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STANDARD

ANSI/ASHRAE/IES Standard 90.1-2022
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2019)
Includes ANSI/ASHRAE/IES addenda listed in Appendix M

Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings (I-P Edition)

See Informative Appendix M for dates of approval by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

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ANSI/ASHRAE/IES Standard 90.1-2022
Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings (I-P Edition)

NOTE

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FOREWORD

The 2022 edition of Standard 90.1 incorporates more than 80 addenda to the 2019 edition and includes numerous energy-saving measures. Notable changes include the following:

General

- *The scope of the standard has been expanded to include sites as well as buildings, enabling regulation of energy use associated with the building but not in the building itself, such as exterior or parking lot lighting not connected to the building electric service. This also allows for equipment, such as photovoltaic (PV) equipment, located on site but not within the building.*
- *A new energy credits requirement (new Section 11) has been added that enables approximately 4% to 5% cost-effective energy savings through 33 different energy-saving measures. The number of required credits varies by building type and climate zone.*
- *A minimum prescriptive requirement for on-site renewable energy has been added. This requirement includes exceptions for small buildings, buildings with limited roof space, and other situations where PV installations would be problematic.*
- *It should be noted that, due to the addition of a new section and several appendices, the number or letter designations of several well-known sections and appendices have changed from those used in the 2019 and previous editions of the standard.*

Administration and Enforcement

- *There were no major changes to administration and enforcement.*

Building Envelope

- *A requirement was added to perform whole-building air-leakage testing and measurement on buildings less than 25,000 ft^2.*
- *Requirements were added that address the impacts of thermal bridges in building envelopes, with a new Informative Appendix K providing supplemental information on application.*
- *A solar reflectance requirement for walls was added for Climate Zone 0. This is similar to the requirements for high albedo roofs.*
- *Specific provisions were added to distinguish roof replacements from other types of alterations.*
- *A new reference was added for steel-framed walls to allow use of ANSI/AISI S250 for U-factor determination.*
- *Added a definition for insulated metal panels (IMPs).*
- *Normative Appendix A was reformatted to clarify the requirements for thermal performance calculations.*

Lighting and Power

- *Reorganized Section 9, "Lighting," to be more consistent with the structure of other main sections of the standard.*
- *Updated installed interior lighting power allowances and minimum control requirements; added a power exception for the germicidal function in luminaires and sources; and removed exceptions for casinos and parking garage daylight transition zone lighting.*
- *Modified a number of lighting requirements to reflect greater use of higher efficiency LED products and revised lighting practices.*
- *Added requirements for indoor horticultural lighting in greenhouses and indoor grow buildings based on a new metric, photosynthetic photon efficacy (PPE), developed in ANSI/ASABE S640.*
- *Provided an additional interior lighting power allowance for video conferencing. Power allowances and controls have been moved to a table for ease of reference.*

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Mechanical

- *Introduced an optional Mechanical System Performance Path that allows HVAC system efficiency trade-offs based on a new metric, total system performance ratio (TSPR).*
- *Required condensing boilers for new construction in order to achieve 90% or greater efficiency for large boilers (1 to 10 million Btuh. The thermal efficiency requirements for high-capacity gas-fired service water-heating equipment were also increased.*
- *Established a minimum enthalpy recovery ratio for energy recovery systems and specified operational requirements to ensure proper economized performance.*
- *Revised demand control ventilation requirements to be based on climate zone and Standard 62.1 airflow requirements.*
- *Modified the minimum efficiency requirements for air-source heat pumps and introduced a new metric, COP_{HR}, for units that perform heat recovery during chiller operation.*
- *Added the minimum energy efficiency requirements (and new CFEI metric) for large-diameter ceiling fans from 10 CFR 430.*

Performance Rating Method (Appendix G)

- *New requirements were added to limit trade-offs between the building envelope and other building systems.*
- *A new Informative Appendix I was added that provides information on how alternative performance metrics other than cost could be used with the Performance Rating Method. These alternative metrics include site energy, source energy, and carbon emissions, and would be useful to assess building performance against carbon emission goals or for similar types of comparison.*
- *A relaxation in stringency was added when using Normative Appendix G for retrofit projects consisting of substantial alterations.*

Both Performance-Based Compliance Paths (Section 12 [Energy Cost Budget Method] and Appendix G)

- *Numerous changes were included to improve clarity and coordinate with revisions to other sections of the standard.*

New Normative Appendix J

- *Contains performance curves that represent minimally compliant chiller performance for the budget and baseline building design and for proposed building designs when specific equipment performance is not known.*

1. PURPOSE

1.1 To establish the minimum *energy efficiency* requirements of *buildings* other than *low-rise residential buildings*, and *sites* for

a. design, *construction*, and a plan for operation and maintenance; and
b. utilization of *on-site renewable energy* resources.

2. SCOPE

2.1 This standard provides

a. minimum *energy*-efficient requirements for the design and *construction*, and a plan for operation and maintenance of,
   1. new *buildings* and their *systems*,
   2. new portions of *buildings* and their *systems*,
   3. new *systems* and *equipment* specifically identified in this standard that are part of a *site*,
   4. new *systems* and *equipment* in *existing buildings*, and
   5. new *equipment* or *building systems* specifically identified in this standard that are part of *process applications*

   and
b. criteria for determining compliance with these requirements.

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2.2 The provisions of this standard do not apply to

a. single-family houses and related incidental *structures*, multifamily *structures* of three *stories* or fewer above *grade*, manufactured houses (mobile homes), and manufactured houses (modular) or
b. *buildings* that use neither electricity nor *fossil fuel*.

2.3 Where specifically noted in this standard, certain other *buildings* or elements of *buildings* or *sites* shall be exempt.

2.4 This standard shall not be used to circumvent any safety, health, or environmental requirements.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 General. Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this standard. When the tense or plurality of the term is different than the defined term, the definition still applies. These definitions are applicable to all sections of this standard, wherever *italicized*. Terms that are not italicized shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based on American standard English language usage as documented in an unabridged dictionary accepted by the *adopting authority*.

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* or the *equipment* or *systems* to a *site*.

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

air economizer: see *economizer, air*.

air leakage: the uncontrolled airflow through the *building envelope* caused by pressure differences across the *building envelope* due to factors such as wind, inside and outside temperature differences, stack effect, and imbalance between supply and exhaust air *systems*. *Air leakage* can move inward (infiltration) or outward (exfiltration) through the *building envelope*.

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

alteration: replacing or adding to *systems*, *equipment*, *structures*, or *building* assemblies; routine maintenance, *repair*, and service, or a change in the *building* or *structure* use classification or *space conditioning 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.

attic and other roofs: see *roof*.

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

automatic **or** ***automatically:*** 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.

baseline building design: a computer representation of a hypothetical design based on the *proposed design*. 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.

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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*.

best efficiency point (BEP): the *pump* hydraulic power operating point (consisting of both flow and head conditions) that results in the maximum *efficiency*.

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 outlets; 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 design*. This representation is used as the basis for calculating the *energy cost budget*.

building: any *structure* used or intended for supporting or sheltering any use or occupancy.

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 semiexterior 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.
>
> ***semiexterior 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 Normative Appendix C.

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.

building official: the officer or other designated *authority having jurisdiction* charged with the administration and enforcement of this standard, or a duly authorized representative.

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

building 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 undergrounded conductors in a *building* or other *structure* from the service-entrance conductors.

C-factor: see *thermal conductance*.

ceiling fan: a nonportable (*permanently installed*) device suspended from a ceiling or overhead *structure* for circulating air via the rotation of fan blades.

ceiling fan energy index (CFEI): the ratio of the electric input power of a reference *ceiling fan* to the electric input power of the actual *ceiling fan* as calculated per AMCA 208 with the following modifications to

1. Schedules and internal loads by *building* area type are at https://web.ashrae.org/90_1files.

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the calculations for the reference fan: using an airflow constant (Q_0) of 26,500 cfm, a pressure constant (P_0) of 0.002700 in. of water, and a fan *efficiency* constant (η_0) of 42%.

ceiling fan, large diameter: a *ceiling fan* that is greater than or equal to 84.5 in. in diameter.

chi-factor (χ or Chi): *thermal transmittance* of a *point thermal bridge* in units of Btu/(h·°F).

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*.)

clear-field thermal bridge: see *thermal bridge.*

code official: see *building official.*

coefficient of performance (COP_H), 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.

combined energy efficiency ratio (CEER): a ratio of the total cooling one year divided by the total *energy* from active, standby, and OFF modes as specified in 10 CFR 430.23.

commissioning: a quality-focused process for enhancing the delivery of a project for verifying and documenting that the *building* and its *systems*, controls, and *building envelope* are planned, designed, installed, tested, and include plans for operation and maintenance to meet specified requirements.

commissioning provider: an entity who manages the *commissioning* team to implement *building commissioning*.

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.*

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

construction documents: drawings and specifications used to construct, add to, or alter *building*s, *systems*, or *equipment*, 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 dimming: a lighting control strategy that varies the light output of a *lighting system* over a continuous range from full light output to a minimum light output in imperceptible steps without flickering.

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*. (***Informative Note:*** This definition is not applicable to the use of this word as a noun to describe a combination of *control devices* and software, used to achieve control of HVAC, lighting, or other *equipment* or *systems*.)

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

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cooldown: reduction of *space* temperature down to occupied *set point* 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.

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: the *floor* area substantially illuminated by daylight.

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).

daylight area under skylights in multistory spaces: the *daylight area under skylights in multistory spaces* shall include *floor* areas directly beneath the *skylight* and portions of the uppermost *floor* adjacent to the multistory *space* that meet the criteria for a *daylight area under skylights*, where CH is the ceiling height of the uppermost *floor* (see Figure 3.2-3).

primary sidelighted area: the total *primary sidelighted area* is the combined *primary sidelighted area* within each *space*. Each *primary sidelighted area* is directly adjacent to *vertical fenestration* in an exterior *wall* below the ceiling (see Figure 3.2-4).

a. The *primary sidelighted area* width is the width of the *vertical fenestration* plus, on each side, the smaller of
   1. one half of the *vertical fenestration* head height (where head height is the distance from the *floor* to the top of the glazing) or
   2. the distance to any 5 ft or higher *opaque* vertical obstruction.
b. The *primary sidelighted area* depth is the horizontal distance perpendicular to the *vertical fenestration*, which is the smaller of
   1. one *vertical fenestration* head height or
   2. the distance to any 5 ft or higher *opaque* vertical obstruction.

secondary sidelighted area: the total *secondary sidelighted area* is the combined *secondary sidelighted area* within a *space*. Each *secondary sidelighted area* is directly adjacent to a *primary sidelighted area* (see Figure 3.2-5):

a. The *secondary sidelighted area* width is the width of the *vertical fenestration* plus, on each side, the smaller of
   1. one half of the *vertical fenestration* head height or
   2. the distance to any 5 ft or higher *opaque* vertical obstruction.

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b. The *secondary sidelighted area* depth is the horizontal distance perpendicular to the *vertical fenestration*, which begins at the edge of the *primary sidelighted area* depth and ends at the smaller of
   1. one *vertical fenestration* head height or
   2. the distance to any 5 ft or higher *opaque* vertical obstruction.

If the adjacent *primary sidelighted area* ends at a 5 ft or higher *opaque* vertical obstruction, there is no *secondary sidelighted area* beyond such obstruction.

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*.

degree-day: the difference in temperature between the outdoor *mean temperature* over a twenty-four-hour period and a given base temperature. 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.

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.

dimmer: a lighting *control device* that is capable of varying the light output and *energy* usage of light sources.

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 and then converted back to analog or binary form to *control* physical devices.

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: an *operable* opening area in the *building envelope* that is not *fenestration*. A door where more than one-half of the *door area* is glazed is considered *fenestration*, and a door where one-half or less of the *door area* is glazed is considered an *opaque door*. An *access hatch* is considered a *door*. 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 any other *door* that is not a *swinging door*.

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

swinging door: a *door* having an *operable opaque* panel with hinges or pivots on one side.

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

driver: a device designed to operate a solid-state (e.g., LED) light source.

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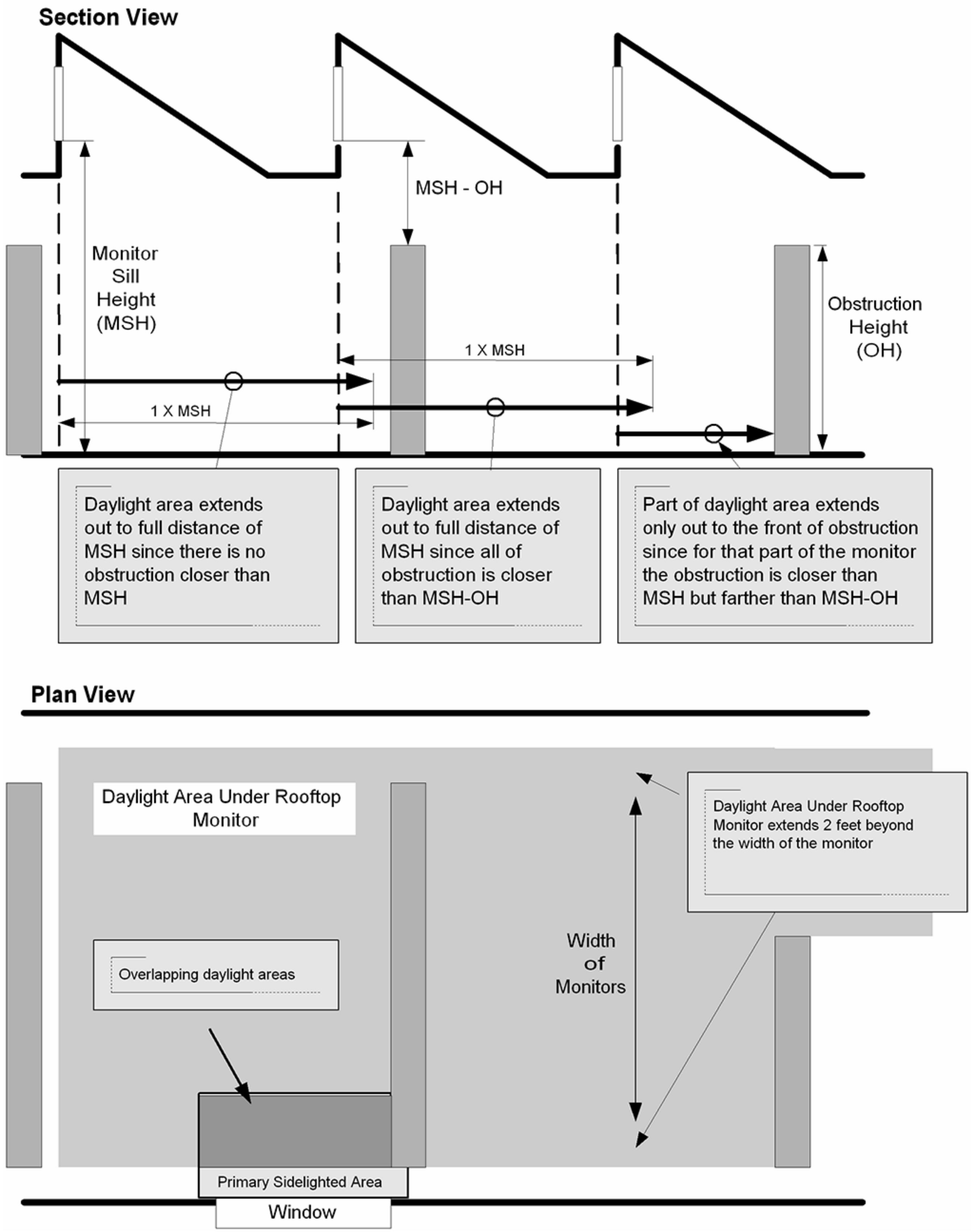

Figure 3.2-1 Computing the daylight area under roof monitors.

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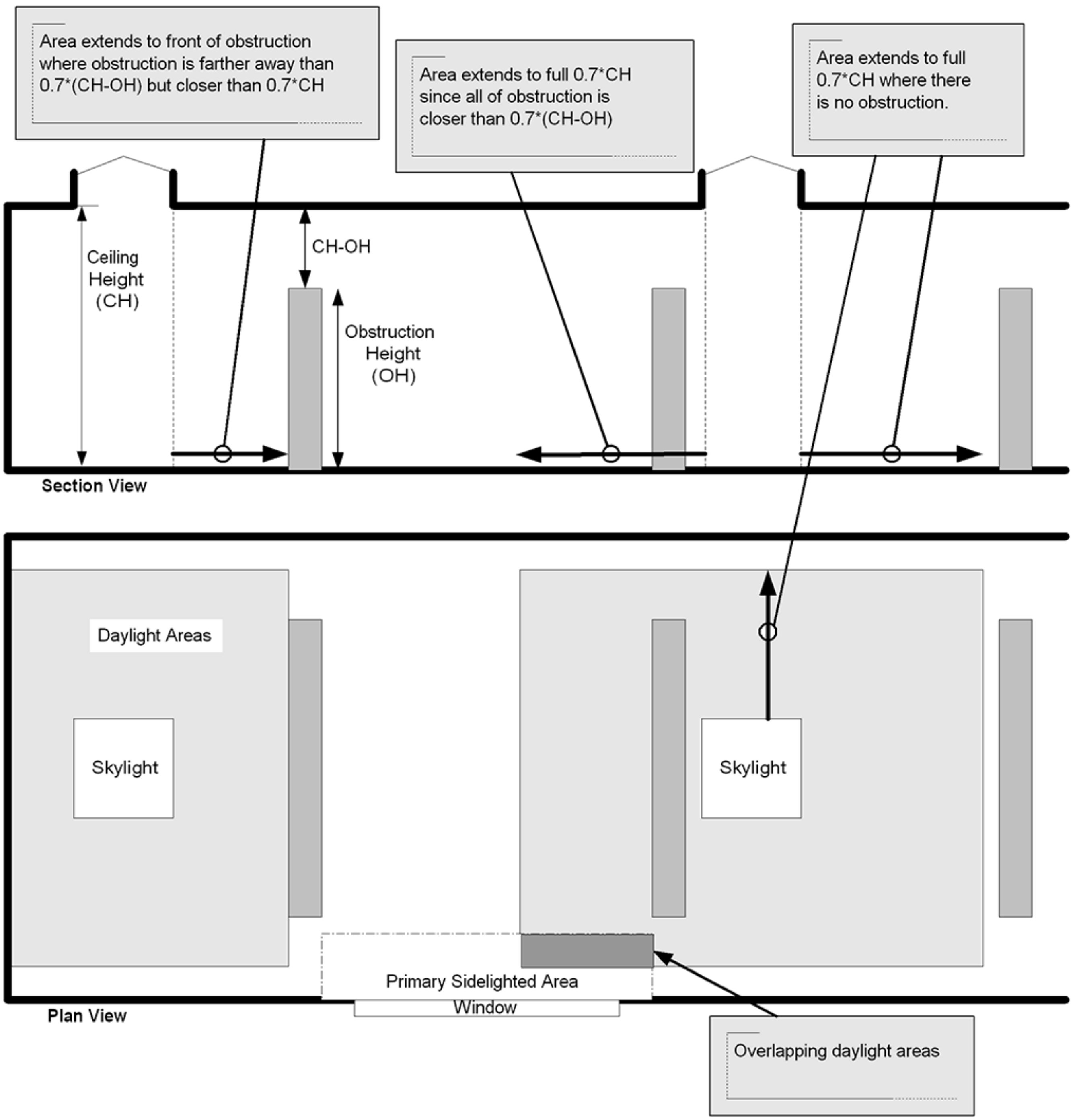

Figure 3.2-2 Computing the daylight area under skylights.

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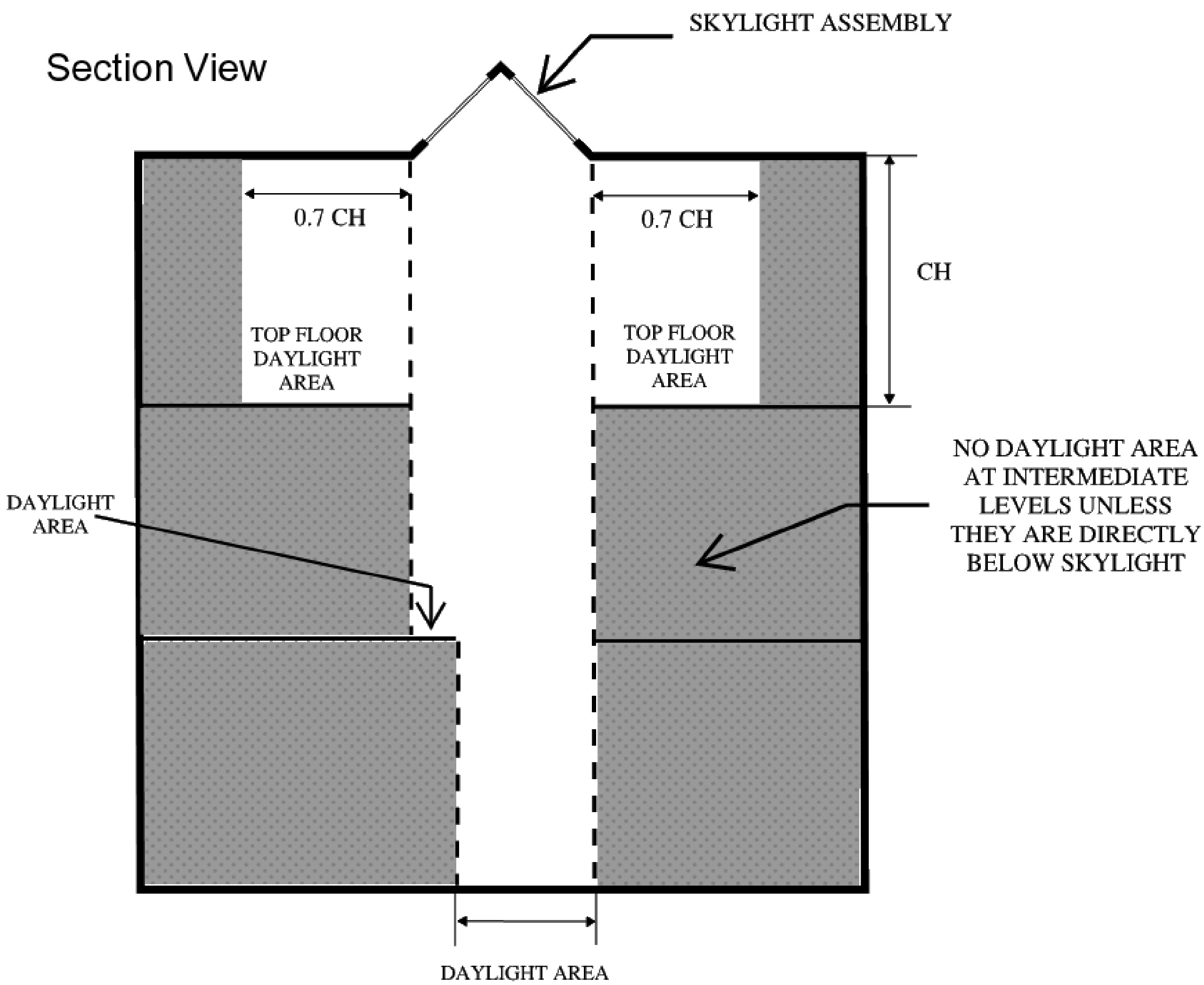

Figure 3.2-3 Computing the daylight area under skylights in multistory spaces.

