be set back from any existing or new, permanently affixed object on the building or site that is located south, east or west of the *solar-ready zone* a distance not less than two times the object's height above the nearest point on the roof surface. Such objects include, but are not limited to, taller portions of the building itself, parapets, chimneys, antennas, signage, rooftop equipment, trees and roof plantings.

INDEX

A

B

C

D

E

F

G

H

I

L

M

O

P

R

S

T

U

V

W