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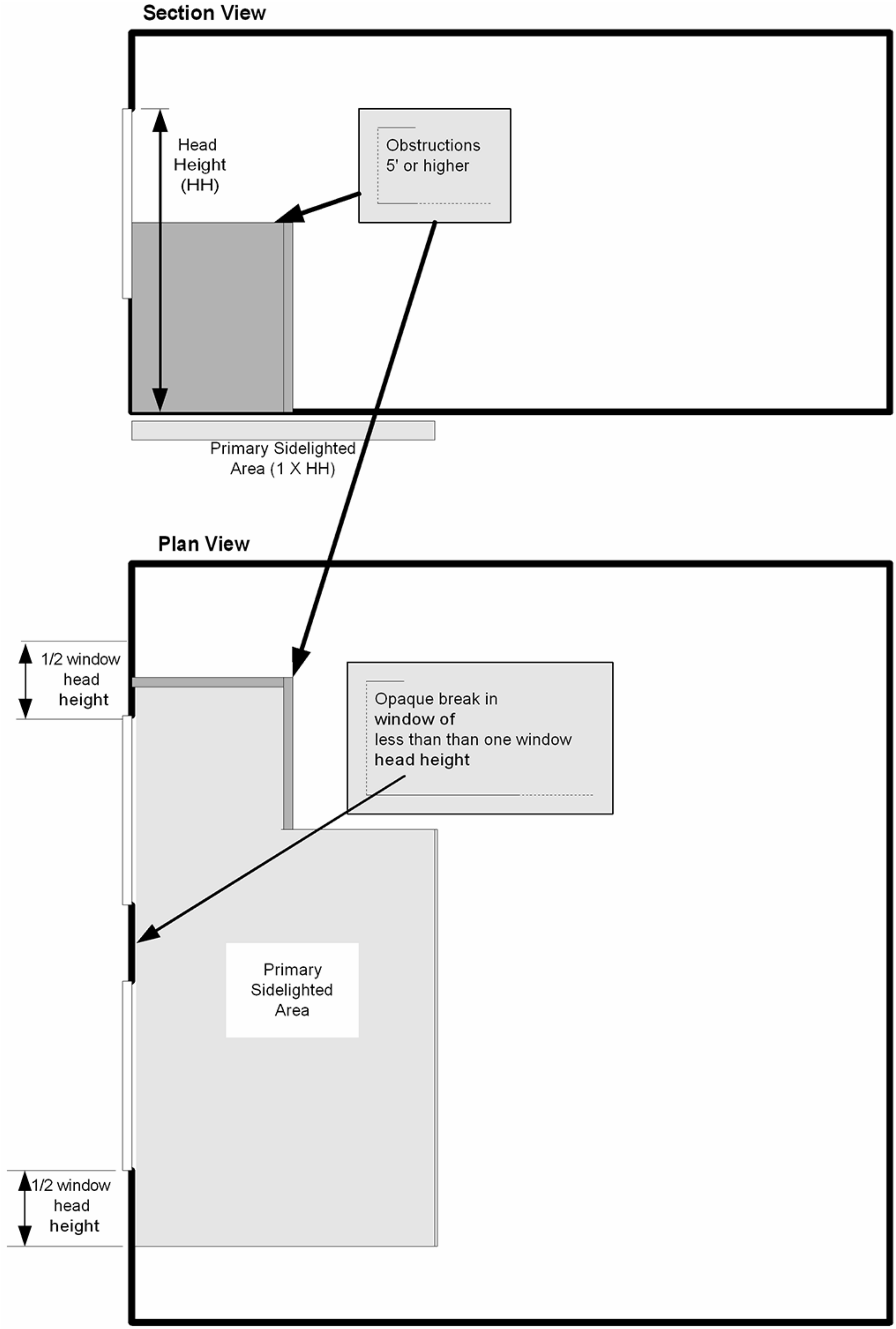

Figure 3.2-4 Computing the primary sidelighted area.

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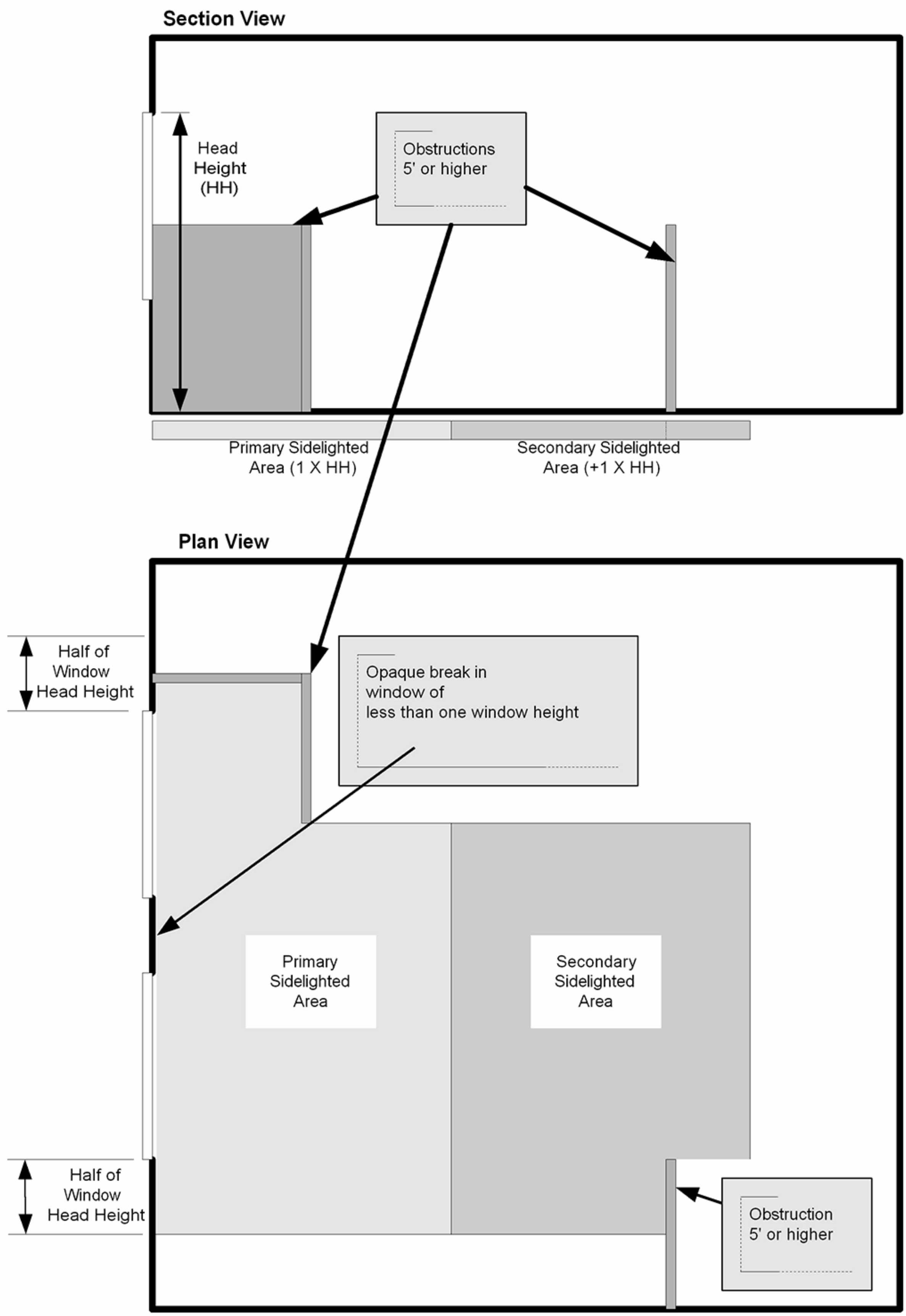

Figure 3.2-5 Computing the secondary sidelighted area.

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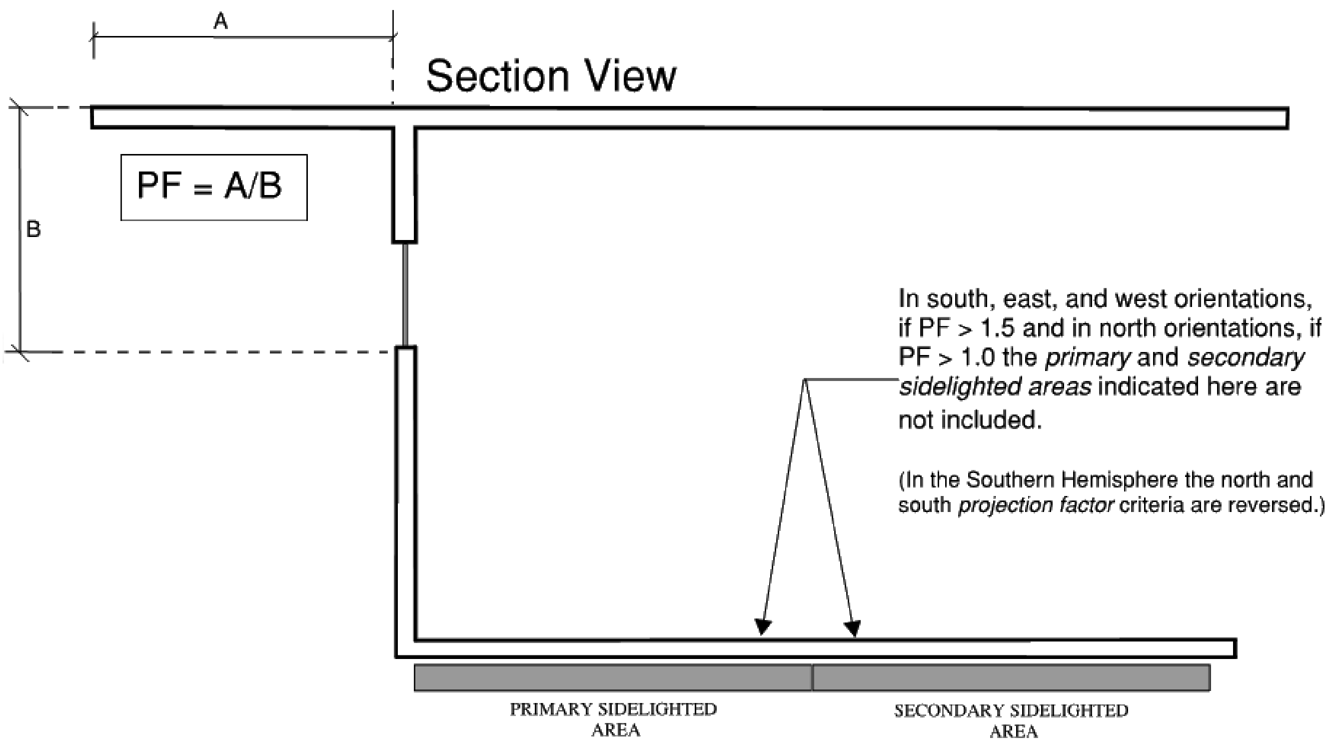

Figure 3.2-6 Computing the primary and secondary sidelighted areas with external projections.

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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.

direct-expansion dedicated outdoor air system units (DX-DOAS units): a type of air-cooled, water-cooled, or water-source factory-assembled product that dehumidifies 100% *outdoor air* to a low dew point and includes *reheat* that is capable of controlling the supply dry-bulb temperature of the dehumidified air to the designed supply air temperature. This conditioned *outdoor air* is then delivered directly or indirectly to the *conditioned spaces*. It may precondition *outdoor air* by containing an enthalpy wheel, sensible wheel, desiccant wheel, plate heat exchanger, heat pipes, or other heat or mass transfer apparatus.

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.

east-oriented: facing within 45 degrees of true east to the south and within less than 22.5 degrees of true east to the north in the northern hemisphere; facing within 45 degrees of true east to the north and within less than 22.5 degrees of true east to the south in the southern hemisphere.

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, fluid: a *system* by which the supply air of a cooling *system* is cooled indirectly with a fluid that is itself cooled by heat or mass transfer to the environment without the use of *mechanical cooling*. Examples of commonly used fluids are water, glycol mixtures, and refrigerants.

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.*

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. (***Informative Note:*** *EER2* reflects the new higher static effective 1/1/2023.)

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

envelope performance factor: the trade-off value for the *building envelope* performance compliance option, expressed in annual *energy* cost, calculated using the procedures specified in Section 5.6. 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*.

energy recovery ratio, series (SERR): the difference between the dry-bulb air temperatures leaving the *series energy recovery* unit and leaving the dehumidifying coil divided by the difference between 75°F and the dry-bulb temperature of the air leaving the dehumidifying cooling coil.

energy recovery, series: a three-step process in which the first step is to remove *energy* from a single airstream without the use of *mechanical cooling*. In the second step, the airstream is mechanically cooled for the purpose of dehumidification. In the third step, the *energy* removed in step one is reintroduced to the airstream.

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enthalpy recovery ratio: change in the enthalpy of the *outdoor air* supply divided by the difference between the *outdoor air* and entering exhaust air enthalpy, expressed as a percentage.

entrance door: see *vertical fenestration.*

equipment: devices for *space* heating, *space* cooling, *ventilation*, humidification, dehumidification, electric power, lighting, transportation, refrigeration, cooking, 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 used 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* or on an *existing site.*

existing site: a *site* or portion thereof that was previously approved by the *authority having jurisdiction*.

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

exterior building envelope: see *building envelope*.

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

exterior wall: see *building envelope* and *wall*.

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).

facade area: area of the facade, 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 *facade area* by measuring the area in a plane parallel to the surface.

fan array: multiple fans in parallel between two *plenum* sections in an air *distribution system*.

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, embedded: a fan that is part of a manufactured assembly where the assembly includes functions other than air movement.

fan energy index (FEI): the ratio of the electric input power of a reference fan to the electric input power of the actual fan as calculated per AMCA 208.

fan nameplate electrical input power: the nominal electrical input power rating stamped on a fan assembly nameplate.

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 spaces* 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*, other than during *air economizer* operation.

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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 spaces* 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: an assembly, including the frame, in the *building envelope* that allows light to pass. *Fenestration* assemblies include (but are not limited to) windows, plastic panels, clerestories, *roof monitors*, *skylights*, glass block, and *doors* where more than one-half of the *door area* is glazed. For the purposes of determining *building envelope* requirements, the classifications are defined as follows:

> ***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 *fenestration*, 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*.)

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*/*driver*.

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 (a) 7 Btu/ft^2·°F or (b) 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 (a) is not a *mass floor* and (b) 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 *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 conditioned floor area:*** the *gross floor area* of *conditioned spaces*.
>
> ***gross lighted floor area:*** the *gross floor area* of lighted *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.

fluid economizer: see *economizer, fluid.*

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.

functional performance testing (FPT): a systematic process to verify that controls and other elements of the *building* project are capable of and configured to operate or perform as required.

general lighting: see *lighting, general*.

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

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

greenhouse: a *space* with a *skylight roof* ratio of 50% or more above the growing area used exclusively for horticultural production, cultivation, or maintenance by utilizing a sunlit environment. *Greenhouses* are *spaces* erected for a period of 180 days or more.

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

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

gross lighted floor area: 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 recovery coefficient of performance (COP_{HR}): a ratio of the net heat recovery capacity plus the net refrigerating capacity to the total input power at any given set of rating conditions. COP_{HR} applies to units that are operating in a manner that uses either all or only a portion of heat generated during chiller operation to heat a load, while the remaining heat, if any, is rejected to the outdoor ambient. COP_{HR} takes into account the beneficial cooling capacity as well as the heat recovery capacity.

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. (***Informative Note:*** *HSPF2* reflects the new higher static and load line effective 1/1/2023.)

high-end trim: process of setting the maximum light output of individual *luminaires* or groups of *luminaires* to support visual needs of a *space*, task, or area. *High-end trim* is also known as "institutional tuning" or "task tuning."

historic: a *building* or *space* that has been specifically designated 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.

humidistatic controls: *automatic* controls used to maintain humidity at a fixed or adjustable *set point*.

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*.

IEC Design H motor: an electric motor that

a. is an induction motor designed for use with three-phase power;
b. contains a cage rotor;
c. is capable of direct-on-line starting;
d. has 4, 6, or 8 poles;

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e. is rated from 0.4 to 1600 *kW* at a frequency of 60 Hz; and
f. conforms to Sections 8.1, 8.2, and 8.3 of IEC 60034-12 (edition 2.1) requirements for starting torque, locked rotor apparent power, and starting.

IEC Design N motor: an electric motor that

a. is an induction motor designed for use with three-phase power;
b. contains a cage rotor;
c. is capable of direct-on-line starting;
d. has 2, 4, 6, or 8 poles;
e. is rated from 0.4 to 1600 *kW* at a frequency of 60 Hz; and
f. conforms to Sections 6.1, 6.2, and 6.3 of IEC 60034-12 (edition 2.1) requirements for torque characteristics, locked rotor apparent power, and starting.

indirectly conditioned space: see *space*.

indoor grow: a *space,* other than a *greenhouse*, used exclusively for horticultural production, cultivation, or maintenance.

indoor pool dehumidifier: a type of air-cooled or water-cooled electrically operated vapor compression refrigeration *system*, factory assembled as a single package or split *system*, that includes an indoor cooling/dehumidifying coil, an air *reheat* coil, one or more compressors, and an air-moving device. It may also include a refrigerant heat recovery unit, an auxiliary refrigerant condenser, an economizer, and an air-to-air heat recovery device. It shall provide the function of dehumidification, air circulation, and air *reheating* and may include the function of air-cooling, air-cleaning, *pool* water heating, and air-to-air heat recovery.

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

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*.

insulated metal panel: a factory-manufactured panel consisting of metal facings, an insulative core, and a panel joint intended for use in an assembly forming an *exterior wall*, an *exterior wall* covering, or a *roof covering* of a *building envelope*.

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*.IP*): a single-number figure of merit based on part-load *EER* expressing part-load *efficiency* for air-conditioning and heat-pump *equipment* on the basis of weighted operation at various load capacities for the *equipment*.

integrated seasonal coefficient of performance (ISCOP): a seasonal *efficiency* number that is a combined value based on the formula listed in AHRI Standard 920 of the two *COP* values for the heating season of a *DX-DOAS unit* water or air source heat pump, expressed in W/W.

integrated seasonal moisture removal efficiency (ISMRE): a seasonal *efficiency* number that is a combined value based on the formula listed in AHRI Standard 920 of the four dehumidification *moisture removal efficiency* (*MRE*) ratings required for *DX-DOAS units*, expressed in lb of moisture/kWh.

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

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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."

> ***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.

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 ornamental or 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, horticultural: electric lighting used for horticultural production, cultivation, or maintenance with either plug-in or hard-wired connections for electric power.

lighting power allowance (LPA), exterior: the maximum lighting power in watts allowed for the exterior of a *property*.

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

lighting power density (LPD): the lighting power per unit area of a *building*, *space*, or outdoor area expressed in W/ft^2.

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

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

linear thermal bridge: see *thermal bridge.*

low-rise residential buildings: single-family houses, multifamily *structures* of three *stories* or fewer above *grade*, manufactured houses (mobile homes), and manufactured houses (modular).

lumen maintenance: a lighting control strategy that increases light source power over time to maintain light levels as sources age, dirt accumulates in *luminaires*, or both. Also known as "lumen depreciation compensation" or "constant lumen output."

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.

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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*.

metal building envelope: see *building envelope*.

metal framing: see *vertical fenestration*.

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

moisture removal efficiency (MRE): a ratio of the moisture removal capacity in lb of moisture/h to the power input values in *kW* at any given set of standard rating conditions expressed in lb of moisture/kWh.

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

nameplate horsepower (hp): the nominal motor output power 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.

NEMA Design A motor: a squirrel-cage motor that

a. is designed to withstand full-voltage starting and developing locked-rotor torque as shown in NEMA MG 1, paragraph 12.38.1;
b. has pull-up torque not less than the values shown in NEMA MG 1, paragraph 12.40.1;
c. has breakdown torque not less than the values shown in NEMA MG 1, paragraph 12.39.1;
d. has a locked-rotor current higher than the values shown in NEMA MG 1, paragraph 12.35.1, for 60 Hz, and NEMA MG 1, paragraph 12.35.2, for 50 Hz; and
e. has a slip at rated load of less than 5% for motors with fewer than 10 poles.

NEMA Design B motor: a squirrel-cage motor that is

a. designed to withstand full-voltage starting;
b. develops locked-rotor, breakdown, and pull-up torques adequate for general application as specified in NEMA MG1, paragraphs 12.38, 12.39, and 12.40;
c. draws locked-rotor current not to exceed the values shown in NEMA MG1, paragraph 12.35.1, for 60 Hz, and paragraph 12.35.2 for 50 Hz; and
d. has a slip at rated load of less than 5% for motors with fewer than 10 poles.

NEMA Design C motor: a squirrel-cage motor that

a. is designed to withstand full-voltage starting and developing locked-rotor torque for high-torque applications up to the values shown in NEMA MG1, paragraph 12.38.2 (incorporated by reference; see §431.15);
b. has pull-up torque not less than the values shown in NEMA MG1, paragraph 12.40.2;
c. has breakdown torque not less than the values shown in NEMA MG1, paragraph 12.39.2;
d. has a locked-rotor current not to exceed the values shown in NEMA MG1, paragraph 12.35.1, for 60 Hz, and paragraph 12.35.2 for 50 Hz; and
e. has a slip at rated load of less than 5%.

networked guest room control system: a *control system*, accessible from the hotel/motel front desk or other central location, that is capable of identifying rented and unrented rooms according to a timed schedule, and is capable of controlling HVAC in each hotel/motel guest room separately.

nonautomatic: see *manual*.

nonmetal framing: see *vertical fenestration*.

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

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

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nonstandard part-load value (NPLV.*IP*): a single-number part-load *efficiency* figure of merit calculated and referenced to conditions other than *IPLV.*IP conditions, for units that are not designed to operate at AHRI standard rating conditions.

nonswinging door: see *door*.

nontransient: occupancy of a *dwelling unit* or sleeping unit for more than 30 days.

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* or *semiexterior 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* or *semiexterior wall*
g. Is restricted to applications where an existing air conditioner, heat pump, or gas/electric unit, installed in an existing *exterior wall* or *semiexterior 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 67.5 degrees of true north in the northern hemisphere; facing within 67.5 degrees of true south in the southern hemisphere.

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

occupied-standby mode: when a zone is scheduled to be occupied, and an occupant sensor indicates no occupants are within the zone.

off-mode power consumption ($P_{W,OFF}$): the power consumption when the unit is connected to its main power source but is neither providing cooling nor heating to the *building* it serves.

on-site electricity generation systems: *systems* located at the *building site* that generate electricity, including, but not limited to, generators, combined heat and power *systems*, *fuel* cells, and *on-site renewable energy systems*.

on-site renewable energy: *energy* from renewable resources harvested at the *building site*.

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

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.

parking garage daylight transition zone: covered vehicle entrances and exits from *buildings* and parking *structures* not exceeding a depth of 66 ft inside the *structure*, or a depth as determined by ANSI/IES RP-8,

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and not exceeding a width of 30 ft to either side of the drive aisle centerline and not extending beyond adjacent walls.

parking garage section: a part of a parking garage where airflow is restricted from other parts of the garage by solid walls.

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

PEI_{CL}: the *pump* energy index for a constant load, hp.

PEI_{VL}: the *pump* energy index for a variable load.

PER_{CL}: the *pump* energy rating for a constant load, hp, determined in accordance with either testing for bare *pumps*, *pumps* sold with single-phase induction motors, and *pumps* sold with drivers other than electric motors, or testing for *pumps* sold with motors and rated using the testing-based approach, or testing for *pumps* sold with motors and rated using the calculation-based approach.

PER_{STD}: the PER_{CL} for a *pump* that is minimally compliant with U.S. DOE *energy* conservation standards with the same flow and specific speed characteristics as the tested *pump* (hp).

PER_{VL}: the *pump energy* rating for a variable load, hp, determined in accordance with testing for *pumps* sold with motors and continuous or noncontinuous controls rated using the testing-based approach, or testing for *pumps* sold with motors and continuous controls rated using the calculation-based approach.

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*.

photosynthetic photon efficacy (PPE): photosynthetic photon flux emitted by a light source between 400 and 700 nm divided by its electrical input power, expressed in units of micromoles per joule as defined by ANSI/ASABE S640-2017.

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*.

point thermal bridge: see *thermal bridge.*

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 *pools*, whirlpools, spas, and hot tubs.

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.

primary sidelighted area: see *daylight area*.

process application: a manufacturing, industrial, or commercial procedure or activity where the primary purpose is other than conditioning *spaces* and maintaining comfort and amenities for the occupants of a *building*.

process energy: *energy* consumed in support of a *process application*.

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.

property: *building* or *site.*

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

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

psi-factor (ψ or Psi): *thermal transmittance* per unit length of a *linear thermal bridge* in units of Btu/(h·ft·°F).

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

pump: *equipment* designed to move liquids that may include entrained gases, free solids, and totally dissolved solids by physical or mechanical action and that includes a bare pump and, if included by the *manufacturer* at the time of sale, mechanical *equipment*, driver, and controls. (***Informative Note:*** The U.S. *Code of Federal Regulations* (CFR) contains official definitions related to pumps in 10 CFR 431.462. In the United States, the official definitions take precedence over the definitions shown below.)

clean-water pump: a device that is designed for use in pumping water with a maximum nonabsorbent free solid content of 0.016 lb/ft^3 and with a maximum dissolved solid content of 3.1 lb/ft^3, provided that the total gas content of the water does not exceed the saturation volume, and disregarding any additives necessary to prevent the water from freezing at a minimum of 14°F.

end-suction close-coupled (ESCC) pump: a close-coupled, dry-rotor, end-suction device that has a shaft input power greater than or equal to 1.0 hp and less than or equal to 200 hp at its *best efficiency point* (*BEP*) and full impeller diameter and that is not a dedicated-purpose *pool pump*. It is also a single-stage, rotodynamic *pump* in which the liquid enters the bare *pump* in a direction parallel to the impeller shaft and on the side opposite the bare *pump*'s driver end and is then discharged through a volute in a plane perpendicular to the shaft.

end-suction frame-mounted/own-bearings (ESFM) pump: a mechanically coupled, dry-rotor, end-suction device that has a shaft input power greater than or equal to 1.0 hp and less than or equal to 200 hp at its *best efficiency point* (*BEP*) and full impeller diameter and that is not a dedicated-purpose *pool pump*. It is also a single-stage, rotodynamic *pump* in which the liquid enters the bare *pump* in a direction parallel to the impeller shaft and on the side opposite the bare *pump*'s driver end and is then discharged through a volute in a plane perpendicular to the shaft.

inline (IL) pump: a device that is either a twin-head *pump* or a single-stage, single-axis flow, dry-rotor, rotodynamic *pump* that has a shaft input power greater than or equal to 1.0 hp and less than or equal to 200 hp at its *best efficiency point* (*BEP*) and full impeller diameter, in which liquid is discharged through a volute in a plane perpendicular to the shaft. Such *pumps* do not include *pumps* that are mechanically coupled or close-coupled, have a *pump* power output that is less than or equal to 5.0 hp at its *BEP* at full impeller diameter, and are distributed in commerce with a horizontal motor.

radially split, multistage, vertical, inline diffuser casing (RSV) pump: a device that is a vertically suspended, multistage, single-axis-flow, dry-rotor, rotodynamic *pump* and

a. has a shaft input power greater than or equal to 1.0 hp and less than or equal to 200 hp at its *best efficiency point* (*BEP*) and full impeller diameter and at the number of stages required for testing;
b. in which liquid is discharged in a place perpendicular to the impeller shaft;
c. for which each stage (or bowl) consists of an impeller and diffuser; and
d. for which no external part of such a *pump* is designed to be submerged in the pumped liquid.

submersible turbine (ST) pump: a device that is a single-stage or multistage, dry-rotor, rotodynamic *pump* that is designed to be operated with the motor and stage(s) fully submerged in the pumped liquid; that has a shaft input power greater than or equal to 1.0 hp and less than or equal to 200 hp at its *best efficiency point* (*BEP*) and full impeller diameter and at the number of stages required for testing; and in which each stage of this *pump* consists of an impeller and diffuser, and liquid enters and exits each stage of the bare *pump* in a direction parallel to the impeller shaft.

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*.

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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·ft^2·°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 or agency that adopts or sanctions use of Normative Appendix G when quantifying performance that exceeds requirements of this standard.

readily accessible: installed in a manner and location that allows it to be 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*).

recool: to lower the temperature of air that has been previously heated by a *mechanical heating system*.

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

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

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

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

regulated energy use: *energy* used by *building systems* and components with requirements prescribed in Sections 5 through 10. This includes *energy* used for HVAC, lighting, *service water heating*, motors, *transformers*, vertical transportation, refrigeration *equipment*, *computer-room* cooling *equipment*, and other *building systems*, components, and processes with requirements prescribed in Sections 5 through 10.

reheat: to raise the temperature of air that has been previously cooled either by mechanical refrigeration or an economizer *system*.

renewable energy resources: *energy* from solar, wind, biomass or hydro, or extracted from hot fluid or steam heated within the earth.

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, and *transfer air*.

reset: *automatic* adjustment of the controller *set point* to a higher or lower value.

residential: *spaces* in *building*s 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.

residential associated HVAC zone: any *HVAC zone* that primarily includes *nonresidential spaces* designed to serve occupants of *residential* **spaces**, including but not limited to corridors, stairwells, elevator lobbies, and common restrooms, on a *floor* where over 75% of the *gross conditioned floor area* are *residential spaces*. This definition does not apply to *HVAC zones* within hospitals.

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*.

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

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

roof replacement: an *alteration* that includes the removal of all existing layers of the *roof* assembly materials down to the *roof* deck and installing a new *roof* assembly above the *roof* deck.

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 on 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 *refrigerant dew-point* temperature and the bubble-point temperature 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 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 (W). (***Informative Note:*** *SEER2* reflects the new higher static effective 1/1/2023.)

secondary sidelighted area: see *daylight area.*

sectional garage door: see *door*.

semiexterior building envelope: see *building envelope*.

semiexterior wall: see *building envelope* and *wall*.

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

semiheated space: see *space*.

sensible energy recovery ratio: change in the dry-bulb temperature of the *outdoor air* supply divided by the difference between the *outdoor air* and entering exhaust air dry-bulb temperatures, expressed as a percentage.

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.

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

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

set point: 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.

sidelighting effective aperture: relationship of daylight transmitted through *vertical fenestration* to the *primary sidelighted areas*. The *sidelighting effective aperture* is calculated according to the following formula:

$$\textit{Sidelighting Effective Aperture} = \frac{\sum \textit{Vertical Fenestration}\ \text{Area} \times \textit{Vertical Fenestration VT}}{\text{Area of Primary Sidelighted Area}}$$

where "*Vertical Fenestration VT*" is the *visible transmittance* of *vertical fenestration* as determined in accordance with Section 5.8.2.6.

simulation program: a computer program, including the simulation engine and the corresponding user interface, that is capable of simulating the *energy* performance of *building systems*.

simultaneous cooling and heating coefficient of performance (COP_{SHC}): a ratio of the net heating capacity plus the net refrigerating capacity to the total input power at any given set of rating conditions. COP_{SHC} applies to units that are operating in a manner that uses both the net heating and refrigerating capacities generated during operation. COP_{SHC} takes into account the beneficial capacity as well as the heating capacity.

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 grilles, 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 uses 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: an area of land that is under the control of a single owner or entity, which contains *systems* or *equipment*.

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

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*.

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

$$\textit{Sidelighting Effective Aperture} = \frac{0.85 \times \textit{Skylight}\ \text{Area} \times \textit{Skylight}\ \textit{VT} \times \text{WF}}{\textit{Daylight Area Under Skylights}}$$

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 *skylight well* factor, where *skylight well* factor is 0.9 if *skylight well* depth is less than 2 ft, or 0.7 if *skylight well* depth is 2 ft or greater. *Skylight 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*.)

south-oriented: facing within 45 degrees of true south in the northern hemisphere; facing within 45 degrees of true north in the southern hemisphere.

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 is ≥3.4 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 *spaces*, provided
   1. the product of the *U-factors* and surface areas of the *space* adjacent to connected *spaces* exceeds the combined sum of the product of the *U-factor*s and surface areas 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*.)

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Table 3.2 Heated Space Criteria

Climate Zone	Heating Output, Btu/h·ft^2
0	>5
1	>5
2	>5
3A, 3B	>9
3C	>7
4A, 4B	>10
4C	>8
5	>12
6	>14
7	>16
8	>19

standby power mode consumption ($P_{W,SB}$): the power used by a product or appliance when enabled but in the standby operating mode (refer to 10 CFR 430).

steel-framed wall: see *wall*.

steel-joist floor: see *floor*.

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.

structure: that which is built or constructed.

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: 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. (***Informative Note:*** This definition is not applicable to the use of this word in *building envelope* contexts such as, but not limited to, "curtain wall system," "drainage system," "fenestration system," "framing system," "roof system," and "shading system.")

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 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: an element that has higher thermal conductivity than the surrounding materials, which creates a path of least resistance for heat transfer. For the purposes of determining *building envelope* requirements, the classifications for *thermal bridges* are defined as follows:

> ***clear-field thermal bridge:*** elements of a *building envelope* assembly that are distributed over the area of the assembly and addressed in determining the thermal performance of the assembly in accordance with Normative Appendix A. Examples of *clear-field thermal bridges* include studs, webs and face shells of masonry units, ties, tracks, plates, girts and purlins for *metal building envelopes*, and fasteners. Fasteners used to construct assemblies in accordance with Normative Appendix A are not considered nor separately defined as *point thermal bridges*.
>
> ***linear thermal bridge:*** a length-based element associated with horizontal, vertical, or diagonal elements that penetrates the insulation in the *building envelope* and with length measured along the exterior sur-

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face of the *building envelope*. Examples of *linear thermal bridges* include edges of *floors*, balconies, columns and beams in the plane of an assembly, parapets, *roof-wall-floor* intersections, *fenestration* interfaces, shelf angles, and similar conditions not otherwise defined as a *clear field thermal bridge* or *point thermal bridge*.

point thermal bridge: a discrete element that penetrates the insulation in the *building envelope*. Examples of *point thermal bridges* include a beam penetrating a *wall,* a column penetrating a *roof* or *floor*, and an anchor or connection used to attach an element to the *building* and not otherwise defined as a *clear field thermal bridge* or *linear thermal bridge*. The cross-sectional area of the *point thermal bridge* is measured at the outer surface of the outermost layer of insulation that is penetrated by the element.

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·ft^2·°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·ft^2·°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 that 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 *set point*.

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

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.

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

total system performance ratio (TSPR): ratio of the sum of a *building's* annual heating and cooling load in kBtu to the sum of annual *energy* input of the *building* mechanical *systems,* where the input units are in accordance with Section L5.

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.

trim compressor: a compressor that is designated for part-load operation, handling the short-term variable trim load of end uses in addition to the fully loaded base compressors.

TSPR reference building design: a computer representation of a hypothetical *building* design based on modifications to the *proposed design* in accordance with Section L4.3. This representation is used as the basis for calculating the mechanical *total system performance ratio* for determining alternative mechanical *system* performance in accordance with Section 6.6.2.

U-factor: see *thermal transmittance*.

unconditioned space: see *space*.

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

unitary air conditioners: 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.

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unitary heat pump: one or more factory-made assemblies that normally include an indoor conditioning coil, compressors, 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 set point* 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*.

unregulated energy use: *energy* used by *building systems* and components that is not *regulated energy use*. (See *regulated energy use*.)

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 uses 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 and testing provider (V&T provider): an entity who completes the activities needed to implement the *building functional performance testing* (*FPT*) activities or verify that elements of the *building* project meet stated 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:

> ***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*.)
>
> ***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 clerestory windows, *roof* monitors with nonopenable windows, and nonopenable sidelights and transoms.
>
> ***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*, *roof* monitors with openable windows, and *doors* that are not *entrance doors*.

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

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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 (a) 7 Btu/ft^2·°F or (b) 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 *set point* after a period of shutdown or *setback*.

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

west-oriented: facing within 45 degrees of true west to the south and within less than 22.5 degrees of true west to the north in the northern hemisphere; facing within 45 degrees of true west to the north and within less than 22.5 degrees of true west to the south in the southern hemisphere.

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

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

3.3 Abbreviations and Acronyms

χ	*chi-factor*, *thermal transmittance* of a *point thermal bridge*
Ψ	*psi-factor*, *thermal transmittance* per unit length of a *linear thermal bridge*
ac	alternating current
ach	air changes per hour
AFUE	annual fuel utilization efficiency
AHAM	Association of Home Appliance Manufacturers
ANSI	American National Standards Institute
AHRI	Air-Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement Control Association
ASTM	ASTM International
BEP	best efficiency point
(*fan*) *bhp*	(*fan*) *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*
*CDD*50	*cooling degree-days* base 50°F
CEER	*combined energy efficiency ratio*
CFEI	*ceiling fan energy index*

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cfm	cubic feet per minute
CHW	chilled water
CHWST	chilled-water supply temperature
c.i.	*continuous insulation*
COP	*coefficient of performance*
COP_H	*coefficient of performance, heat pump—heating*
COP_{HR}	*heat recovery coefficient of performance*
COP_{SHC}	*simultaneous cooling and heating coefficient of performance*
CTI	Cooling Technology Institute
CV	constant volume
db	dry-bulb
DCV	*demand control ventilation*
DDC	*direct digital control*
DOAS	dedicated *outdoor air system*
DOE	U.S. Department of Energy
DX	direct expansion
E_c	combustion *efficiency*
EER/EER2	*energy efficiency ratio*
EF	*energy factor*
ER	*energy* recovery
E_t	thermal *efficiency*
ESCC	*end-suction close-coupled*
ESFM	*end-suction frame-mounted/own-bearings*
°F	Fahrenheit
FC	filled cavity
FEI	*fan energy index*
FL	full-load
FPT	*functional performance testing*
FPTU	fan-powered *terminal* unit
ft	foot
gr	grains of moisture per pound of dry air
h	hour
HC	*heat capacity*
HDD	*heating degree-day*
*HDD*65	*heating degree-days* base 65°F
$h \cdot ft^2 \cdot °F/Btu$	hour per square foot per degree Fahrenheit per British thermal unit
HW	heating water
HWST	heating-water supply temperature
HID	high-intensity discharge
hp	horsepower
HSPF/HSPF2	*heating seasonal performance factor*
HVAC	heating, ventilating, and air conditioning

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HVACR	heating, ventilating, air conditioning, and refrigeration
IEC	International Electrotechnical Commission
IEER	*integrated energy efficiency ratio*
IES	Illuminating Engineering Society
IL	inline
in.	inches
I-P	inch-pound
IPLV.IP	*integrated part-load value*
ISCOP	integrated seasonal coefficient of performance
ISMRE	integrated seasonal moisture removal efficiency
IT	information technology
J	joule
K	kelvin
kJ	kilojoule
kVA	*kilovolt-ampere*
kW	*kilowatt*
L	length of a *linear thermal bridge*
LED	light-emitting diode
lb	pound
lin	linear
lin ft	linear foot
LPA	maximum *lighting power allowance* in watts (W)
LPD	*lighting power density*
Ls	*liner system*
LSG	*light-to-solar-gain ratio*
MICA	Midwest Insulation Contractors Association
min.	minimum
MPF	mechanical performance factor
MRE	*moisture removal efficiency*
MSH	monitor seal height
n	number of occurrences a *point thermal bridge*
NAECA	U.S. National Appliance Energy Conservation Act
NEMA	National Electric Manufacturers Association
NFPA	National Fire Protection Association
NFRC	National Fenestration Rating Council
NPLV.IP	nonstandard part-load value
OAT	*outdoor air* temperature (dry-bulb unless wet-bulb is specified)
OA	*outdoor air*
PEI	*pump* energy index
PER	*pump* energy rating
PF	*projection factor*
PFP	parallel fan-powered

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PPE	photosynthetic photon efficacy
PRV	power roof/wall ventilator
PSZ-AC	packaged single-zone air conditioner
PSZ-HP	packaged single-zone heat pump
PTAC	*packaged terminal air conditioner*
PTHP	*packaged terminal heat pump*
R	*R-value* (*thermal resistance*)
RAT	return air temperature (dry-bulb unless wet-bulb is specified)
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
RSV	radially split, multistage, vertical, inline diffuser casing
SAT	supply air temperature (dry-bulb unless wet-bulb is specified)
SC	*shading coefficient*
SEER/*SEER2*	*seasonal energy efficiency ratio*
SERR	*series energy recovery ratio*
SHGC	*solar heat gain coefficient*
SHW	service hot water
SL	standby loss
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SPVAC	*single-package vertical air conditioner*
SPVHP	*single-package vertical heat pump*
ST	submersible turbine
SZ	single zone
T_{db}	dry-bulb temperature
TDA	total display area
TSPR	*total system performance ratio*
$TSPR_p$	*TSPR* of a *proposed design*
$TSPR_r$	*TSPR* of a *TSPR reference building design*
T_{wb}	wet-bulb temperature
UPS	uninterruptible power supply
VAV	*variable air volume*
VRF	*variable refrigerant flow*
VSD	variable-speed drive
VT	*visible transmittance* (also known as visible light transmittance [VLT])
V&T	verification and testing
W	watt
wb	wet-bulb
W/ft^2	watts per square foot
WF	well factor
Wh	watt-hour

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4. ADMINISTRATION AND ENFORCEMENT

4.1 General

4.1.1 Scope

4.1.1.1 New Buildings. New *buildings* shall comply with the standard as described in Section 4.2.

4.1.1.2 Additions to Existing Buildings. *Additions* to *existing buildings* shall comply with the standard as described in Section 4.2.

4.1.1.3 Alterations of Existing Buildings. *Alterations* of *existing buildings* shall comply with the standard as described in Section 4.2.

4.1.1.4 Replacement of Portions of Existing Buildings. Portions of a *building envelope*, heating, ventilating, air-conditioning, *service water heating*, power, lighting, and other *systems* and *equipment* that are being replaced shall be considered as *alterations* of *existing buildings* and shall comply with the standard as described in Section 4.2.

4.1.1.5 Changes in Space Conditioning. Whenever *unconditioned space* or *semiheated space* in a *building* is converted to a *conditioned space*, such *conditioned space* shall be brought into compliance with all the applicable requirements of this standard that would apply to the *building envelope*, heating, ventilating, air-conditioning, *service water heating*, power, lighting, and other *systems* and *equipment* of the *space* as if the *building* was new.

4.1.1.6 Sites and New Site Systems and Equipment. *Sites*, with or without a contiguous *building* or *buildings*, and s*ite systems* and *equipment* using or producing *energy*, such as *site* lighting, motors for *pumps* (for example, fountain *pumps* and water movement *equipment*), and transportation *equipment* (for example, elevators and escalators) shall comply with the standard as described in Section 4.2 for *systems* and *equipment* specifically identified in the standard.

4.1.2 Administrative Requirements. Administrative requirements relating to permit requirements, enforcement by the *authority having jurisdiction*, locally adopted *energy* standards, interpretations, claims of exemption, and rights of appeal are specified by the *authority having jurisdiction*.

4.1.3 Alternative Materials, Methods of Construction, or Design. The provisions of this standard are not intended to prevent the use of any material, method of *construction*, design, *equipment*, or *building system* not specifically prescribed herein.

4.1.4 Validity. If any term, part, provision, section, paragraph, subdivision, table, chart, or referenced standard of this standard shall be held unconstitutional, invalid, or ineffective, in whole or in part, such determination shall not be deemed to invalidate any remaining term, part, provision, section, paragraph, subdivision, table, chart, or referenced standard of this standard.

4.1.5 Other Laws. The provisions of this standard shall not be deemed to nullify any provisions of local, state, or federal law. Where there is a conflict between a requirement of this standard and such other law affecting *construction* of the *building*, precedence shall be determined by the *authority having jurisdiction*.

4.1.6 Referenced Standards. The standards referenced in this standard and listed in Section 13 shall be considered part of the requirements of this standard to the prescribed extent of such reference. Where differences occur between the provision of this standard and referenced standards, the provisions of this standard shall apply. Informative references are cited to acknowledge sources and are not part of this standard. They are identified in Informative Appendix E.

4.1.7 Normative Appendices. The normative appendices to this standard are considered to be integral parts of the mandatory requirements of this standard, which, for reasons of convenience, are placed apart from all other normative elements.

4.1.8 Informative Appendices. The informative appendices to this standard, and informative notes located within this standard, contain additional information and are not mandatory or part of this standard.

4.1.9 Reference Standard Reproduction Annex. The reference standard reproduction annex contains material that is cited in this standard but contained in another standard. The reference standard reproduction annex is not part of this standard but is included in the publication of this standard to facilitate use of this standard.

4.2 Compliance

4.2.1 Compliance Paths

4.2.1.1 New Buildings. New *buildings* shall comply with Section 4.2.2 through 4.2.5 and either the provisions of

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a. Sections 5, "Building Envelope"; 6, "Heating, Ventilating, and Air Conditioning"; 7, "Service Water Heating"; 8, "Power"; 9, "Lighting"; 10, "Other Equipment"; and 11, "Additional Efficiency Requirements," or
b. Section 12, "Energy Cost Budget Method," or
c. Normative Appendix G, "Performance Rating Method."

When using Normative Appendix G, the Performance Cost Index (PCI) of new *buildings*, *additions* to *existing buildings*, and/or *alterations* to *existing buildings* shall be less than or equal to the Performance Cost Index Target (PCI_t) when calculated in accordance with the following:

$$PCI_t = [BBUEC + (BPF \times BBREC) - PRE] / BBP$$

where

PCI	=	Performance Cost Index calculated in accordance with Section G1.2.2
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*
BPF	=	*building* performance factor from Table 4.2.1.1. For *building* area types not listed in Table 4.2.1.1, 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 based on their *gross floor area*. Where a project includes an *existing building* and an *addition*, the required BPF shall be equal to the area-weighted average, based on the *gross floor area*, of the *existing building* BPF determined as described in Section 4.2.1.3 and the *addition* BPF from Table 4.2.1.1.
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*
PRE	=	$PBP_{nre} - PBP_{pre}$
PBP	=	*proposed building performance*, including the reduced, annual *purchased energy* cost associated with all *on-site renewable energy* generation *systems*
PBP_{nre}	=	*proposed building performance* without any credit for reduced annual *energy* costs from *on-site renewable energy* generation *systems*
PBP_{pre}	=	*proposed building performance*, excluding any renewable *energy system* in the *proposed design* and including an *on-site renewable energy system* that meets but does not exceed the requirements of Section 10.5.1.1 modeled following the requirements for a *budget building design* in Table 12.5.1, row 15
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.

Table 4.2.1.1 Building Performance Factor (BPF)

Building Area Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.69	0.68	0.71	0.70	0.72	0.72	0.71	0.76	0.63	0.69	0.76	0.71	0.66	0.72	0.71	0.65	0.67	0.65	0.67
Healthcare/hospital	0.69	0.69	0.70	0.68	0.67	0.65	0.65	0.66	0.64	0.64	0.66	0.63	0.67	0.65	0.65	0.66	0.67	0.68	0.70
Hotel/motel	0.66	0.66	0.69	0.65	0.65	0.64	0.64	0.65	0.65	0.63	0.65	0.63	0.62	0.63	0.62	0.61	0.62	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.48	0.48	0.53	0.48	0.49	0.52	0.48	0.48	0.49	0.46	0.48
Restaurant	0.62	0.59	0.57	0.57	0.57	0.53	0.57	0.53	0.51	0.55	0.54	0.54	0.57	0.56	0.55	0.59	0.58	0.61	0.64
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.43	0.44	0.42	0.43	0.46	0.43	0.42	0.47	0.43	0.43	0.41	0.44
School	0.52	0.57	0.57	0.56	0.52	0.53	0.52	0.49	0.50	0.46	0.47	0.47	0.47	0.46	0.46	0.46	0.44	0.45	0.45
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.19	0.25	0.22	0.22	0.28	0.24	0.22	0.31	0.28	0.29	0.32
All others	0.62	0.60	0.62	0.59	0.55	0.51	0.53	0.52	0.55	0.53	0.52	0.55	0.53	0.53	0.56	0.54	0.54	0.54	0.54

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When $(PBP_{pre} - PBP)/BBP > 0.05$, new *buildings*, *additions* to *existing buildings*, and/or *alterations* to *existing buildings* shall comply with the following:

$$PCI + [(PBP_{pre} - PBP)/BBP] - 0.05 < PCI_t$$

Informative Notes:

1. PBP_{nre} = *proposed building performance*, no renewable *energy*.
2. PBP_{pre} = *proposed building performance*, prescriptive renewable *energy*.
3. PRE = prescriptive renewable *energy*.
4. See Informative Appendix I for using other metrics, including *site energy*, source *energy*, and carbon emissions, in conjunction with the Normative Appendix G *Performance Rating Method* when approved by the *rating authority*.

4.2.1.2 Additions to Existing Buildings. *Additions* to *existing buildings* shall comply with the provisions of Section 4.2.2 through 4.2.5 and one of the following:

a. Sections 5, "Building Envelope"; 6, "Heating, Ventilating, and Air Conditioning"; 7, "Service Water Heating"; 8, "Power"; 9, "Lighting"; 10, "Other Equipment"; and 11, "Additional Efficiency Requirements," or
b. Section 12, "Energy Cost Budget Method," or
c. Normative Appendix G, "Performance Rating Method," in accordance with Section 4.2.1.1.

4.2.1.2.1 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 Section 12 or Normative 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.

4.2.1.3 Alterations of Existing Building Assemblies, Systems, and Equipment. *Alterations* of *existing building* assemblies, *systems*, and *equipment* shall comply with the provisions of Section 4.2.2 through 4.2.5 and one of the following:

a. Sections 5, "Building Envelope"; 6, "Heating, Ventilating, and Air Conditioning"; 7, "Service Water Heating"; 8, "Power"; 9, "Lighting"; 10, "Other Equipment"; and 11, "Additional Efficiency Requirements," or
b. Section 12, "Energy Cost Budget Method," or
c. Normative Appendix G, "Performance Rating Method," in accordance with Section 4.2.1.1 with the following modifications:
   1. *Alterations* that meet the criteria in Section G3.1.4(a) shall use the BPF from Table 4.2.1.1 multiplied by 1.05.
   2. All other *alterations* modeled following Section G3.3 shall use BPF = 1.

Exceptions to 4.2.1.3: A *building* 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 listing by the U.S. Secretary of the Interior need not comply with these requirements.

4.2.1.4 New Sites and New Site Systems and Equipment. New *sites* and new *site systems* and *equipment* shall comply with either the provisions of

a. Sections 6, "Heating, Ventilating, and Air Conditioning"; 7, "Service Water Heating"; 8, "Power"; 9, "Lighting"; and 10, "Other Equipment," or
b. Section 12, "Energy Cost Budget Method."

4.2.1.5 Additions and Alterations to Existing Sites and Site Systems and Equipment. *Additions* and *alterations* to *existing sites and existing site systems and equipment* shall comply with the provisions of Sections 5, 6, 7, 8, 9, and 10, or Section 11. This section shall not apply to *buildings* on the *site* where the *alterations* or *additions* are to be performed except as required by Sections 4.2.1.2 and 4.2.1.3.

4.2.2 Compliance Documentation

4.2.2.1 Construction Details. Compliance documents shall show all the pertinent data and features of the *building*, *equipment*, and *systems* in sufficient detail to permit a determination of compliance by the *building official* and to indicate compliance with the requirements of this standard.

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4.2.2.2 Supplemental Information. Supplemental information necessary to verify compliance with this standard, such as calculations, worksheets, compliance forms, vendor literature, or other data, shall be made available when required by the *building official*.

4.2.2.3 Manuals. Operating and maintenance information shall be provided to the *building* owner. This information shall include but not be limited to the information specified in Sections 5.7.3.2, 6.7.3.2, 7.7.3.2, 8.7.3.2, 9.7.3.2, and 10.7.3.2.

4.2.3 Labeling of Material and Equipment. Materials and *equipment* shall be *labeled* in a manner that will allow for a determination of their compliance with the applicable provisions of this standard.

4.2.4 Inspections. All *building construction*, *additions*, or *alterations* work subject to the provisions of this standard shall remain accessible and exposed for inspection purposes until approved in accordance with the procedures specified by the *building official*. The *building official*, upon notification, shall make the inspections set forth in Section 4.2.4.1 through 4.2.4.6.

4.2.4.1 Fenestration Inspections. *Fenestration* shall be inspected in accordance with the compliance path selected in Section 4.2.1 and approved documentation provided in Section 4.2.2.

4.2.4.2 Opaque Assembly Thermal Insulation Inspections. *Opaque* assemblies shall be inspected in accordance with the compliance path selected in Section 4.2.1 and approved documentation provided in Section 4.2.2.

4.2.4.3 Continuous-Air-Barrier Inspections. Where a *continuous air barrier* is installed as a component of an *opaque roof*, *above-grade walls* and *below-grade walls*, or *floors*, it shall be inspected for compliance in accordance with Section 5.8.3.1. Integration with adjoining *fenestration* and other *continuous air barrier* elements shall be in accordance with Section 5.4.3.1.

4.2.4.4 Operable Fenestration and Door Inspections. *Fenestration* and *door* closers, inclusive of operating mechanisms, shall be installed in accordance with the *manufacturer*'s installation instructions. Associated seals and gaskets shall be installed in accordance with the *manufacturer*'s installation instructions and consistent with the provisions of Section 5.4.3.

4.2.4.5 Loading-Dock Weatherseals Inspections. Loading-dock weatherseals shall be inspected for installation and to verify that the seals are in good condition.

4.2.4.6 Other Inspections. Other inspections related to mechanical, plumbing, lighting, and other *equipment* shall be inspected in accordance with the compliance path selected in Section 4.2.1 and approved documentation provided in Section 4.2.2, or as otherwise required by the *building official*.

4.2.5 Verification, Testing, and Commissioning. Building *systems*, controls, and the *building envelope* shall comply with Sections 4.2.5.1, 4.2.5.2, and 4.2.5.3.

Informative Notes:

1. There are additional requirements within specific sections of this standard regarding documentation, procedures, independence of providers, and reporting. Requirements in individual sections are in addition to the general requirements provided in Section 4.2.5.
2. See Informative Appendix H for additional *commissioning* guidance.

4.2.5.1 Building Systems Verification and Testing Requirements. Verification or *functional performance testing* (*FPT*) to confirm compliance with required provisions of this standard shall be performed on *building systems*, controls, and the *building envelope*, as required by Sections 5.9.1, 6.9.1, 7.9.1, 8.9.1, 9.9.1, 10.9.1, 12.2(e), and G1.2.1(e). Where testing is required but specific *FPT* procedures are not specified in this standard, testing shall use *generally accepted engineering standards* acceptable to the *building official*.

For *alterations* and *additions*, verification and testing (V&T) shall be performed for new *systems*, and their interface and integration with existing *building systems* shall be verified or tested.

V&T providers shall be the owner's qualified employees, *commissioning providers*, *design professionals*, qualified designers, or qualified technicians experienced with verification or *FPT* of the designated *systems*. *V&T providers* shall not be individuals who performed design or installation of the *systems* or assemblies being verified or tested.

4.2.5.1.1 Information on Building Permit Application. The following information shall be included on the *construction documents* as part of the *building* permit application:

a. For *systems* that are required to comply with Section 4.2.5.1, the *construction documents* shall identify *V&T providers.*
b. *V&T providers* shall review the *construction documents* to verify that the relevant sensor locations, devices, and control sequences are properly specified; performance and testing criteria are included; and *equipment* to be tested is accessible for testing and maintenance.

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c. *FPT* and verification processes and *system* performance requirements shall be incorporated into the *construction documents*.

4.2.5.1.2 FPT and Verification Documentation. The completed verification and *FPT* documentation shall include the results of the *FPT* and verification, be provided to the owner, and be retained with the project records. The *V&T providers* shall certify completion of required verification and *FPT* and include a plan for the completion of any deferred *FPT*, including climatic and other conditions required for performance of the deferred tests. A copy of verification and *FPT* documentation shall be submitted to the *building official* if requested.

4.2.5.2 Building Commissioning Requirements. *Commissioning* shall be performed in accordance with this section and Sections 5.9.2, 6.9.2, 7.9.2, 8.9.2, 9.9.2, 10.9.2, 12.2(e), and G1.2.1(f). *Commissioning* shall use ASHRAE/IES Standard 202 or other *generally accepted engineering standards* acceptable to the *building official*. *FPT* and verification requirements for *commissioning* are as stated in Section 4.2.5.1. *Commissioning* shall also document in sufficient detail compliance of the *building systems*, controls, and *building envelope* with required provisions of this standard. *Commissioning* requirements shall be incorporated into the *construction documents*.

The *commissioning provider* shall have the necessary training, experience, and *FPT equipment*. The *commissioning* team shall include *V&T providers*. The *commissioning provider* shall be (a) a third-party entity not associated with the *building* project, (b) owner's qualified employees, or (c) an individual associated with the design firm or contractor but not directly associated with design or installation of the *building systems*, controls, or *building envelope* being commissioned.

Exceptions to 4.2.5.2:

1. *Buildings*, *additions*, or *alterations* with less than 10,000 ft^2 of *conditioned space* and combined heating, cooling, and *service water heating equipment* totaling less than 960,000 Btu/h in capacity.
2. *Buildings* or portions of *buildings* that use the simplified approach building compliance path for HVAC systems in Section 6.3.
3. *Dwelling units*.
4. Nonrefrigerated warehouses.

4.2.5.2.1 Commissioning Activities Prior to Building Permit Issuance. The following activities shall be completed prior to issuance of a *building* permit:

a. A copy of the *commissioning* plan shall be submitted to the owner. A copy of the *commissioning* plan shall be submitted with the *building* permit application if requested by the *building official*.
b. A *commissioning provider* shall be designated by the owner to manage *commissioning* activities prior to completion of *construction documents*. The *construction documents* shall identify the *commissioning provider*.
c. The *commissioning provider* shall submit the design review report to the owner.
d. *Construction* phase *commissioning* requirements shall be incorporated into *construction documents*.

4.2.5.2.2 Project Commissioning Documents. Project *commissioning* documents shall comply with ASHRAE/IES Standard 202 or other *generally accepted engineering standards* acceptable to the *building official.* The *commissioning provider* shall certify completion of the required *commissioning process* and provide the following documents to the owner and design teams:

a. **Commissioning Plan.** Identify *FPT* or verification procedures for all *systems* to be verified, commissioned, or tested.
b. **Design Review Report.** Detail compliance of the design with the Owner's Project Requirements and provisions of this standard. This *commissioning* design review shall not be considered a design peer review or a code or regulatory review.
c. **Preliminary Commissioning Report.** The preliminary *commissioning* report shall include the following:
    1. Required performance of commissioned *equipment*, *systems*, and assemblies, and results of *FPT* and verification
    2. Summary of compliance of the *building* and its components, assemblies, controls, and *systems* with required provisions of this standard
    3. Issues and resolution logs, including itemization of deficiencies found during verification, testing, and *commissioning* that have not been corrected at the time of report preparation
    4. Deferred tests that cannot be performed at the time of report preparation

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5. Documentation of the training of operating personnel and *building* occupants on commissioned *systems*, and a plan for the completion of any deferred trainings not completed at the time of report preparation
6. A plan for the completion of *commissioning* and training, including climatic and other conditions required for performance of the deferred tests

d. **Final Commissioning Report.** The *construction documents* shall require the *commissioning provider* to provide a final *commissioning* report to the owner before completion of the contractor's general warranty period.

4.2.5.3 Activities Prior to Building Occupancy. Before issuance of a certificate of occupancy, the *V&T providers* or *commissioning provider* shall complete the following activities:

a. Verification and *FPT* of the *systems* specified in Section 4.2.5.1 shall be completed and documented.
   Exception to 4.2.5.3(a): *Systems* for which operation is seasonally dependent, and which cannot be fully verified or tested at the time of occupancy, shall be functionally tested or commissioned when allowed for by post-occupancy operating conditions as determined by the *commissioning* or *V&T providers.*
b. The owner shall be provided with the verification and *FPT* documentation as provided for in Section 4.2.5.1.2, or a preliminary *commissioning* report as provided for in Section 4.2.5.2.2.
c. The owner shall provide the *building official* with one of the following:
   1. A letter of transmittal acknowledging that the *building* owner or owner's authorized agent has received and accepted all required verification documentation, *FPT* documentation, and required preliminary *commissioning* report
   2. A copy of the reports listed in Section 4.2.5.3(b), if requested by the *building official*

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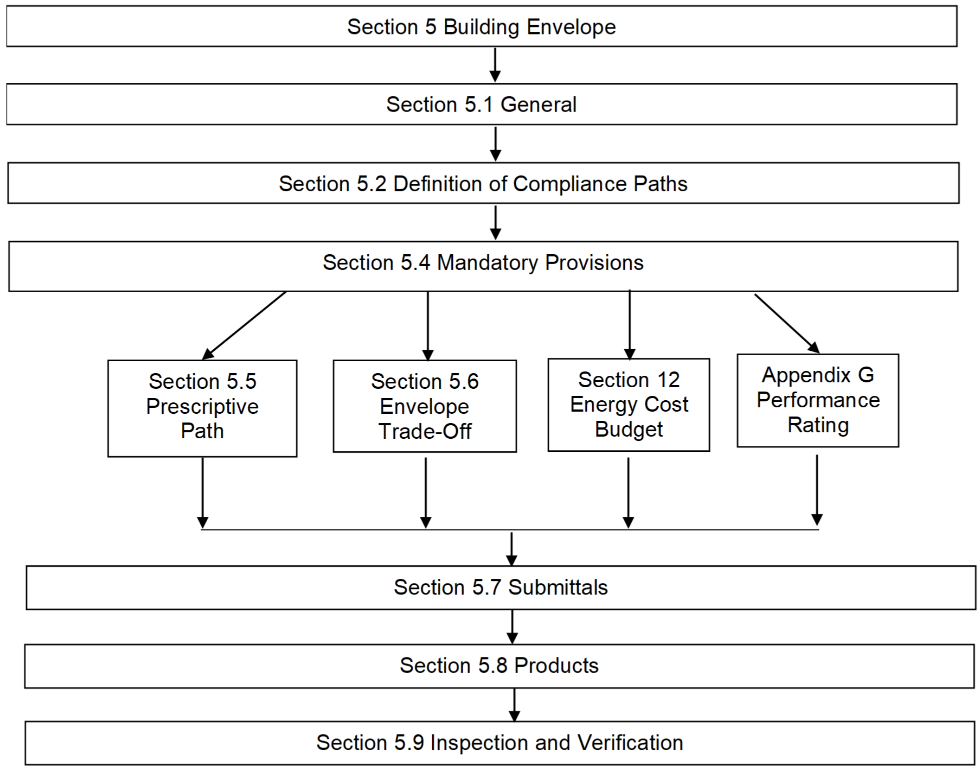

5. BUILDING ENVELOPE

5.1 General

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

5.1.2 New Buildings. *Building envelope* components installed in new *buildings* shall comply with the requirements of Section 5.2.

5.1.3 Additions to Existing Buildings. *Building envelope* components installed in *additions* shall comply with the requirements of Section 5.2.

5.1.4 Alterations to Building Envelopes. *Alterations* to the *building envelope* shall comply with the requirements of Section 5.2 for insulation, *air leakage*, and *fenestration* applicable to those specific portions of the *building* that are being altered.

Exceptions to 5.1.4: The following *alterations* need not comply with these requirements, provided such *alterations* will not increase the *energy* use 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, provided the *U-factor* and *SHGC* will be equal to or lower than before the glass replacement.
3. *Alterations* to *roof*, *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. *Roof replacements*, where the existing *roof* insulation is integral to or is located below the *roof* deck.
7. *Roof replacement*, provided the area of the replacement *roof covering* complies with the *opaque* element requirements for *roofs* in Tables 5.5-0 through 5.5-8 and Section 5.5.3.1.4.
8. 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.

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9. Replacement of existing *fenestration*, provided that the area of the replacement *fenestration* does not exceed 25% of the total *fenestration area* of an *existing building* and that the *U-factor* and *SHGC* will be equal to or lower than before the *fenestration* replacement.

5.1.4.1 Roof Replacement for Roofs with Insulation Entirely Above Deck. *Roof replacement* for *roofs with insulation entirely above deck* shall comply with Section 5.5.3.1, shall not be required to comply with the requirements of Section 5.4.3, and shall not increase the *energy* use of the *building*. Where the insulation requirements in Section 5.5.3.1.1 cannot be met due to existing *roof* conditions, the *roof replacement* shall be constructed in accordance with approved *construction documents*, which shall include

a. a *roof* inspection report documenting existing *roof* conditions and
b. a *roof* design minimizing deviation from the requirements of Section 5.5.3.1.1.

Informative Note: The proposed *roof* design should be prepared by an approved entity capable of determining whether the design complies with the requirements of Section 5.1.4.1 to the extent practical.

5.1.5 Climate. Determine the climate zone for the location. For U.S. locations, follow the procedure in Section 5.1.5.1. For international locations, follow the procedure in Section 5.1.5.2.

5.1.5.1 United States Locations. For locations in the United States and its territories, use ASHRAE Standard 169, Table B-1, “U.S. Climate Zones by State and County,” to determine the assigned climate zone and, where required, the assigned climate zone letter.

Exception to 5.1.5.1: 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*.

Informative Note: Annex 1 (included at the end of this document) contains an extraction from ASHRAE Standard 169, Table B-1, “U.S. Climate Zones by State and County.”

5.1.5.2 International Locations. For locations in Canada that are listed in ASHRAE Standard 169, Table A-5, “Canada Stations and Climate Zones,” use this table to determine the required assigned climate zone number and, where required, the assigned climate zone letter. For locations in other international countries that are listed in ASHRAE Standard 169, Table A-6, “International Stations and Climate Zones,” use this table to determine the required climate zone number and, where required, the assigned climate zone letter. For all international locations that are not listed either in ASHRAE Standard 169, Table A-5, “Canada Stations and Climate Zones,” or ASHRAE Standard 169, Table A-6, “International Stations and Climate Zones,” use ASHRAE Standard 169, Section A3, “Climate Zone Definitions,” and Table A-3, “Thermal Climate Zone Definitions,” to determine both the climate zone number and letter.

Informative Note: Annex 1 (included at the end of this document) contains extractions from ASHRAE Standard 169, Table A-5, “Canada Stations and Climate Zones”; ASHRAE Standard 169, Table A-6, “International Stations and Climate Zones”; ASHRAE Standard 169, Section A3, “Climate Zone Definitions”; and Table A-3, “Thermal Climate Zone Definitions.”

5.1.6 Space Conditioning Categories

5.1.6.1 Separate *building envelope* requirements are specified for (a) *nonresidential conditioned space*, (b) *residential conditioned space*, and (c) *semiheated space*.

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

5.1.6.3 *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.

Exception to 5.1.6.3: A *space* may be designated as either a *semiheated space* or an *unconditioned space* only if approved by the *building official*.

5.2 Compliance Paths. The *building envelope* shall comply with Sections 5.2.1 and 5.2.2.

5.2.1 Requirements for All Compliance Paths. The *building envelope* shall comply with Sections 5.1, “General”; 5.4, “Mandatory Provisions”; 5.7, “Submittals”; 5.8, “Product Information and Installation Requirements”; and 5.9, “Verification, Testing, and Commissioning.”

5.2.2 Additional Requirements to Comply with Section 5. The *building envelope* shall comply with either

a. Section 5.5, “Prescriptive Building Envelope Compliance Path,” 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 Compliance Path.”

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5.3 Simplified Building Compliance Path (Not Used)

5.4 Mandatory Provisions

5.4.1 Insulation. Where insulation is required in Section 5.5 or Section 5.6, it shall comply with the requirements found in Section 5.8.1.

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

a. *Air leakage* control for the *building envelope* shall comply with this section. Materials and assemblies that are part of the *continuous air barrier* and *fenestration* and *doors* shall comply with Section 5.8.3.
b. The *exterior building envelope* and the *semiexterior building envelope* shall have a *continuous air barrier* complying with Sections 5.4.3.1 and 5.4.3.2.

   Exceptions to 5.4.3(b):
   1. *Semiheated spaces* in Climate Zones 0 through 6, except as required to complete the *continuous air barrier* of an adjacent *conditioned space*.
   2. Single wythe concrete masonry *buildings* in Climate Zone 2B.

5.4.3.1 Whole-Building Air Leakage

5.4.3.1.1 New *buildings* less than 10,000 ft^2 of *gross conditioned floor area* shall comply with measured *air leakage* requirements in Section 5.4.3.1.4.

5.4.3.1.2 New *buildings* not less than 10,000 ft^2 of *gross conditioned floor area* shall comply with one of the following:

a. Measured *air leakage* requirements in Section 5.4.3.1.4
b. A *continuous air barrier* design and installation verification program performed in accordance with Section 5.9.1.2

5.4.3.1.3 In *alterations* and *additions* to an *existing building* where portions of the *continuous air barrier* are impacted, those portions shall be installed or reinstalled and comply with one of the following:

a. Measured *air leakage* requirements in Section 5.4.3.1.4
b. A *continuous air barrier* design and installation verification program performed in accordance with Section 5.9.1.2

5.4.3.1.4 Measured Air Leakage. Where measured *air leakage* is used for compliance, the rate of *air leakage* of the *building envelope* shall not exceed 0.35 cfm/ft^2 under a pressure differential of 75 Pa (0.30 in. of water), with this *air leakage* rate normalized by the sum of the above-*grade* and below-*grade building envelope* areas of the *conditioned space* and *semiheated space* and in accordance with this section.

a. Whole-*building* pressurization testing shall be conducted in accordance with ASTM E3158. For *buildings* less than 10,000 ft^2 of *gross conditioned floor area*, and that contain no more than one *single-zone system*, *air leakage* testing may be conducted in accordance with ASTM E779, ASTM E1827, or ASTM E3158. Testing shall be conducted excluding HVAC related elements and be performed by an independent third-party *verification and testing provider* in accordance with Section 4.2.5.1.
b. Where a *building* contains both *conditioned space* and *semiheated space*, compliance shall be shown using one of the following as applicable:
   1. Separately for the *conditioned space* and for the *semiheated space*, with the *air leakage* rate for the *conditioned space* normalized by the *exterior building envelope* area of the *conditioned space* and the *air leakage* rate for the *semiheated space* normalized by the *semiexterior building envelope* area of the *semiheated space*
   2. For the *conditioned space* and for the *semiheated space* together, with the *air leakage* rate for the overall *space* normalized by the sum of the *exterior building envelope* area and the *semiexterior building envelope* area minus the *semiexterior building envelope* area that separates the *conditioned space* from the *semiheated space*
c. Where the measured *air leakage* rate exceeds 0.35 cfm/ft^2 but does not exceed 0.45 cfm/ft^2, a diagnostic evaluation, such as a smoke tracer or infrared imaging, shall be conducted while the *building* is pressurized, and any leaks noted shall be sealed if such sealing can be made without destruction of *existing building* components. In addition, a visual inspection of the air barrier shall be conducted, and any leaks noted shall be sealed if such sealing can be made without destruction of *existing building* components.

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An additional report identifying the corrective actions taken to seal leaks shall be submitted to the *code official* and the *building* owner and shall be deemed to satisfy the requirements of this section.

d. Where the measured *air leakage* rate exceeds 0.45 cfm/ft^2, corrective actions must be made to the *envelope* and an additional test completed where results are 0.45 cfm/ft^2 or less in order to demonstrate compliance.
e. Reporting shall be in compliance with Section 4.2.5.1.2.

5.4.3.2 Continuous Air Barrier Design and Installation. The *continuous air barrier* shall be designed and installed in the following manner:

a. Components designed to provide the *continuous air barrier*, and the component's position within each of the *building envelope* assemblies, shall be clearly identified on *construction documents*.
b. The joints, interconnections, and penetrations of the *continuous air barrier* components shall be detailed in the *construction documents*.
c. The *continuous air barrier* shall extend over all surfaces of the *building envelope* and be identified in the *construction documents* to be continuous across the components of the below-*grade* areas, *walls*, *fenestration*, *doors*, and *roofs*.
d. The *continuous air barrier* shall be designed to resist positive and negative pressures from wind, stack effect, and mechanical *ventilation* and allow for anticipated movements.
e. 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*:
   1. Joints around *fenestration* and *door* frames
   2. Junctions between *walls* and *floors*; between *walls* at *building* corners; between *walls* and *roofs*, including parapets and copings; and *walls* at foundations
   3. Penetrations through the *continuous air barrier* in *building envelope roofs*, *walls*, and *floors*
   4. *Building* assemblies used as ducts or *plenums*
   5. Joints, seams, connections between planes, and other changes in *continuous air barrier* materials
   6. *Building* and *service* components projecting through or attached through the *continuous air barrier*
   7. Junctions of the *continuous air barrier* that separate *conditioned spaces* from *unconditioned spaces*, *semiheated spaces,* and areas that are not *enclosed spaces*

5.4.3.3 Loading Dock Weatherseals. In Climate Zones 0 and 4 through 8, cargo *doors* and loading dock *doors* shall be equipped with weatherseals to restrict *air leakage* when vehicles are parked in the doorway.

5.4.3.4 Vestibules and Revolving Doors. Vestibules and revolving *doors* shall be installed in accordance with this section.

5.4.3.4.1 Location. *Building entrances* that separate *conditioned space* from the exterior shall have one of the following:

a. An enclosed vestibule, with all *doors* opening into and out of the vestibule equipped with self-closing devices
b. A revolving *door* or *doors* opening into a vestibule or directly into the *conditioned space*
c. A combination of (a) and (b)

5.4.3.4.2 Vestibule Size. 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*.

5.4.3.4.3 Vestibule Envelope. The exterior surfaces of both conditioned vestibules and unconditioned vestibules shall comply with the *continuous air barrier* requirements.

Exceptions to 5.4.3.4.3:

1. *Doors* not intended to be used as a *building entrance.*
2. *Doors* opening directly from a *dwelling unit.*
3. *Building entrances* in *buildings* located in Climate Zone 1 or 2.
4. *Doors* opening into *semiheated spaces*.
5. Enclosed elevator lobbies for *building entrances* directly from parking garages.
6. *Building entrances* in *buildings* that are located in Climate Zone 3, where the *building* is less than four *stories* above *grade* and less than 10,000 ft^2 in *gross conditioned floor area.*
7. *Building entrances* in *buildings* that are located in Climate Zone 0, 4, 5, 6, 7, or 8, where the *building* is less than 1000 ft^2 in *gross conditioned floor area.*

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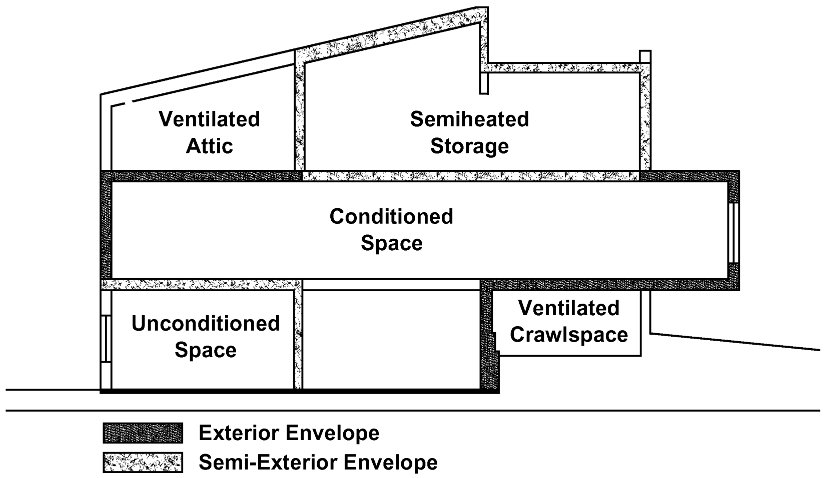

Figure 5.5.2 Exterior and semiexterior building envelope.

8. *Doors* that open directly from a *space* that is less than 3000 ft^2 in area and is separate from the *building entrance.*
9. Self-closing *doors* in *buildings* in Climate Zones 0, 3, and 4 that have an air curtain unit complying with Sections 6.4.3.9 and 10.4.5.
10. Self-closing *doors* in *buildings* 15 *stories* or less in Climate Zones 5 through 8 that have an air curtain unit complying with Sections 6.4.3.9 and 10.4.5.

5.4.3.4.4 Vestibules for Large Spaces. Where vestibules are required under Sections 5.4.3.4 and 10.4.5, 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.

5.5 Prescriptive Building Envelope Compliance Path

5.5.1 Exterior Building Envelope. For a *conditioned space*, the *exterior building envelope* shall comply with either the *nonresidential* or *residential* requirements in Tables 5.5-0 through 5.5-8 for the appropriate climate.

The exterior surfaces of conditioned vestibules shall comply with the *building envelope* requirements for a *conditioned space*.

5.5.2 Semiexterior Building Envelope. If a *building* contains any *semiheated space* or *unconditioned space* then the *semiexterior building envelope* shall comply with the requirements for *semiheated space* in Tables 5.5-0 through 5.5-8 for the appropriate climate. (See Figure 5.5.2.)

The interior surfaces and exterior surfaces of unconditioned vestibules shall comply with the *building envelope* requirements for a *semiheated space*.

5.5.3 Opaque Elements. For all *opaque* elements, compliance with Tables 5.5-0 through 5.5-8 for each *class of construction* as described in Normative Appendix A, Sections A2 through A8 shall be demonstrated by one of the following two methods:

a. Providing a minimum *rated R-value of insulation* added to the assembly equal to or greater than the insulation minimum *R-value* required of each insulation component.
b. Providing insulation such that the maximum *U-factor*, *C-factor*, or *F-factor* for the entire assembly is not exceeded as determined by one of the following:
    1. Precalculated values in accordance with Normative Appendix A, Section A1.1.
    2. Applicant-determined values in accordance with Normative Appendix A, Section A1.2 where such values are approved by the *code official*.

Exceptions to 5.5.3:

1. For *opaque* assemblies not complying with the *classes of construction* as described in Normative Appendix A, Sections A2 through A8, compliance with the maximum *U-factors* for the "attic and other" or "wood frame and other" *opaque* element conditions in Tables 5.5-0 through 5.5-8 shall be

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Table 5.5.3.1.4 Increased Roof Insulation Levels

Roofs	Nonresidential		Residential	
Opaque Elements	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
		Climate Zone 0		
Insulation entirely above deck	U-0.027	R-36 *c.i.*	U-0.027	R-36 *c.i.*
Metal buildings	U-0.028	R-35		
		Climate Zones 1 to 3		
Insulation entirely above deck	U-0.030	R-33 *c.i.*	U-0.029	R-34 *c.i.*
Metal buildings	U-0.028	R-35		

demonstrated by testing or calculations representative of the designed assembly in accordance with Normative Appendix A, Section A9.1 where approved by the *code official*.

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 Roofs

5.5.3.1.1 All *roofs* shall comply with the insulation values specified in Tables 5.5-0 through 5.5-8.

5.5.3.1.2 Roof Curbs. *Skylight* and other *roof* curbs shall be insulated to not less than R-5.0.

5.5.3.1.3 Joints in Roof Insulation. Joints in the insulation shall be installed in accordance with Section 5.8.1.10.

5.5.3.1.4 Roof Solar Reflectance and Thermal Emittance. *Roofs* in Climate Zones 0 through 3 shall have one of the following:

a. 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 S100.
b. A minimum Solar Reflectance Index of 64 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 S100.
c. Increased *roof* insulation levels found in Table 5.5.3.1.4.

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*.

Exceptions to 5.5.3.1.4:

1. Ballasted *roofs* with a minimum stone *ballast* of 17 lb/ft^2 or 23 lb/ft^2 pavers.
2. *Vegetative 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*;
   b. is covered by offset photovoltaic arrays, *building*-integrated photovoltaic arrays, or solar air or water collectors; or
   c. is permitted to be interpolated using a combination of 1 and 2 above.
4. Steep-sloped *roofs*.
5. Low-sloped *metal building roofs* in Climate Zones 2 and 3.
6. *Roofs* over ventilated attics, *roofs* over *semiheated spaces*, or *roofs* over *conditioned spaces* that are not *cooled spaces*.
7. Asphaltic membranes in Climate Zones 2 and 3.

5.5.3.1.5 Insulated Metal Panels. The *U-factor* of *roof* assemblies that include *insulated metal panels* shall not be greater than the *U-factors* of Tables 5.5-0 through 5.5-8 for the applicable *class of construction*. *U-factors* of *insulated metal panels* shall be determined in accordance with Section A9.4.7.

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Table 5.5-0 Building Envelope Requirements for Climate Zone 0 (A,B)*

	Nonresidential		Residential		Semiheated	
Opaque Elements	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
			Roofs			
Insulation entirely above deck	U-0.039	R-25 *c.i.*	U-0.032	R-30 *c.i.*	U-0.218	R-3.8 *c.i.*
Metal building [a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.115	R-10
Attic and other	U-0.027	R-38	U-0.027	R-38	U-0.081	R-13
			Walls, above-Grade			
Mass	U-0.580	NR	U-0.151[b]	R-5.7 *c.i.*[b]	U-0.580	NR
Metal building	U-0.094	R-0 + R-9.8 *c.i.*	U-0.094	R-0 + R-9.8 *c.i.*	U-0.352	NR
Steel-framed	U-0.124	R-13	U-0.124	R-13	U-0.352	NR
Wood-framed and other	U-0.089	R-13	U-0.089	R-13	U-0.292	NR
			Wall, below-Grade			
Below-grade wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
			Floors			
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood-framed and other	U-0.282	NR	U-0.282	NR	U-0.282	NR
			Slab-on-Grade Floors			
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.700	
Nonswinging	U-0.310		U-0.310		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% to 40% of *Wall*					
Fixed	0.50	0.22	1.10 (for all types)	0.50	0.22	1.10 (for all types)	1.20	NR (for all types)	NR (for all types)
Operable	0.62	0.20		0.62	0.20		1.20		
Entrance door	0.83	0.20		0.83	0.20		1.10		
				Skylight, 0% to 3% of *Roof*					
All types	0.70	0.30	NR	0.70	0.30	NR	1.80	NR	NR

* The following definitions apply: *c.i.* = *continuous insulation* (see Section 3.2), FC = filled cavity (see Section A2.3.2.5), NR = no (insulation) requirement.

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

b. Exception to Section 5.5.3.2 applies for *mass walls* above *grade*.

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Table 5.5-1 Building Envelope Requirements for Climate Zone 1 (A,B)*

	Nonresidential		Residential		Semiheated	
Opaque Elements	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
			Roofs			
Insulation entirely above deck	U-0.048	R-20 *c.i.*	U-0.039	R-25 *c.i.*	U-0.218	R-3.8 *c.i.*
Metal building [a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.115	R-10
Attic and other	U-0.027	R-38	U-0.027	R-38	U-0.081	R-13
			Walls, above Grade			
Mass	U-0.580	NR	U-0.151[b]	R-5.7 *c.i.*[b]	U-0.580	NR
Metal building	U-0.094	R-0 + R-9.8 *c.i.*	U-0.094	R-0 + R-9.8 *c.i.*	U-0.352	NR
Steel-framed	U-0.124	R-13	U-0.124	R-13	U-0.352	NR
Wood-framed and other	U-0.089	R-13	U-0.089	R-13	U-0.292	NR
			Wall, below Grade			
Below-grade wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
			Floors			
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood-framed and other	U-0.282	NR	U-0.282	NR	U-0.282	NR
			Slab-on-Grade Floors			
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.700	
Nonswinging	U-0.310		U-0.310		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% to 40% of *Wall*					
Fixed	0.50	0.23	1.10 (for all types)	0.50	0.23	1.10 (for all types)	1.20	NR (for all types)	NR (for all types)
Operable	0.62	0.21		0.62	0.21		1.20		
Entrance door	0.83	0.21		0.83	0.21		1.10		
				Skylight, 0% to 3% of *Roof*					
All types	0.70	0.30	NR	0.70	0.30	NR	1.80	NR	NR

* The following definitions apply: *c.i.* = *continuous insulation* (see Section 3.2), FC = filled cavity (see Section A2.3.2.5), NR = no (insulation) requirement.
a. When using the *R-value* compliance method for *metal building roofs*, a thermal spacer block is required (see Section A2.3.2).
b. Exception to Section 5.5.3.2 applies for *mass walls* above *grade*.

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Table 5.5-2 Building Envelope Requirements for Climate Zone 2 (A,B)*

	Nonresidential		Residential		Semiheated	
Opaque Elements	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
			Roofs			
Insulation entirely above deck	U-0.039	R-25 *c.i.*	U-0.039	R-25 *c.i.*	U-0.173	R-5 *c.i.*
Metal building [a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.096	R-16
Attic and other	U-0.027	R-38	U-0.027	R-38	U-0.053	R-19
			Walls, above Grade			
Mass	U-0.151[b]	R-5.7 *c.i.*[b]	U-0.123	R-7.6 *c.i.*	U-0.580	NR
Metal building	U-0.094	R-0 + R-9.8 *c.i.*	U-0.094	R-0 + R-9.8. *c.i.*	U-0.162	R-13
Steel-framed	U-0.084	R-13 + R-3.8 *c.i.*	U-0.064	R-13 + R-7.5 *c.i.*	U-0.124	R-13
Wood-framed and other	U-0.089	R-13	U-0.089	R-13	U-0.089	R-13
			Wall, below Grade			
Below-grade wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
			Floors			
Mass	U-0.107	R-6.3 *c.i.*	U-0.087	R-8.3 *c.i.*	U-0.322	NR
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.069	R-13
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.066	R-13
			Slab-on-Grade Floors			
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.900	R-10 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.700	
Nonswinging	U-0.310		U-0.310		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% to 40% of *Wall*					
Fixed	0.45	0.25	1.10 (for all types)	0.45	0.25	1.10 (for all types)	0.50	NR (for all types)	NR (for all types)
Operable	0.60	0.23		0.60	0.23		0.65		
Entrance door	0.77	0.23		0.77	0.23		0.77		
				Skylight, 0% to 3% of *Roof*					
All types	0.65	0.30	NR	0.65	0.30	NR	0.90	NR	NR

* The following definitions apply: *c.i.* = *continuous insulation* (see Section 3.2), FC = filled cavity (see Section A2.3.2.5), NR = no (insulation) requirement.
a. When using the *R-value* compliance method for *metal building roofs*, a thermal spacer block is required (see Section A2.3.2).
b. Exception to Section 5.5.3.2 applies for *mass walls* above *grade*.

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Table 5.5-3 Building Envelope Requirements for Climate Zone 3 (A,B,C)*

	Nonresidential		Residential		Semiheated	
Opaque Elements	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
			Roofs			
Insulation entirely above deck	U-0.039	R-25 *c.i.*	U-0.039	R-25 *c.i.*	U-0.119	R-7.6 *c.i.*
Metal building [a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.096	R-16
Attic and other	U-0.027	R-38	U-0.027	R-38	U-0.053	R-19
			Walls, above Grade			
Mass	U-0.123	R-7.6 *c.i.*	U-0.104	R-9.5 *c.i.*	U-0.580	NR
Metal building	U-0.094	R-0 + R-9.8 *c.i.*	U-0.072	R-0 + R-13 *c.i.*	U-0.162	R-13
Steel-framed	U-0.077	R-13 + R-5 *c.i.*	U-0.064	R-13 + R-7.5 *c.i.*	U-0.124	R-13
Wood-framed and other	U-0.089	R-13	U-0.064	R-13 + R-3.8 *c.i.* or R-20	U-0.089	R-13
			Wall, below Grade			
Below-grade wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
			Floors			
Mass	U-0.074	R-10 *c.i.*	U-0.074	R-10 *c.i.*	U-0.137	R-4.2 *c.i.*
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
			Slab-on-Grade Floors			
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

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% to 40% of *Wall*					
Fixed	0.42	0.25	1.10 (for all types)	0.42	0.25	1.10 (for all types)	0.50	NR (for all types)	NR (for all types)
Operable	0.54	0.23		0.54	0.23		0.65		
Entrance door	0.68	0.23		0.68	0.23		0.77		
				Skylight, 0% to 3% of *Roof*					
All types	0.55	0.30	NR	0.55	0.30	NR	0.90	NR	NR

* The following definitions apply: *c.i.* = *continuous insulation* (see Section 3.2), FC = filled cavity (see Section A2.3.2.5), NR = no (insulation) requirement.

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

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

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
			Roofs			
Insulation entirely above deck	U-0.032	R-30 *c.i.*	U-0.032	R-30 *c.i.*	U-0.093	R-10 *c.i.*
Metal building [a]	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.082	R-19
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
			Walls, above Grade			
Mass	U-0.104	R-9.5 *c.i.*	U-0.090	R-11.4 *c.i.*	U-0.580	NR
Metal building	U-0.060	R-0 + R-15.8 *c.i.*	U-0.050	R-0 + R-19 *c.i.*	U-0.162	R-13
Steel-framed	U-0.064	R-13 + R-7.5 *c.i.*	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-13
Wood-framed and other	U-0.064	R-13 + R-3.8 *c.i.* or R-20	U-0.064	R-13 + R-3.8 *c.i.* or R-20	U-0.089	R-13
			Wall, below Grade			
Below-grade wall	C-0.119	R-7.5 *c.i.*	C-0.092	R-10 *c.i.*	C-1.140	NR
			Floors			
Mass	U-0.057	R-14.6 *c.i.*	U-0.051	R-16.7 *c.i.*	U-0.107	R-6.3 *c.i.*
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
			Slab-on-Grade Floors			
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

Fenestration	Nonresidential Assembly Max. U	Nonresidential Assembly Max. SHGC	Nonresidential Assembly Min. VT/SHGC	Residential Assembly Max. U	Residential Assembly Max. SHGC	Residential Assembly Min. VT/SHGC	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC	Semiheated Assembly Min. VT/SHGC
				Vertical Fenestration, 0% to 40% of *Wall*					
Fixed	0.36	0.36	1.10 (for all types)	0.36	0.36	1.10 (for all types)	0.50	NR (for all types)	NR (for all types)
Operable	0.45	0.33		0.45	0.33		0.65		
Entrance door	0.63	0.33		0.63	0.33		0.77		
				Skylight, 0% to 3% of *Roof*					
All types	0.50	0.40	NR	0.50	0.40	NR	0.75	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) requirement.

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

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Table 5.5-5 Building Envelope Requirements for Climate Zone 5 (A,B,C)*

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
			Roofs			
Insulation entirely above deck	U-0.032	R-30 *c.i.*	U-0.032	R-30 *c.i.*	U-0.063	R-15 *c.i.*
Metal building [a]	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.082	R-19
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
			Walls, above grade			
Mass	U-0.090	R-11.4 *c.i.*	U-0.080	R-13.3 *c.i.*	U-0.151[b]	R-5.7 *c.i.*[b]
Metal building	U-0.050	R-0 + R-19 *c.i.*	U-0.050	R-0 + R-19 *c.i.*	U-0.094	R-0 + R-9.8 *c.i.*
Steel-framed	U-0.055	R-13 + R-10 *c.i.*	U-0.055	R-13 + R-10 *c.i.*	U-0.084	R-13+R-3.8 *c.i.*
Wood-framed and other	U-0.051	R-13 + R-7.5 *c.i.* or R-19 + R-5 *c.i.*	U-0.051	R-13 + R-7.5 *c.i.* or R-19 + R-5 *c.i.*	U-0.089	R-13
			Wall, below Grade			
Below-grade wall	C-0.119	R-7.5 *c.i.*	C-0.092	R-10 *c.i.*	C-1.140	NR
			Floors			
Mass	U-0.057	R-14.6 *c.i.*	U-0.051	R-16.7 *c.i.*	U-0.107	R-6.3 *c.i.*
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
			Slab-on-Grade Floors			
Unheated	F-0.520	R-15 for 24 in	F-0.510	R-20 for 24 in.	F-0.730	NR
Heated	F-0.688	R-20 for 48 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

Fenestration	Nonresidential Assembly Max. U	Nonresidential Assembly Max. SHGC	Nonresidential Assembly Min. VT/SHGC	Residential Assembly Max. U	Residential Assembly Max. SHGC	Residential Assembly Min. VT/SHGC	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC	Semiheated Assembly Min. VT/SHGC
				Vertical Fenestration, 0% to 40% of *Wall*					
Fixed	0.36	0.38	1.10 (for all types)	0.36	0.38	1.10 (for all types)	0.50	NR (for all types)	NR (for all types)
Operable	0.45	0.33		0.45	0.33		0.65		
Entrance door	0.63	0.33		0.63	0.33		0.77		
				Skylight, 0% to 3% of *Roof*					
All types	0.50	0.40	NR	0.50	0.40	NR	0.75	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) requirement.

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

b. Exception to Section 5.5.3.2 applies for *mass walls* above *grade*.

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Table 5.5-6 Building Envelope Requirements for Climate Zone 6 (A,B)*

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
			Roofs			
Insulation entirely above deck	U-0.032	R-30 *c.i.*	U-0.032	R-30 *c.i.*	U-0.063	R-15 *c.i.*
Metal building [a]	U-0.031	R-25 + R-11 *Ls*	U-0.029	R-30 + R-11 *Ls*	U-0.060	R-19 + R-19
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
			Walls, above Grade			
Mass	U-0.080	R-13.3 *c.i.*	U-0.071	R-15.2 *c.i.*	U-0.151[b]	R-5.7 *c.i.*[b]
Metal building	U-0.050	R-0 + R-19 *c.i.*	U-0.050	R-0 + R-19 *c.i.*	U-0.094	R-0 + R-9.8 *c.i.*
Steel-framed	U-0.049	R-13 + R-12.5 *c.i.*	U-0.049	R-13 + R-12.5 *c.i.*	U-0.084	R-13 + R-3.8 *c.i.*
Wood-framed and other	U-0.051	R-13 + R-7.5 *c.i.* or R-19 + R-5 *c.i.*	U-0.051	R-13 + R-7.5 *c.i.* or R-19 + R-5 *c.i.*	U-0.089	R-13
			Wall, below Grade			
Below-grade wall	C-0.092	R-10 *c.i.*	C-0.063	R-15 *c.i.*	C-0.119	R-7.5 c.i
			Floors			
Mass	U-0.051	R-16.7 *c.i.*	U-0.051	R-16.7 *c.i.*	U-0.087	R-8.3 *c.i.*
Steel joist	U-0.032	R-38	U-0.032	R-38	U-0.052	R-19
Wood-framed and other	U-0.027	R-38	U-0.027	R-38	U-0.051	R-19
			Slab-on-Grade Floors			
Unheated	F-0.510	R-20 for 24 in.	F-0.434	R-20 for 48 in	F-0.730	NR
Heated	F-0.688	R-20 for 48 in.	F-0.671	R-25 for 48 in.	F-0.860	R-15 for 24 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

Fenestration	Nonresidential Assembly Max. U	Nonresidential Assembly Max. SHGC	Nonresidential Assembly Min. VT/SHGC	Residential Assembly Max. U	Residential Assembly Max. SHGC	Residential Assembly Min. VT/SHGC	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC	Semiheated Assembly Min. VT/SHGC
				Vertical Fenestration, 0% to 40% of *Wall*					
Fixed	0.34	0.38	1.10 (for all types)	0.34	0.38	1.10 (for all types)	0.39	NR (for all types)	NR (for all types)
Operable	0.42	0.34		0.42	0.34		0.48		
Entrance door	0.63	0.34		0.63	0.34		0.68		
				Skylight, 0% to 3% of *Roof*					
All types	0.47	0.40	NR	0.50	0.40	NR	0.75	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) requirement.

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

b. Exception to Section 5.5.3.2 applies for *mass walls* above *grade*.

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Table 5.5-7 Building Envelope Requirements for Climate Zone 7*

	Nonresidential		Residential		Semiheated	
Opaque Elements	**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-35 *c.i.*	U-0.028	R-35 *c.i.*	U-0.039	R-25 *c.i.*
Metal building [a]	U-0.029	R-30 + R-11 *Ls*	U-0.029	R-30 + R-11 *Ls*	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*
Attic and other	U-0.017	R-60	U-0.017	R-60	U-0.027	R-38
			Walls, above Grade			
Mass	U-0.071	R-15.2 *c.i.*	U-0.071	R-15.2 *c.i.*	U-0.123	R-7.6 *c.i.*
Metal building	U-0.044	R-0 + R.22.1 *c.i.*	U-.044	R-0 + R.22.1 *c.i.*	U-0.072	R-0 + R-13 *c.i.*
Steel-framed	U-0.049	R-13 + R-12.5 *c.i.*	U-0.042	R-13 + R-15.6 *c.i.*	U-0.064	R-13 + R-7.5 *c.i.*
Wood-framed and other	U-0.051	R-13 + R-7.5 *c.i.* or R-19 + R-5 *c.i.*	U-0.051	R-13 + R-7.5 *c.i.* or R-19 + R-5 *c.i.*	U-0.064	R-13 + R-3.8 *c.i.*
			Wall, below Grade			
Below-grade wall	C-0.063	R-15 *c.i.*	C-0.063	R-15 *c.i.*	C-0.119	R-7.5 *c.i.*
			Floors			
Mass	U-0.042	R-20.9 *c.i.*	U-0.042	R-20.9 *c.i.*	U-0.074	R-10.4 *c.i.*
Steel joist	U-0.032	R-38	U-0.032	R-38	U-0.052	R-19
Wood-framed and other	U-0.027	R-38	U-0.027	R-38	U-0.051	R-19
			Slab-on-Grade Floors			
Unheated	F-0.510	R-20 for 24 in.	F-0.434	R-20 for 48 in.	F-0.730	NR
Heated	F-0.671	R-25 for 48 in.	F-0.671	R-25 for 48 in.	F-0.860	R-15 for 24 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.310	

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% to 40% of *Wall*					
Fixed	0.29	0.40	1.10 (for all types)	0.29	0.40	1.10 (for all types)	0.36	NR (for all types)	NR (for all types)
Operable	0.36	0.36		0.36	0.36		0.44		
Entrance door	0.63	0.36		0.63	0.36		0.63		
				Skylight, 0% to 3% of *Roof*					
All types	0.44	NR	NR	0.44	NR	NR	0.75	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) requirement.

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

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Table 5.5-8 Building Envelope Requirements for Climate Zone 8*

	Nonresidential		Residential		Semiheated	
Opaque Elements	**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-35 *c.i.*	U-0.028	R-35 *c.i.*	U-0.039	R-25 *c.i.*
Metal building [a]	U-0.026	R-25 + R-11+R-11 *Ls*	U-0.026	R-25 + R-11+R-11 *Ls*	U-0.037	R-19+R-11 *Ls* or R-25 + R-8 *Ls*
Attic and other	U-0.017	R-60	U-0.017	R-60	U-0.027	R-38
Walls, above Grade						
Mass	U-0.048	R-19 *c.i.*	U-0.048	R-19 *c.i.*	U-0.104	R-9.5 *c.i.*
Metal building	U-0.039	R-0 + R-25 *c.i.*	U-0.039	R-0 + R-25 *c.i.*	U-0.060	R-0 + R-15.8 *c.i.*
Steel-framed	U-0.037	R-13 + R-18.8 *c.i.*	U-0.037	R-13 + R-18.8 *c.i.*	U-0.064	R-13 + R-7.5 *c.i.*
Wood-framed and other	U-0.032	R-13 + R-18.8 *c.i.*	U-0.032	R-13 + R-18.8 *c.i.*	U-0.051	R-13 + R-7.5 *c.i.*
Wall, below Grade						
Below-grade wall	C-0.063	R-15 *c.i.*	C-0.063	R-15 *c.i.*	C-0.119	R-7.5 *c.i.*
Floors						
Mass	U-0.038	R-23 *c.i.*	U-0.038	R-23 *c.i.*	U-0.064	R-12.5 *c.i.*
Steel joist	U-0.032	R-38	U-0.032	R-38	U-0.052	R-19
Wood-framed and other	U-0.027	R-38	U-0.027	R-38	U-0.033	R-30
Slab-on-Grade Floors						
Unheated	F-0.434	R-20 for 48 in.	F-0.424	R-25 for 48 in.	F-0.540	R-10 for 24 in.
Heated	F-0.671	R-25 for 48 in.	F-0.373	R-20 full slab	F-0.860	R-15 for 24 in.
Opaque Doors						
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.310	

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% to 40% of *Wall*									
Fixed	0.26	0.40	1.10 (for all types)	0.26	0.40	1.10 (for all types)	0.36	NR (for all types)	NR (for all types)
Operable	0.32	0.36		0.32	0.36		0.44		
Entrance door	0.63	0.36		0.63	0.36		0.63		
Skylight, 0% to 3% of *Roof*									
All types	0.41	NR	NR	0.41	NR	NR	0.75	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) requirement.

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

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5.5.3.2 Above-Grade Walls. *Above-grade walls* shall comply with the insulation values specified in Tables 5.5-0 through 5.5-8. For the purposes of this provision, *wall* plates, tracks, headers, or bond beams are considered part of the base *wall* assembly.

Exception to 5.5.3.2: For *mass walls*, where the requirement in Tables 5.5-0 through 5.5-8 is for a maximum assembly U-0.151 followed by footnote "b," concrete masonry unit (CMU) walls complying with ASTM C90 that are ungrouted or partially grouted at 32 in. or greater on center vertically and 48 in. or greater on center horizontally, shall have their ungrouted openings (e.g., cores, cells) filled with insulating material having a maximum thermal conductivity of 0.44 Btu·in./h·ft^2·°F.

5.5.3.2.1 Walls That Are Both Above and Below Grade. 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.

a. If insulated on the interior, the *wall* shall be insulated to the *above-grade wall* requirements.
b. 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.

5.5.3.2.2 Wall Solar Reflectance and Thermal Emittance. For Climate Zone 0, *above-grade east-*, *south-*, and *west-oriented walls* shall comply with subparagraph (a) or (b):

a. A minimum of 75% of the *opaque wall* area shall have a minimum area-weighted initial solar reflectance of 0.30 when tested in accordance with ASTM C1549 with AM1.5GV output, or ASTM E903 with the AM1.5GV output, or determined in accordance with *generally accepted engineering standards*, and a minimum *emittance* or emissivity of 0.75 when tested in accordance with ASTM C835, C1371, E408, or determined in accordance with *generally accepted engineering standards.* For the portion of the *opaque wall* that is glass spandrel area, a minimum solar reflectance of 0.29, determined in accordance with NFRC 300 or ISO 9050, shall be permitted. Area-weighting is permitted only between the *south-*, *east-*, and *west-oriented walls* and only between *walls* of the same *space conditioning category*.
b. A minimum of 30% of the *above-grade wall* area shall be shaded through the use of human-made *structures*, *existing buildings*, hillsides, permanent *building* projections, *on-site renewable energy systems*, or a combination of these. Shade coverage shall be calculated by projecting the shading surface downward on the *wall* at an angle of 45 degrees.

Exception to 5.5.3.2.2: *Exterior walls* of *semiheated spaces*.

5.5.3.2.3 Insulated Metal Panels. The *U-factor* of *wall* assemblies that include *insulated metal panels* shall not be greater than the *U-factors* of Tables 5.5-0 through 5.5-8 for the applicable *class of construction*. *U-factors* of *insulated metal panels* shall be determined in accordance with Section A9.4.7.

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 Tables 5.5-0 through 5.5-8.

Exception to 5.5.3.3: Where framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly *C-factor*.

5.5.3.4 Floors

5.5.3.4.1 Floor Insulation. All *floors* shall comply with the insulation values specified in Tables 5.5-0 through 5.5-8.

5.5.3.4.2 Insulated Metal Panels. The *U-factor* of *floor* assemblies that include *insulated metal panels* shall not be greater than the *U-factors* of Tables 5.5-0 through 5.5-8 for the applicable *class of construction*. *U-factors* of *insulated metal panels* shall be determined in accordance with Section A9.4.7.

5.5.3.5 Slabs-on-Grade. 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 Tables 5.5-0 through 5.5-8.

5.5.3.6 Opaque Doors. All *opaque doors* shall have a *U-factor* not greater than that specified in Tables 5.5-0 through 5.5-8.

Exceptions to 5.5.3.6:

1. For *conditioned spaces*, *nonswinging doors* that are horizontally hinged sectional *doors* with a single row of *fenestration* shall have an assembly *U-factor* less than or equal to 0.440 in Climate Zones 0 through 6 and less than or equal to 0.360 in Climate Zones 7 and 8, provided the *fenestration area* is at least 14% and no more than 25% of the total *door area*.

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2. For *semiheated spaces*, *nonswinging doors* that are horizontally hinged sectional *doors* with a single row of *fenestration* shall have an assembly *U-factor* less than or equal to 0.440 in Climate Zones 3 through 6 and less than or equal to 0.360 in Climate Zones 7 and 8, provided the *fenestration area* is at least 14% and no more than 25% of the total *door area*.

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.

Exceptions to 5.5.4.1:

1. If there are multiple assemblies within a single *class of construction* for a single *space conditioning category*, it shall be permitted to demonstrate compliance based on an area-weighted average *U-factor*, *SHGC*, *VT/SHGC*, or *LSG*. The area-weighted average across multiple *classes of construction* or multiple *space conditioning categories* shall not be permitted for use to demonstrate compliance.
2. *Vertical fenestration* shall be permitted to demonstrate compliance based on an area-weighted average *U-factor*, *SHGC*, *VT/SHGC*, or *LSG* across multiple *classes of construction* for a single *space conditioning category*, but not across 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 Tables 5.5-0 through 5.5-8.

Exception to 5.5.4.2.1: *Vertical fenestration* complying with Section 5.5.4.4.1, Exception 3.

5.5.4.2.2 Maximum Skylight Fenestration Area. The total *skylight* area shall not be greater than that specified in Tables 5.5-0 through 5.5-8.

Exception to 5.5.4.2.2: 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 Section 5.5.4.4.2, Exception 1 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
   1. provide a minimum *skylight* area to *daylight area under skylights* of 3% with a *skylight VT* of at least 0.40 or
   2. 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 to 5.5.4.2.3:

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 sidelighted area* and *secondary sidelighted area* is less than 2500 ft^2 and where the lighting is controlled according to sidelighting requirements described in Section 9.4.1.1(e).

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Table 5.5.4.4.1 SHGC Multipliers for Permanent Projections

Projection Factor (PF)	SHGC Multiplier (South, East, and West *Orientations*)
0 to 0.10	1.00
>0.10 to 0.20	0.91
>0.20 to 0.30	0.82
>0.30 to 0.40	0.74
>0.40 to 0.50	0.67
>0.50 to 0.60	0.61
>0.60 to 0.70	0.56
>0.70 to 0.80	0.51
>0.80 to 0.90	0.47
>0.90 to 1.00	0.44

5.5.4.3 Fenestration U-Factor. *Fenestration* shall have a *U-factor* not greater than that specified in Tables 5.5-0 through 5.5-8.

Exception to 5.5.4.3: The *U-factor* for *skylights* is permitted to be increased to no greater than 0.90 Btu/h·ft^2·°F in Climate Zones 0 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 Section 5.5.4.4.2, Exception 1.

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 Tables 5.5-0 through 5.5-8.

Exceptions to 5.5.4.4.1:

1. For demonstrating compliance for *south*-, *east*-, or *west-oriented vertical fenestration* shaded by *opaque* permanent projections that will last as long as the *building* itself, the *SHGC* of the shaded *vertical fenestration* in the *proposed design* is permitted to 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 *south*-, *east*-, or *west-oriented 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* of the shaded *vertical fenestration* in the proposed *building* is permitted to then 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*.

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When this exception is used, separate calculations shall be performed for these sections of the *building envelope*, and these values shall not be averaged with any others for compliance purposes. 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 permitted to have an *SHGC* equal to or less than the area-weighted average *SHGC* of the *south*-, *east*-, or *west-oriented vertical fenestration* before any reductions made for permanent projections in Section 5.5.4.4.1, Exceptions 1 and 2.

5.5.4.4.2 SHGC of Skylights. *Skylights* shall have an *SHGC* not greater than that specified in Tables 5.5-0 through 5.5-8.

Exceptions to 5.5.4.4.2:

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. For Climate Zones 0 through 8:

$$A_W \leq (A_T)/4 \text{ and } A_E \leq (A_T)/4$$

b. For Climate Zones 0 through 3,

$$A_W \times SHGC_W \leq (A_T \times SHGC_C)/4 \text{ and } A_E \times SHGC_E \leq (A_T \times SHGC_C)/4$$

For Climate Zones 4 through 8,

$$A_W \times SHGC_W \leq (A_T \times SHGC_C)/5 \text{ and } A_E \times SHGC_E \leq (A_T \times SHGC_C)/5$$

where

A_W = *west-oriented vertical fenestration area*
A_E = *east-oriented vertical fenestration area*
A_T = total *vertical fenestration area*
$SHGC_C$ = *SHGC* criteria in Tables 5.5-0 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 to 5.5.4.5:

1. *Vertical fenestration* that complies with Section 5.5.4.4.1, Exception 3.
2. *Buildings* with shade on 75% of the *east*- and *west-oriented vertical fenestration areas* from permanent projections, *existing buildings*, existing permanent infrastructure, or topography at 9 a.m. and 3 p.m., respectively, on the summer solstice (June 21 in the northern hemisphere).
3. *Alterations* and *additions* with no increase in *vertical fenestration area*.
4. *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 facades, and *SHGC* on those facades is no greater than 90% of the criteria in Tables 5.5-0 through 5.5-8.
5. *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 5.5-0 through 5.5-8 for the appropriate *fenestration area*.

Exceptions to 5.5.4.6:

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 deter-

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mined 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 roof monitors* is greater than 50% of the *enclosed space floor* area.
4. *Enclosed spaces* with *skylights* 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.

5.5.5 Linear Thermal Bridges and Point Thermal Bridges. Where *linear thermal bridges* and *point thermal bridges* occur as described in Sections 5.5.5.1 through 5.5.5.5, they shall

a. comply with the applicable requirements of Sections 5.5.5.1 through 5.5.5.5 or
b. not exceed the mitigated *psi-factors* and *chi-factors* in Table A10.1, where the *psi-factors* and *chi-factors* for the *thermal bridges* are determined in accordance with Normative Appendix A, Section A10.

For the purposes of Section 5.5.5, linear elements that are connected to the *building* structure by a series of point connections shall be permitted to be characterized as *linear thermal bridges* or as individual *point thermal bridges*.

Exceptions to 5.5.5:

1. *Buildings* located in Climate Zones 0 through 3.
2. *Semiheated spaces* in *buildings* located in Climate Zones 0 through 6.
3. *Clear-field thermal bridges*.
4. *Thermal bridges* in uninsulated assemblies.
5. *Linear and point thermal bridges* that have a material thermal conductivity less than 3.0 Btu·in/h·ft^2·°F.
6. *Alterations* to *existing buildings* other than *additions.*
7. *Roofs* that project over *exterior walls.*

Informative Note: For *linear thermal bridges* and *point thermal bridges* that fall under the provisions of Section 4.2 and cannot comply prescriptively with the provisions of Sections 5.5.5.1 through 5.5.5.4, projects can use Section 5.5.5.5, Section 12, Normative Appendix C, or Normative Appendix G.

5.5.5.1 Roof and Wall Intersections. Where a *roof with insulation entirely above deck* intersects an exterior *wall,* the intersection shall comply with Sections 5.5.5.1.1 through 5.5.5.1.3, as applicable. Blocking, nailers, and similar elements shall be permitted to interrupt insulation for securement of the *roof covering*, coping, flashing materials, or similar elements.

5.5.5.1.1 Roof Edges. At *roof* edges without parapets or overhangs, the *roof* insulation and the *wall* insulation shall comply with the following, as applicable to the location of the insulation:

a. Where a *wall* has exterior *continuous insulation*, the *roof* insulation shall extend to the exterior of the *wall* insulation and the *wall* insulation shall extend to the *roof* insulation.
b. Where a *wall* has cavity or integral insulation that represents more than 50% of the total wall insulation *R-value*, the *roof*-to-wall insulation shall comply with one of the following:
   1. The cavity or integral insulation shall extend to the underside of the *roof* insulation.
   2. The cavity or integral insulation shall extend to the underside of the *roof* deck, and the *roof* insulation shall extend to the exterior face of the *wall*. The *wall* insulation shall be permitted to be interrupted by *roof* framing members.
   3. Additional insulation having a *rated R-value of insulation* not less than R-5 shall extend inward on the underside of the *roof* deck for not less than 2 ft and be permitted to be interrupted by *roof* framing members.
   4. Insulation having a *rated R-value of insulation* not less than R-5 shall be placed at the exterior of the *roof* edge and be located between the bottom plane of the *roof* insulation and the plane of the bottom of the *roof* deck.
   5. The *wall* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-1.
   6. The *roof* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-2.

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Table 5.5.5.1.1-1 Additional Wall Insulation Required for Mass Walls with Insulation on the Interior or Integral at Intersections with Roof Edges and Parapets

Climate Zone	R-Value Increase	U-factor % Decrease
4	R-1.0	8%
5	R-1.0	8%
6	R-1.5	10%
7	R-1.5	10%
8	R-2.5	14%

Table 5.5.5.1.1-2 Additional Roof Insulation Required for Mass Walls with Insulation on the Interior or Integral at Intersections with Roof Edges and Parapets

Climate Zone	R-Value Increase	U-factor % Decrease
4	R-7.0	24%
5	R-7.0	24%
6	R-7.0	26%
7	R-9.0	26%
8	R-9.0	26%

c. Where a *mass wall* has interior insulation that represents more than 50% of the total wall insulation *R-value*, the interior insulation shall extend to the underside of the *roof* deck, shall be permitted to be interrupted by framing members, and shall comply with one of the following:
   1. Additional insulation having a *rated R-value of insulation* not less than R-5 shall extend inward on the underside of the *roof* deck for not less than 2 ft and be permitted to be interrupted by *roof* framing members.
   2. Additional insulation having a *rated R-value of insulation* not less than R-5 shall be placed at the exterior of the *roof* edge and be located between the bottom plane of the *roof* insulation and the plane of the bottom of the *roof* assembly in contact with the exterior *wall*.
   3. The *wall* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-1.
   4. The *roof* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-2.

   Informative Note: See Informative Appendix K, Figure K-1.

5.5.5.1.2 Parapets. At *roof* edges with parapets, the *exterior wall* insulation shall comply with one or more of the following as applicable to the location of the insulation and *wall* assembly:

a. Where a *wall* has exterior *continuous insulation*, such *insulation* shall be applied to both vertical sides of the parapet.

   Informative Note: See Informative Appendix K, Figure K-2(a).

b. Where a *wall* has cavity or integral insulation that represents more than 50% of the total wall insulation *R-value*, the *roof* to *wall* intersections at parapets shall comply with one of the following:
   1. The *wall* insulation shall extend within the cavity of the parapet not less than the height of the top of the *roof* insulation. The *wall* insulation shall be permitted to be interrupted by *roof* framing members.
   2. Additional insulation having a *rated R-value of insulation* not less than R-5 shall extend inward on the underside of the *roof* deck for not less than 2 ft and be permitted to be interrupted by *roof* framing members.
   3. Insulation having a *rated R-value of insulation* not less than R-5 shall be placed at the exterior of the *roof* edge and be located between the bottom plane of the *roof* insulation and the plane of the bottom of the *roof* deck.
   4. The *wall* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-1.

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5. The *roof* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-2.

Informative Note: See Informative Appendix K, Figure K-2(b).

c. Where a *mass wall* has interior insulation that represents more than 50% of the total wall insulation *R-value*, the interior insulation shall extend to the underside of the *roof* deck, shall be permitted to be interrupted by framing members, and shall comply with one of the following:
   1. Additional insulation having a *rated R-value of insulation* not less than R-5 shall extend inward on the underside of the *roof* deck for not less than 2 ft and be permitted to be interrupted by *roof* framing members.
   2. Additional insulation having a *rated R-value of insulation* not less than R-5 shall be placed at the exterior of the *roof* edge and be located between the bottom plane of the *roof* insulation and the plane of the bottom of the *roof* assembly in contact with the exterior *wall*.
   3. The *wall* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-1.
   4. The *roof* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.1.1-2.

Informative Note: See Informative Appendix K, Figures K-2(c) and K-2(d).

5.5.5.1.3 Parapets within the Field of a Roof. Exterior *continuous insulation* having a minimum *rated R-value of insulation* not less than R-5 shall be applied to both vertical sides of the parapet and extend from the coping at the top of the parapet to not less than the top of the *roof* insulation below.

Informative Notes:
1. See Informative Appendix K, Figure K-3.
2. Parapets that are an integral part of a fire-resistance-rated wall, and the exterior *continuous insulation* applied to the parapet, shall comply with the fire resistance ratings of the building code.

5.5.5.2 Walls and Intermediate Floor Intersections. At *floor* and *exterior wall* intersections, the *exterior wall* insulation shall comply with Sections 5.5.5.2.1 and 5.5.5.2.2 as applicable to the type of *floor* intersection, *exterior wall* assembly, and location of the *exterior wall* insulation.

5.5.5.2.1 Intermediate *floor* edges that do not serve as balconies or *floor* overhangs shall comply with the following as applicable:

a. Where a *wall* has *exterior continuous insulation*, such insulation shall extend continuously past the *floor* edge.
b. Where a *wall* has cavity insulation that represents more than 50% of the total wall insulation *R-value*, the cavity insulation shall extend to the underside of the *floor* deck and shall be permitted to be interrupted by *floor* framing members and *wall* top and bottom plates or tracks. (***Informative Note:*** See Informative Appendix K, Figures K-4[a] and K-4[b].)
c. Where a *mass wall* has integral insulation that represents more than 50% of the total wall insulation *R-value*, the intermediate *floor* intersection shall comply with one of the following:
   1. The full thickness of integral insulation shall extend past the *floor* edge.
   2. Where the intermediate *floor* deck extends through the integral insulation, insulation having a *rated R-value of insulation* not less than R-5 shall be maintained to the full depth of the *floor* edge on the exterior side of the *floor* edge.

   See Informative Appendix K, Figures K-4(c) and K-4(d).
d. Where a *mass wall* has interior insulation that represents more than 50% of the total wall insulation *R-value*, the interior insulation shall extend to the underside of the *floor* deck, shall be permitted to be interrupted by framing members, and shall comply with one of the following:
   1. Additional interior insulation having a *rated R-value of insulation* not less than R-5 shall cover the full depth of the *floor* edge. Such insulation shall be permitted to be interrupted by *floor* framing members. Fire safing applied to the full depth of the *floor* edge meets this requirement.
   2. Additional insulation having a *rated R-value of insulation* not less than R-5 shall cover the full depth of the *floor* edge on the exterior side of the wall.
   3. The *wall* insulation values in Tables 5.5-0 through 5.5-8 shall be adjusted in accordance with Table 5.5.5.2.1.

   Informative Note: See Informative Appendix K, Figures K-4(e) and K-4(f).
e. Where *mass walls* have not less than 50% of the *rated R-value of insulation* on the exterior side of the *wall* and the remainder on the interior side, the insulation on the interior side of the *wall* shall be permit-

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Table 5.5.5.2.1 Additional Wall Insulation Required for Mass Walls With Insulation on the Interior Complying with Section 5.5.5.2.1(d)(3)

Climate Zone	R-Value Increase	U-factor % Decrease
4	R-1.5	13%
5	R-2.0	15%
6	R-2.5	16%
7	R-3.0	20%
8	R-4.0	25%

Table 5.5.5.2.2 Mass Floor Balcony or Floor Overhang Allowances

Climate Zone	Maximum Percent of Building Perimeter
4	35%
5	30%
6	20%
7	10%
8	0%

ted to be interrupted by an intermediate *floor*. (***Informative Note:*** See Informative Appendix K, Figure K-4[g].)

5.5.5.2.2 The total length of *mass floor* assembly projections serving as balconies or *floor* overhangs that penetrate the *building envelope* shall not exceed the percentages of the total *building* perimeter depicted in Table 5.5.5.2.2. For this calculation, total *building* perimeter is the sum of the perimeters of each above-*grade floor* where it intersects the *exterior building envelope*.

Exceptions to 5.5.5.2.2:

1. *Mass floor* assembly projections located directly above and providing protection to a pedestrian walkway at street-level.
2. *Mass floor* assembly projections thermally broken with a continuous thermal spacer block not less than R-12. The thermal spacer block shall be permitted to be interrupted by structural connections.

5.5.5.3 Exterior Cladding Support. Shelf angles that support masonry exterior cladding shall be offset from the *floor* edge or primary structural frame using point connections to accommodate the full depth of any exterior *continuous insulation* between the support and *floor* or structure, exclusive of the point connections. The cross-sectional area of point connections shall not exceed 1.5 in.^{2}/lin ft for carbon steel connections or 2.3 in.^{2}/lin ft for stainless steel. Other cladding supports that penetrate the exterior *continuous insulation* shall be subject to the provisions of Section 5.5.5.5 and be mounted away from the backup construction using point connections to accommodate the full depth of any exterior *continuous insulation* exclusive of the point connections.

Exception to 5.5.5.3: Girts in *metal building walls* as described in Normative Appendix A.

(***Informative Note:*** See Informative Appendix K, Figure K-5.)

5.5.5.4 Opaque Wall and Vertical Fenestration Intersection. *Vertical fenestration* shall be installed in accordance with one or more of the following:

a. For *vertical fenestration*, the outermost glazing layer shall be aligned within the thickness of or within 2 in. of either face of the *continuous insulation* layer. (***Informative Note:*** See Informative Appendix K, Figures K-6[a] and K-6[b].)
b. For *vertical fenestration*, where *continuous insulation* is not present, the outermost glazing layer shall be aligned within the thickness of the *wall* insulation layer and not more than 2 in. from the exterior side of the outermost insulation layer. (***Informative Note:*** See Informative Appendix K, Figure K-6[c].)
c. Intersections between *vertical fenestration* and *opaque walls* where the surfaces of the rough opening located between the edge of the frame of the *vertical fenestration* and the *opaque wall* insulation shall be

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Table 5.5.5.5 Allowable Point Thermal Bridge Cross-Sectional Area

Allowable Area per Point Thermal Bridge, in.^{2}	Common Material Name
3	Carbon steel
9	Stainless steel
65	Concrete and masonry

1. covered with a material having an *R-value* not less than R-3, or
2. covered with wood framing not less than 1.5 in. thick, or
3. covered with a material having a thermal conductivity of not more than 3.0 Btu·in/ h·ft^2·°F.

Informative Note: See Informative Appendix K, Figures K-6(d) and K-6(e).

d. Intersections between *vertical fenestration* and *opaque* spandrel in a shared *fenestration* framing system shall have a thermal break with a thermal conductivity of 3.6 Btu·in/ h·ft^2·°F or less.

Exception to 5.5.5.4: Intersections between *vertical fenestration* and uninsulated *opaque walls*.

5.5.5.5 Other Elements and Building Assembly Intersections. Individual *point thermal bridges* and *linear thermal bridges* not addressed in Sections 5.5.5.1 through 5.5.5.4 shall comply with Equation 5.5.5.5.

$$347 \text{ Btu·in./(ft}^2\text{·h·°F)} \times 0.003\% \times \textit{Above grade} \text{ area of the } \textit{building envelope} \geq (k_1 \times A_1) + (k_2 \times A_2) + (k_3 \times A_3) \ldots \quad (5.5.5.5)$$

where

k_1, k_2, k_3 … = thermal conductivity of material 1, material 2, material 3, etc., expressed in Btu·in./(ft^2·h·°F) for *point thermal bridge* material 1, material 2, material 3, etc. (e.g., concrete, carbon steel, stainless steel, wood)

A_1, A_2, A_3, … = the total cross-sectional area of *point thermal bridges* and *linear thermal bridges* of material 1, material 2, material 3, etc., expressed in ft^2

Exceptions to 5.5.5.5:

1. Service penetrations, including mechanical, electrical, plumbing, telecommunications, and fire services, that pass through the *opaque building envelope*.
2. Insulated *roof* curbs and blocking.
3. Individual *point thermal bridges* that are less than the allowances in Table 5.5.5.5.

(***Informative Note:*** See *ASHRAE Handbook—Fundamentals* Appendix A, Chapter 26, or Chapter 33 for typical material thermal conductivity.)

5.6 Building Envelope Trade-Off Compliance Path

5.6.1 The *building envelope* complies with the standard if

a. the *proposed design* satisfies the provisions of Sections 5.1, 5.4, 5.7, 5.8, and 5.9 and
b. the *proposed envelope performance factor* of the *proposed design* is less than or equal to the *proposed envelope performance factor* of the *base design*.

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 design*. The *simulation program* model *fenestration* and *opaque building* envelope types and area shall be consistent with the *construction documents*. Any *building envelope* assembly not subject to the provisions of Section 5.5.5 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 a *building 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. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

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5.7.2 Permit Application Documentation. Application documents shall include, at a minimum, the type and *rated R-value of insulation* for each product; *opaque door* schedule showing the *U-factor* for each *opaque door* product as determined in accordance with Section 5.8.2; *fenestration* schedule showing the *manufacturer*, model number, *orientation*, area, *U-factor*, *SHGC*, and *VT* for each *fenestration* product, as determined in accordance with Section 5.8.2; *air leakage* details in accordance with Section 5.4.3; and *point* and *linear thermal bridge* details in the *proposed building* shall be represented on the compliance documents in accordance with Section 5.5.5. In addition:

a. **Labeling of space conditioning categories.** For *buildings* that contain *spaces* that will be only *semiheated space* or *unconditioned space*, and compliance is sought using the *semiheated space building envelope* criteria, such *spaces* shall be clearly indicated on the *floor* plans.
b. **Labeling of daylight areas.** Daylighting documentation shall identify *daylight areas* on *floor* plans, including the *primary sidelighted areas*, *secondary sidelighted areas*, *daylight area under skylights*, and *daylight area under roof monitor*.
c. **Identify air leakage compliance.** *Continuous air barrier* compliance with whole-*building* pressurization testing in accordance with Section 5.4.3.1.4 or verification in accordance with Section 5.9.1.2 shall be clearly indicated on the *construction documents*.

5.7.3 Completion Requirements

5.7.3.1 Record Documents. *Construction documents* shall require that, within 90 days after the date of *building envelope* acceptance, *record documents* be provided to the *building* owner or the designated representative of the *building* owner. *Record documents* shall include, as a minimum, those items listed in Section 5.7.2, and the following:

a. A report complying with Section 4.2.5.1.2 providing the results of *continuous air barrier* compliance with whole-*building* pressurization testing in accordance with Section 5.4.3.1.4 or verification of the *building envelope* in accordance with Section 5.9.1.2.
b. Insulation documentation in accordance with Section 5.8.1.11.

5.7.3.2 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 *building envelope* acceptance. These manuals shall be in accordance with industry-accepted standards (see Informative Appendix E) and shall include, at a minimum, operation manuals and maintenance manuals for each component of the *building envelope* requiring maintenance, except components not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

5.8 Product Information and Installation Requirements

5.8.1 Insulation

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

Exceptions to 5.8.1.1: When insulation does not have such an identification mark, the *rated R-value of insulation* and the additional information specified below shall be identified by the *manufacturer* on each package, shipping container, or bundle of insulation. Insulation documentation shall be provided in accordance with Section 5.8.1.11 and the following:

1. For batts and blankets of any type: The *rated R-value of insulation*, length, width, thickness.
2. For boardstock: The *rated R-value of insulation*, length, width, and thickness of the boards in the package.
3. For all loose-fill insulation: The minimum settled thickness, initial installed thickness, maximum net coverage area, number of bags per 1000 ft^2 and minimum weight per ft^2 at *R-values* of 13, 19, 30, 38, and 49. The package shall also state the minimum net weight of the insulation in the package.
4. For spray-applied polyurethane foam: The *R-value* for the insulation at a 1 in. thickness and additional inch increments up to the maximum thickness allowed.

5.8.1.2 Manufacturer's Installation Instructions. Insulation materials shall be installed in accordance with the *manufacturer*'s recommendations and in such a manner as to achieve the *rated R-value of insulation*.

Exceptions to 5.8.1.2:

1. The *R-value* of compressed cavity insulation is determined in accordance with Table A9.4.3.
2. Where *metal building roof* or wall insulation is compressed between the steel structure and the metal *roof* or wall panels, the overall assembly *U-factor* is determined in accordance with Section A2.3, Section A3.2, or Section A9.4.6.

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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 the *manufacturer*'s 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 to 5.8.1.5: 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 A9.4.3.

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.

5.8.1.11 Insulation Installation Documentation. The insulation installer shall provide a signed and dated document for the installed insulation listing the type of insulation; the *manufacturer*; *manufacturer*'s *rated R-value of insulation*; and, where appropriate, the initial installed thickness, the settled thickness, and the coverage area. The insulation documentation shall be included in the *record documents*.

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 to 5.8.2.2: *Doors* with less than 25% glazing are not required to list *SHGC* and *VT*.

5.8.2.3 Manufacturer's Installation Instructions. Fenestration products shall be installed in accordance with *manufacturer*'s instructions.

5.8.2.4 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 to 5.8.2.4:

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*.

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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 *sectional garage doors* and *metal coiling doors*, ANSI/DASMA105 shall be an acceptable alternative for determining *U-factors*.

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

Exceptions to 5.8.2.5:

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*.

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

Exceptions to 5.8.2.6:

1. VT_{annual} determined in accordance with NFRC 203 shall be an acceptable alternative for determining compliance with the *VT* requirements for tubular daylighting devices.
2. For *skylights* whose transmittances are not within the scope of NFRC 200, their transmittance shall be the solar photometric transmittance of the *skylight* glazing materials determined in accordance with ASTM E972.

5.8.3 Air Leakage

5.8.3.1 Testing, Acceptable Materials, and Assemblies. *Air leakage* for materials or assemblies used as components of the *continuous air barrier* shall be determined in accordance with the test method and minimum air pressure specified in Table 5.8.3.1 and shall not exceed the maximum *air leakage* specified in Table 5.8.3.1 when complying with the *continuous air barrier* design and installation verification program in accordance with Section 5.9.1.2. *Air leakage* shall be determined by a laboratory accredited by a nationally recognized accreditation organization.

5.8.3.2 Fenestration and Doors. *Air leakage* for *fenestration* and *doors* shall be determined in accordance with the test method and minimum air pressure specified in Table 5.8.3.2 and shall not exceed the maximum *air leakage* specified in Table 5.8.3.2 when complying with the *continuous air barrier* design and installation verification program in accordance with Section 5.9.1.2. *Air leakage* shall be determined by a laboratory accredited by a nationally recognized accreditation organization and shall be *labeled* and certified by the *manufacturer*.

Exceptions to 5.8.3.2:

1. *Field-fabricated fenestration* and *doors*.
2. *Metal coiling doors* in *semiheated spaces* in Climate Zones 0 through 6 shall have an *air leakage* not exceeding 1.0 cfm/ft^2 when tested at a pressure of at least 1.57 psf in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.
3. Products in *buildings* that are tested and shown to comply with a whole-*building air leakage* in accordance with Section 5.4.3.1.4.

5.9 Verification, Testing, and Commissioning

5.9.1 Verification and Testing

5.9.1.1 Building Envelope Performance Verification. The *building envelope* shall be verified in accordance with Sections 5.9.1.2 through 5.9.1.3 and 4.2.5.1.

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Table 5.8.3.1 Maximum Air Leakage for Materials and Assemblies

Continuous Air Barrier	Maximum Air Leakage, cfm/ft^2	Minimum Test Pressure, psf	Test Method
Materials [a]	0.004	1.57	ASTM E2178
Assemblies [b]	0.04	1.57	ASTM E2357, ASTM E1677, ASTM E1680, ASTM E283

a. The following materials comply with the requirements in Table 5.8.3.1:
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 polyisocyanurate 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. 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. The following assemblies comply with the requirements in Table 5.8.3.1:
1. Concrete masonry *walls* that are
   (a) fully grouted or
   (b)painted to fill the pores
2. Shale or clay masonry units that are assembled as a solid *wall*: without weeps, with nominal width of 4 in. or more, and with Type S mortar

Table 5.8.3.2 Maximum Air Leakage for Fenestration and Doors

Fenestration and Door Products	Maximum Air Leakage, cfm/ft^2	Minimum Test Pressure, psf	Test Methods
Glazed swinging *entrance doors*, glazed power-operating sliding *entrance doors*, glazed power-operated folding *entrance doors*, and revolving *doors*	1.0	1.57	AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283;
Curtainwall and storefront glazing	0.06	1.57	NRFC 400 or ASTM 283
Unit *skylights* having condensation weepage openings	0.3	1.57	AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400
	OR		
	0.5	6.24	AAMA/WDMA/CSA 101/I.S.2/A440
Nonswinging doors intended for vehicular access and material transportation, with a minimum opening rate of 32 in./s	1.3	1.57	ANSI/DASMA 105, NFRC 400, or ASTM E283
Other *opaque nonswinging doors*, glazed *sectional garage doors*, and upward acting glazed *nonswinging*	0.4	1.57	ANSI/DASMA 105, NFRC 400, or ASTM E283
All other products	0.2	1.57	AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400
	OR		
	0.3	6.24	AAMA/WDMA/CSA 101/I.S.2/A440

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5.9.1.2 Verification of the Design and Installation of the Continuous Air Barrier. Where verification of the design and installation of the *continuous air barrier* is used for compliance in Section 5.4.3.1, it shall be determined in accordance with the following:

a. Requirements for a field inspection plan shall be included in the *construction documents* and shall include as a minimum the following:
   1. Schedule for periodic inspection(s)
   2. C*ontinuous air barrier* scope of work
   3. List of critical inspection items
   4. Inspection document requirements
   5. Provisions for corrective actions when needed
b. An independent third-party *V&T provider* in accordance with Section 4.2.5.1 shall conduct reviews and inspections as follows:
   1. A design review shall be conducted to verify and document compliance with the requirements in Sections 5.4.3 and 5.8.3.2.
   2. Periodic field inspection of the *continuous air barrier* materials and assemblies shall be conducted during *construction* while the *continuous air barrier* is still accessible for inspection and *repair* to verify and document compliance with the requirements of Section 5.4.3.2 and 5.8.3 and the field inspection plan.
   3. Verification and *FPT* documentation shall comply with Section 4.2.5.1.2 and the field inspection plan.

5.9.1.3 Dynamic Glazing. *Dynamic glazing* operation shall be tested for conformance with the *manufacturer's* installation instructions.

5.9.1.4 Air Curtains. Air curtains shall comply with Section 10.4.5.

5.9.2 Commissioning. The *energy* performance of the *building envelope* shall be *commissioned* in accordance with Section 4.2.5.2. *Commissioning* reporting shall comply with Section 4.2.5.2.2.

Informative Note: See Informative Appendix E and Informative Appendix H for *commissioning* references and guidance.

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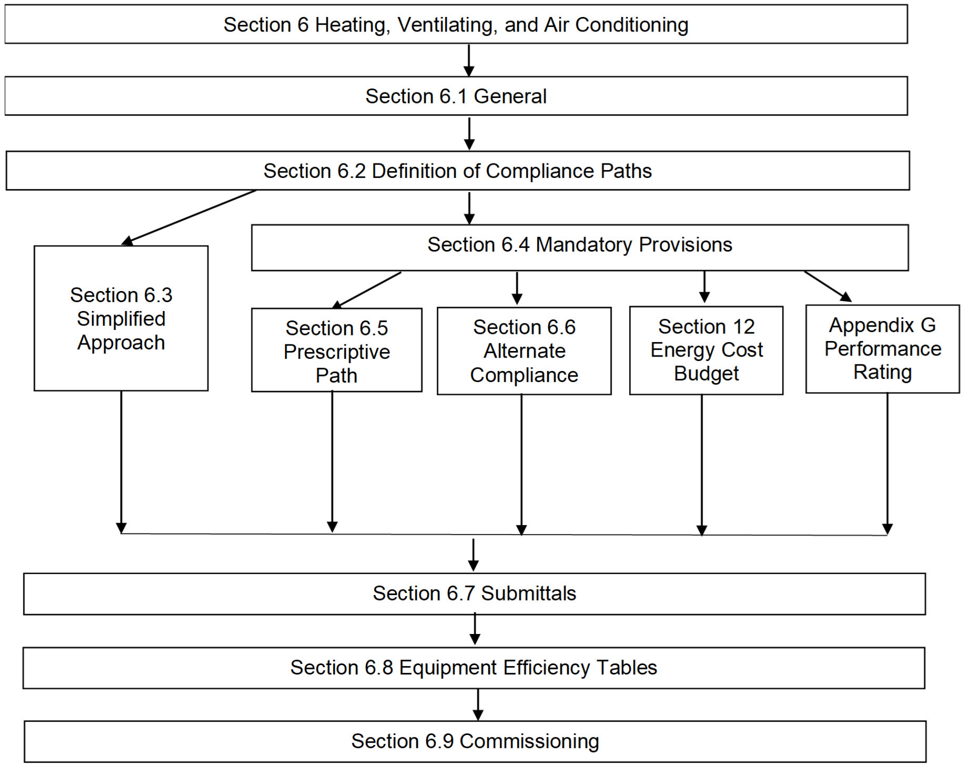

6. HEATING, VENTILATING, AND AIR CONDITIONING

6.1 General

6.1.1 Scope. Section 6 specifies requirements for mechanical *equipment* and*systems.*

6.1.2 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.

6.1.3 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 to 6.1.3: 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*.

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

6.1.4.1 New HVACR *equipment* as a direct replacement of existing HVACR *equipment* shall comply with the following sections as applicable for the *equipment* being replaced:

a. 6.3, “Simplified Approach Building Compliance Path for HVAC Systems”
b. 6.4.1, “Equipment Efficiencies, Verification, and Labeling Requirements”
c. 6.4.3.1, “Zone Thermostatic Controls”
d. 6.4.3.2, “Set-Point Overlap Restrictions”
e. 6.4.3.3, “Off-Hour Controls” except for Section 6.4.3.3.4, “Zone Isolation”
f. 6.4.3.4, “Ventilation System Controls”
g. 6.4.3.7, “Freeze Protection and Snow/Ice Melting Systems”
h. 6.4.3.8, “Ventilation Controls for High-Occupancy Areas” only for single-zone *equipment*
i. 6.4.3.9, “Heated or Cooled Vestibules or Air Curtains with Integral Heating”
j. 6.4.5, “Walk-In Coolers and Walk-In Freezers”
k. 6.5.1.1, “Air Economizers” for units located outdoors
l. 6.5.1.3, “Integrated Economizer Control”
m. 6.5.1.4, “Economizer Heating System Impact”
n. 6.5.3.1.3, “Fan Efficiency”

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o. 6.5.3.2.1, “Supply Fan Airflow Control”
p. 6.5.3.6, “Fractional Horsepower Fan Motors”
q. 6.5.4.1, “Boiler Turndown”
r. 6.5.4.3, “Chiller and Boiler Isolation”
s. 6.5.5.2, “Fan Speed Control”

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

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

6.1.4.4 New and replacement *ductwork* shall comply with Sections 6.4.4.1 and 6.4.4.2.

6.1.4.5 New and replacement *piping* shall comply with Section 6.4.4.1.

Exceptions to 6.1.4.5: 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.

6.1.5 Climate. Climate zones shall be determined in accordance with Section 5.1.5.

6.2 Compliance Paths. Mechanical *equipment* and *systems* providing heating, cooling, ventilating, or refrigeration shall comply with Sections 6.2.1 and 6.2.2.

6.2.1 Requirements for all Compliance Paths. Mechanical *equipment* and *systems* shall comply with all of the following:

a. Section 6.1, “General”
b. Section 6.4, “Mandatory Provisions”

Exception to 6.2.1(b): When compliance is shown using Section 6.2.2(a), compliance with Section 6.4 is not required unless required in Section 6.3.2.

c. Section 6.7, “Submittals”
d. Section 6.8, “Minimum Equipment Efficiency Tables”

6.2.2 Additional Requirements to Comply with Section 6. Refrigeration *equipment* and *systems* shall comply with Section 6.5, “Prescriptive Compliance Path.” All *building HVAC systems* shall comply with one of the following:

a. Section 6.3, “Simplified Approach Building Compliance Path for HVAC Systems”
b. Section 6.5, “Prescriptive Compliance Path”
c. Section 6.6.1, “Computer Room System Path”
d. Section 6.6.2, “Mechanical System Performance Path”

Informative Note: Section 6.3 requires all *HVAC systems* in the *building* to qualify for the simplified path. Section 6.6.2 requires all allowable *systems* to meet Normative Appendix L requirements. Section 6.6.2 does allow part of the *building* to use the Mechanical System Performance Path and part of the *building* to use Section 6.5 where there are excluded occupancy types or *system* types in Section L1.1.1.2. *HVAC systems* for larger *computer rooms* may comply with either Section 6.5, Section 6.6.1, or Section 6.6.2.

6.3 Simplified Approach Building Compliance Path 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* must 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.

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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. Cooling *equipment* shall also comply with Section 6.4.1.4.
d. The *system* shall have an *air economizer* meeting the requirements of Sections 6.5.1 and 6.4.3.12.
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*). Heating *equipment* shall also comply with Section 6.4.1.4.
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 *set-point 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 *set point* 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.

   Exceptions to 6.3.2.(h): 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.

   Exception to 6.3.2(i): Humidity control assisted by hot-gas *reheat* or heat from 100% *site-recovered energy* is permitted.
j. *Systems* serving *spaces* other than *residential spaces*, that do not require continuous operation, with a cooling or heating capacity greater than 7000 Btu/h shall comply with Sections 6.4.3.3.1 and 6.4.3.3.2.
k. *Systems* serving *residential spaces* other than hotel/motel guest rooms shall comply with Sections 6.4.3.3.1 and 6.4.3.3.2 except for *electric resistance* heaters rated at 2 hp or less with a *readily accessible manual* control that lowers the *set point* or turns the unit off.
l. *Systems* serving hotel/motel guest rooms shall comply with Section 6.4.3.3.5.
m. 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.
n. *Ductwork* and *plenums* shall be insulated in accordance with Table 6.8.2 and shall be sealed in accordance with Section 6.4.4.2.1.
o. *Construction documents* shall require a ducted *system* to be air balanced in accordance with industry accepted procedures.
p. *Outdoor air* intake and exhaust *systems* shall meet the requirements of Section 6.4.3.4.
q. Where separate heating and cooling *equipment* serves the same temperature zone, *thermostats* shall be interlocked to prevent simultaneous heating and cooling.
r. *Systems* with a design supply air capacity greater than 10,000 cfm shall have *optimum start controls*.
s. The *system* shall comply with the *demand control ventilation* requirements in Section 6.4.3.8, occupied-standby controls in Section 6.5.3.9, and the *ventilation* design requirements in Section 6.5.3.8.
t. 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 6.8.1-21 shall have a minimum performance at the specified rating conditions when tested in accordance with the specified test procedure. Where multiple rating

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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 *service 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 Air-Cooled Unitary Heat Pumps—Minimum Efficiency Requirements"
c. Table 6.8.1-3, "Liquid-Chilling Packages—Minimum Efficiency Requirements" (See Section 6.4.1.2 for liquid-cooled centrifugal liquid-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 and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters—Minimum Efficiency Requirements"
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—Minimum Efficiency Requirements"
h. Table 6.8.1-8, "Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements"
i. Table 6.8.1-9, "Electrically Operated Variable-Refrigerant-Flow and Applied Heat Pumps—Minimum Efficiency Requirements
j. Table 6.8.1-10, "Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements"
k. Table 6.8.1-11, "Commercial Refrigerators, Commercial Freezers, and Refrigeration—Minimum Efficiency Requirements"
l. Table 6.8.1-12, "Vapor-Compression-Based Indoor Pool Dehumidifiers—Minimum Efficiency Requirements"
m. Table 6.8.1-13, "Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, without Energy Recovery—Minimum Efficiency Requirements"
n. Table 6.8.1-14, "Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, with Energy Recovery—Minimum Efficiency Requirements"
o. Table 6.8.1-15, "Electrically Operated Water-Source Heat Pumps—Minimum Efficiency Requirements"
p. Table 6.8.1-16, "Heat Pump and Heat Recovery Water-Chilling Packages—Minimum Efficiency Requirement"
q. Table 6.8.1-17, "Ceiling-Mounted Computer-Room Air Conditioners—Minimum Efficiency Requirements"
r. Table 6.8.1-18, "Walk-In Cooler and Freezer Display Door Efficiency Requirements"
s. Table 6.8.1-19, "Walk-In Cooler and Freezer Nondisplay Door Efficiency Requirements"
t. Table 6.8.1-20, "Walk-In Cooler and Freezer Refrigeration System Efficiency Requirements"
u. Table 6.8.1-21, "Ceiling Fan Efficiency Requirements"

6.4.1.2 Minimum Equipment Efficiencies—Listed Equipment—Nonstandard Conditions

6.4.1.2.1 Liquid-Cooled Centrifugal Chilling Package Cooling Efficiency Adjustment. Liquid-cooled centrifugal chiller packages not designed for cooling operation at AHRI Standard 550/590 test and rating conditions of 44.00°F leaving and 54.00°F entering chilled-liquid temperatures, and with 85.00°F entering and 94.30°F leaving condenser-liquid temperatures, shall have maximum full-load *kW*/ton (FL) and part-load cooling *energy efficiency* (*IPLV*.IP) rating requirements, listed in Tables 6.8.1-3 and 6.8.1-16, adjusted using the following equations:

$$\mathrm{FL.IP}_{adj} = \mathrm{FL.IP}/K_{adj}$$

$$\mathrm{PLV.IP}_{adj} = IPLV.\mathrm{IP}/K_{adj}$$

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

where

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FL.IP	=	full-load *kW*/ton value from Table 6.8.1-3 or 6.8.1-16
FL.IP_{adj}	=	maximum full-load *kW*/ton rating, adjusted for nonstandard conditions
IPLV.IP	=	*IPLV*.IP value from Table 6.8.1-3 or 6.8.1-16
PLV.IP_{adj}	=	maximum *NPLV*.IP rating, adjusted for nonstandard conditions
A	=	$0.00000014592 \times (\text{LIFT})^4 - 0.0000346496 \times (\text{LIFT})^3 + 0.00314196 \times (\text{LIFT})^2 - 0.147199 \times (\text{LIFT}) + 3.93073$
B	=	$0.0015 \times \text{LvgEvap} + 0.934$
LIFT	=	LvgCond – LvgEvap
LvgCond	=	full-load condenser leaving liquid temperature, °F
LvgEvap	=	full-load evaporator leaving liquid temperature, °F

The FL.IP_{adj} and PLV.IP_{adj} values are only applicable for centrifugal chilling packages meeting all of the following full-load design ranges:

- 36.00°F ≤ LvgEvap ≤ 70.00°F and
- 60.00°F ≤ LvgCond ≤ 135.00°F and
- 20.00°F ≤ LIFT ≤ 80.00°F

Manufacturers shall calculate the FL.IP_{adj} and PLV.IP_{adj} before determining whether to label the chiller per Section 6.4.1.5. Compliance with Standard 90.1-2007, 2010, 2013, 2016, 2019, 2022, or combinations thereof, shall be *labeled* on chilling packages within the scope of the standard.

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

6.4.1.2.2 Chilling Packages Employing Freeze-Protection Liquids. Electrically operated chilling packages that employ freeze-protection liquids in any heat exchanger with an application cooling duty evaporator liquid leaving temperature or heating operation source liquid temperature above 32.00°F shall show *efficiency* compliance in accordance with the applicable requirements in Sections 6.4.1.2.2.1 through 6.4.1.2.2.4.

Absorption chilling packages with freeze-protection liquids are exempt from the *efficiency* requirements listed in Table 6.8.1-3 and shall only show compliance when applied with water.

6.4.1.2.2.1 All electrically operated cooling-only air-cooled and electrically operated positive displacement liquid-cooled chilling packages shall show compliance with the cooling *efficiency* requirements listed in Table 6.8.1-3when applied within the operating limits of AHRI 550/590 at AHRI 550/590 standard rating conditions when tested or rated with water used as a heat transfer liquid.

6.4.1.2.2.2 All liquid-cooled electrically operated cooling-only centrifugal chilling packages shall show compliance with the cooling *efficiency* requirements listed in Table 6.8.1-3 when applied within the operating limits defined in AHRI 550/590 at the application rating conditions for a cooling *efficiency*, adjusted using K_{adj} as defined in Section 6.4.1.2.1, when tested or rated with water used as a heat transfer liquid.

6.4.1.2.2.3 All electrically operated air source and electrically operated positive displacement liquid-source heat pump and heat recovery chilling packages shall show compliance with the cooling *efficiency* requirements listed in Table 6.8.1-16 when applied within the operating limits of AHRI 550/590 at AHRI 550/590 standard rating conditions when tested or rated with water used as a heat transfer liquid. They also shall show compliance with the heating *efficiency* requirements listed in Table 6.8.1-16 at one of the AHRI 550/590 standard heating rating conditions when tested or rated with water used as a heat transfer liquid. Heating-only chilling packages shall meet the *efficiency* requirements at one of the AHRI 550/590 heating liquid temperature rating conditions and are not required to meet the cooling *efficiency* requirements of Table 6.8.1-16.

6.4.1.2.2.4 All liquid-source centrifugal heat pump and heat recovery chilling packages shall show compliance with the cooling *efficiency* requirements listed in Table 6.8.1-16 when applied within the operating limits defined in AHRI 550/590 at the application rating conditions for cooling *efficiency*, adjusted using K_{adj} as defined in Section 6.4.1.2.1, when tested or rated with water. They also shall show compliance with the heating *efficiency* requirements in Table 6.8.1-16 at one of the AHRI 550/590 standard rating conditions when tested or rated with water used as a heat-transfer liquid. Heating-only chilling packages shall meet the heating *efficiency* requirements at one of the AHRI 550/590 heating liquid temperature rating conditions and are not required to meet the cooling *efficiency* requirements of Table 6.8.1-16.

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.

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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.

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 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 and Diagnostics

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 to 6.4.3.1.1: 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 *walls* facing only one *orientation* for 50 contiguous feet or more and
2. the perimeter *system* heating and cooling supply is controlled by *thermostatic controls* located within the zones served by the *system*.

Exterior walls and *semiexterior walls* are considered to have different *orientations* if the exposures 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 and configured to provide 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 to 6.4.3.1.2:

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 Set-Point 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 *set point* from exceeding the cooling *set point*, minus any applicable proportional band.

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6.4.3.3 Off-Hour Controls. *HVAC systems* shall have the off-hour controls required by Sections 6.4.3.3.1 through 6.4.3.3.5.

Exceptions to 6.4.3.3:

1. *HVAC systems* intended to operate continuously.
2. *HVAC systems* not serving *residential spaces* and having a design heating capacity and cooling capacity less than 7000 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 *occupancy 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.

Exceptions to 6.4.3.3.1:

1. Systems serving *residential* occupancies with controls that can start and stop the *system* under at least two different time schedules per week.
2. *Systems* serving non-*residential* occupancies where heating or cooling capacity is less than 15,000 Btu/h, with controls that can start and stop the *system* under at least two different time schedules per week.

6.4.3.3.2 Setback Controls. Heating *systems* shall be equipped with controls capable of and configured to *automatically* restart and temporarily operate the *system* as required to maintain zone temperatures above an adjustable heating *set point* at least 10°F below the occupied heating *set point*. Cooling *systems* shall be equipped with controls capable of and configured to *automatically* restart and temporarily operate the *mechanical cooling system* at the lowest practical fan speed as required to maintain zone temperatures below an adjustable cooling *set point* at least 5°F above the occupied cooling *set point* or to prevent maximum *space* humidity levels as required by Standard 62.1.

Exception to 6.4.3.3.2: *Radiant heating systems* capable of and configured with a *setback* heating *set point* at least 4°F below the occupied heating *set point*.

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 *set point*, 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.

Exception to 6.4.3.3.3 : *Residential spaces* are not required to have *optimum start controls*.

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 *story*. Each isolation area shall be equipped with *isolation devices* capable of and configured to *automatically* shut 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 Sections 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 to 6.4.3.3.4: *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.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for zone isolation using logical groups of zone air *terminal* units serving each isolation area.

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6.4.3.3.5 Automatic Control of HVAC in Hotel/Motel Guest Rooms. Hotels and motels with greater than 50 guest rooms shall be provided with *automatic* controls for the HVAC *equipment* serving each guest room capable of and configured according to the requirements in the following subsections.

6.4.3.3.5.1 Guest Room HVAC Set-Point Control. HVAC *systems* serving hotel guest rooms shall be capable of and configured with three modes of temperature control.

a. **Rented and unoccupied.** Within 20 minutes of all occupants leaving the guest room, HVAC *set points* shall be *automatically* raised by at least 4°F from the occupant *set point* in the cooling mode and *automatically* lowered by at least 4°F from the occupant *set point* in the heating mode.
b. **Unrented and unoccupied.** HVAC *set points* shall be *automatically reset* to 80°F or higher in the cooling mode and to 60°F or lower in the heating mode. The HVAC *set points* in the unrented and unoccupied guest room modes shall be initiated within 16 hours of the guest room being continuously unoccupied or within 20 minutes of the guest room being continuously unoccupied where a *networked guest room control system* indicates the guest room is unrented.
c. **Occupied.** HVAC *set points* shall return to their occupied *set points* once occupancy is sensed.

Exceptions to 6.4.3.3.5.1:

1. A *networked guest room control system* shall be permitted to return the *thermostat set points* to their default occupied *set points* 60 minutes prior to the time the room is scheduled to be occupied.
2. Dehumidification shall be permitted to limit the *space* humidity levels as required by Standard 62.1 during unoccupied mode for both rented and unrented periods.

6.4.3.3.5.2 Guest Room Ventilation Control. Within 20 minutes of all occupants leaving the guest room, *ventilation* and exhaust fans shall *automatically* be turned off, or *isolation devices* serving each guest room shall *automatically* shut off the supply of *outdoor air* to the guest room and shut off exhaust air from the guest room.

Exception to 6.4.3.3.5.2: Guest room *ventilation systems* shall be permitted to have an *automatic* daily preoccupancy purge cycle that provides daily *outdoor air ventilation* during unrented periods at the design *ventilation* rate for 60 minutes, or at a rate and duration equivalent to one air change.

6.4.3.4 Ventilation System Controls

6.4.3.4.1 Stair and Elevator Shaft Vent Dampers. Where stair and elevator shafts have vents, they shall be equipped with motorized dampers that are capable of and configured to *automatically* close during normal *building* operation and are interlocked to open as required by fire and smoke detection *systems* or by *thermostatic control systems*.

Exception to 6.4.3.4.1: Nonmotorized gravity backdraft dampers are acceptable in *buildings* less than three *stories* in height and for *buildings* of any height located in Climate Zones 0, 1, 2, and 3.

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. *Outdoor air* and exhaust/relief dampers shall be capable of and configured to *automatically* shut off during preoccupancy *building warm-up*, *cooldown*, and *setback*, except when the supply of *outdoor air* reduces *energy* costs or when *outdoor air* must be supplied to meet code requirements.

Exceptions to 6.4.3.4.2:

1. Nonmotorized (gravity backdraft) dampers are acceptable for exhaust and relief in *buildings* less than three *stories* in height and for *outdoor air* intakes and exhaust and relief dampers in *buildings* of any height located in Climate Zones 0, 1, 2, and 3. Nonmotorized dampers for *outdoor air* intakes must be protected from direct exposure to wind.
2. 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.
5. Dampers are not required in *systems* intended to operate continuously.

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.

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 and configured to shut off fans when not required.

Exception to 6.4.3.4.4: *HVAC systems* intended to operate continuously.

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Table 6.4.3.4.3 Maximum Damper Leakage[a,b], cfm per ft^2 at 1.0 in. of water

	Outdoor Air Intake		Exhaust/Relief	
Climate Zone	**Nonmotorized [a]**	**Motorized**	**Nonmotorized [c]**	**Motorized**
0, 1, 2				
Any height	20	4	20	4
3				
Any height	20	10	20	10
4, 5B, 5C				
Fewer than three *stories*	20 [d]	10	20	10
Three or more *stories*	20 [d]	10	20 [d]	10
5A, 6, 7, 8				
Fewer than three *stories*	20 [d]	4	20	4
Three or more *stories*	20 [d]	4	20 [d]	4

a. When tested in accordance with AMCA Standard 500-D.
b. Dampers smaller than 12 in. in height, width, or diameter need not be tested but shall be of the same design and construction as the smallest tested damper meeting the listed leakage rate requirement.
c. Nonmotorized dampers smaller than 24 in. in height, width, or diameter may have a leakage rate of 40 cfm/ft^2.
d. Where allowed by Section 6.4.3.4.2, Exception 2.

6.4.3.4.5 Parking Garage Ventilation Systems. Parking garage *ventilation systems* shall meet all of the following:

a. Separate *ventilation systems* and control *systems* shall be provided for each *parking garage section*.
b. Control *systems* for each *parking garage section* shall *automatically* detect and control contaminant levels and shall be capable of and configured to reduce airflow to 20% or less of *design capacity*.
c. The *ventilation system* for each *parking garage section* shall have controls and devices that result in fan motor *demand* of no more than 30% of design wattage at 50% of the design airflow.

Exception to 6.4.3.4.5: Garage *ventilation systems* serving a single *parking garage section* having a total *ventilation system motor nameplate horsepower* not exceeding 5 hp at *fan system design conditions* and where the *parking garage section* has no *mechanical cooling* or *mechanical heating*.

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 to 6.4.3.5: 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 Control

6.4.3.6.1 Dehumidification. *Humidistatic controls* shall not use *mechanical cooling* to reduce the humidity below the lower of a dew point of 55°F or relative humidity of 60% in the coldest zone served by the *system*.

Informative Note: Lower humidity is permitted when operating *mechanical cooling* for temperature control.

6.4.3.6.2 Humidification. *Humidistatic controls* shall not use *fossil fuel* or electricity to produce relative humidity above 30% in the warmest zone served by the *system*.

6.4.3.6.3 Control Interlock. 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 and configured to prevent simultaneous operation of humidification and dehumidification *equipment*.

Exception to 6.4.3.6.1 and 6.4.3.6.2: *Systems* serving zones where specific humidity levels are required, such as museums and hospitals, and approved by the *authority having jurisdiction* or

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Table 6.4.3.8 Demand Control Ventilation (DCV) Floor Area Thresholds

	Occupant Outdoor Airflow Component (cfm/1000 ft^2) [a]					
	100 to 199	200 to 399	≥400	100 to 199	200 to 399	≥400
	Minimum Space Floor Area in ft^2 where DCV Is Required					
Climate Zone	Areas without Exhaust Air Energy Recovery			Areas with Exhaust Air Energy Recovery [b]		
7, 8	400	200	150	800	400	250
5A, 6A, 6B	600	250	150	1400	900	400
0A, 0B, 1B, 3A, 4A, 5B, 5C	800	400	250	2000	1000	500
2A, 2B, 4C	1100	600	300	2300	1100	600
3B, 4B	1500	700	400	5200	2350	1250
1A	2400	1100	600	5800	2600	1400
3C	7000	3000	1700	12,000	6000	3000

a. Occupant outdoor airflow component in cfm per 1000 ft^2 shall be calculated as the product of default occupant density and outdoor airflow rate per occupant (R_p) as shown in ASHRAE Standard 62.1, Table 6.2.2.1.
b. Where exhaust air energy recovery is required by Section 6.5.6.1.

required by accreditation standards, and where *humidistatic controls* are capable of and configured to maintain a *dead band* of at least 10% rh where no active humidification or dehumidification takes place.

Exception to 6.4.3.6.1, 6.4.3.6.2, and 6.4.3.6.3: *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 and configured to shut 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 and configured to shut 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*) is required for *spaces* larger than the floor area shown in Table 6.4.3.8 based on an occupant outdoor airflow component in cfm per 1000 ft^2 and served by *systems* with one or more of the following:

a. *Air economizer*
b. *Automatic* modulating control of *outdoor air* damper
c. Design outdoor airflow greater than 3000 cfm

Exceptions to 6.4.3.8:

1. Multiple-zone *systems* without *DDC* of individual zones communicating with a central control panel.
2. *Spaces* where >75% of the *space* design outdoor airflow is required for *makeup air* that is exhausted from the *space* or *transfer air* that is required for *makeup air* that is exhausted from other *spaces*.
3. *Spaces* with one of the following occupancy categories as defined in ASHRAE Standard 62.1: correctional cells, daycare sickrooms, science labs, barbers, beauty and nail salons, and bowling alley seating.
4. *Spaces* where the requirements of ASHRAE Standard 170, applicable codes, or applicable accreditation standards do not allow the reduction of outdoor airflow.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for CO_2-based *demand control ventilation* and how it can be implemented while complying with ASHRAE Standard 62.1.

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

6.4.3.9 Heated or Cooled Vestibules or Air Curtains with Integral Heating. Heating *systems* for vestibules and air curtain units with integral heating shall include *automatic* controls capable of and configured to shut off the heating *system* when *outdoor air* temperatures are above 45°F. Vestibule heating and cooling *systems* shall be controlled by a *thermostat* in the vestibule capable of and configured to limit heating to a maximum of 60°F and cooling to a minimum of 85°F.

Exception to 6.4.3.9: Heating or cooling provided by *site-recovered energy* or by *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 to 6.4.3.10.1: *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 and configured with 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 zones from the *reset* algorithm

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for monitoring *zone* and *system demand*, *automatically* detecting and alarming zones that are excessively driving *reset* logic, and readily excluding those zones from *reset* logic.

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.

6.4.3.11 Chilled-Water Plant Monitoring

6.4.3.11.1 Monitoring. For electric-motor-driven chilled-water plants in new *buildings*, or for new plants in *existing buildings*, measurement devices shall be installed and shall measure the electric *energy* use and *efficiency* of the chilled-water plant for

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a. water-cooled chilled-water plants larger than 1500 tons peak cooling capacity for Climate Zones 5 through 8, 3C, and 4C, and larger than 1000 tons peak cooling capacity for all other zones; and
b. air-cooled chilled-water plants larger than 860 tons peak cooling capacity for Climate Zones 5 through 8, 3C, and 4C, and larger than 570 tons peak cooling capacity for all other zones.

The *efficiency* shall be calculated in *kW*/ton (see Informative Appendix E).

6.4.3.11.2 Electric-Motor-Driven Chiller System Recording and Reporting. The electrical *energy* use *efficiency* shall be trended every 15 minutes and graphically displayed and include hourly, daily, monthly, and annual data. The *system* shall maintain all data collected for a minimum of 36 months.

6.4.3.12 Economizer Fault Detection and Diagnostics (FDD). Air-cooled direct-expansion cooling units listed in Tables 6.8.1-1 and 6.8.1-2, where an *air economizer* is installed in accordance with Section 6.5.1, shall include a fault detection and diagnostics (FDD) *system* complying with the following:

a. The following temperature sensors shall be *permanently installed* to monitor *system* operation:
   1. *Outdoor air*
   2. Supply air
   3. Return air, where required for economizer control
b. The *system* shall have the capability of displaying the value of each sensor.
c. The FDD *system* or unit controls shall be capable of and configured to provide *system* status by indicating the following:
   1. Free cooling available
   2. Economizer enabled
   3. Compressor enabled
   4. Heating enabled
   5. Mixed-air low-limit cycle active
d. The FDD *system* or unit controls shall have provisions to manually initiate each operating mode so that the operation of compressors, economizers, fans, and the heating *system* can be independently tested and verified.
e. The FDD *system* shall be capable of and configured to detect the following faults:
   1. Air temperature sensor failure/fault
   2. Not economizing when the unit should be economizing
   3. Economizing when the unit should not be economizing
   4. Damper not modulating
   5. Excess *outdoor air*
f. The FDD *system* shall be capable of and configured to report faults to a fault management application or *DDC system* accessible by operating or service personnel, or annunciated locally on zone *thermostats*.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for monitoring and alarming *air economizer* faults for *air economizers* that are controlled by *DDC systems*.

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 Table 6.8.2.

Exceptions to 6.4.4.1.2:

1. Factory-installed *plenums*, casings, or *ductwork* furnished as a part of HVAC *equipment* tested and rated in accordance with Section 6.4.1.

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2. Ducts or *plenums* located in *heated spaces*, *semiheated spaces*, or *cooled 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 space* or *indirectly conditioned space* 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* shall be thermally insulated in accordance with Tables 6.8.3-1 and 6.8.3-2.

Exceptions to 6.4.4.1.3:

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, and natural-gas *piping*).
4. Where heat gain or heat loss will not increase *energy* use (such as liquid refrigerant *piping*).
5. In *piping* 1 in. 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 *building 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 *building envelope* insulation counts toward this requirement.

Exception to 6.4.4.1.5: See Section 5 requirements for *heated slab-on-grade floors* incorporating radiant heating.

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*. Openings for rotating shafts shall be sealed with bushings or other devices that seal off leaking air. 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. of water 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 *building* 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 per 100 ft^2 of duct surface area
C_L	=	4, duct leakage class, cfm per 100 ft^2 of duct surface area per in. of $water^{0.65}$
P	=	test pressure, which shall be equal to the design duct pressure class rating, in. of water

6.4.5 Walk-In Coolers and Walk-In Freezers. Site-assembled or *site*-constructed *walk-in coolers* and *walk-in 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 to 6.4.5(a): *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.

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

Exception to 6.4.5(c): 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 lower efficacy 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 or vacuum insulating glazing. (***Informative Note:*** For applications in the U.S., alternate innovative component technologies (e.g., vacuum insulating glazing for transparent reach-in doors) are allowable only if the *manufacturer* has obtained a waiver from U.S. DOE.)

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 triple-pane glass, either filled with inert gas or with heat-reflective treated glass or vacuum insulating glazing. (***Informative Note:*** For applications in the U.S., alternate innovative component technologies (e.g., vacuum insulating glazing for transparent reach-in doors) are allowable only if the *manufacturer* has obtained a waiver from U.S. DOE.)

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 in response 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 to 6.4.5(l): *Walk-in coolers* and *walk-in freezers* combined in a single enclosure greater than 3000 ft^2.

m. Doors in *walk-in coolers* and *walk-in freezers* shall meet the requirements of Tables 6.8.1-18 and 6.8.1-19. *Walk-in cooler* and *walk-in freezer* refrigeration *systems*, except for walk-in process cooling refrigeration *systems* as defined in 10 CFR 431.302, shall meet the requirements of Table 6.8.1-20.

6.4.6 Refrigerated Display Case

a. All refrigerated display cases shall conform to Section 6.4.1.1 and Table 6.8.1-11.

b. Lighting in refrigerated display cases and glass *doors* installed on *walk-in coolers* and *walk-in 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 *walk-in 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 on 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 in response to the condensation on the inner glass pane.

6.4.7 Liquid-to-Liquid Heat Exchangers. Plate-type liquid-to-liquid heat exchangers shall be rated in accordance with AHRI 400. Section 12 contains a complete specification of the referenced test procedure.

6.5 Prescriptive Compliance Path

6.5.1 Economizers. Each cooling *system* shall include either an *air economizer* or *fluid economizer* meeting the requirements of Sections 6.5.1.1 through 6.5.1.5.

Exceptions to 6.5.1: 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.

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Table 6.5.1-1 Minimum Fan-Cooling Unit Size for which an Economizer Is Required

Climate Zone	Cooling Capacity for which an Economizer Is Required	Application
0A, 0B, 1A, 1B	No economizer requirement	All
2A, 2B, 3A, 4A, 5A, 6A, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	≥33,000 Btu/h	Fan-cooling units located outside the *building*
	≥54,000 Btu/h	All other fan-cooling-unit locations

Table 6.5.1-2 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 annualized or part-load metric, then to eliminate the required economizer, only the annualized or part-load minimum cooling *efficiency* of the unit must be increased by the percentage shown. If the unit is only rated with a full-load metric like *EER* cooling then these must be increased by the percentage shown. To determine the *efficiency* required to eliminate the economizer when the unit *equipment efficiency* is rated with an energy-input divided by a thermal-output metric, the metric shall first be converted to COP by the *efficiency* improvement percentage shown. The COP shall then be converted back to the original rated metric to establish the *efficiency* required to eliminate the economizer.

Informative Note: Some examples of annualized or part-load metrics are *IPLV*.IP, *IEER*, and *SEER*.

2. Chilled-water cooling *systems* without a fan or that use induced airflow, where the total capacity of these *systems* is less than 1,000,000 Btu/h in Climate Zones 0, 1B, and 2 through 4; less than 1,400,000 Btu/h in Climate Zones 5 through 8; or any size in Climate Zone 1A.
3. *Systems* that include nonparticulate air treatment as required by Standard 62.1, Section 6.2.1.
4. 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 application* needs. This exception does not apply to *computer rooms*.
5. *Systems* that include a condenser heat recovery *system* with a minimum capacity as defined in Section 6.5.6.2.2.
6. *Systems* that serve *residential spaces* where the *system* capacity is less than five times the requirement listed in Table 6.5.1-1.
7. *Systems* that serve *spaces* whose sensible cooling load at *design conditions*, excluding transmission less than or equal to transmission losses at an outdoor temperature of 60°F.
8. *Systems* expected to operate fewer than 20 hours per week.

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Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers [a]

Control Type	Allowed Only in Climate Zone at Listed Set Point	Required High-Limit Set Points (Economizer Off when): Equation	Description
Fixed dry-bulb temperature	0B, 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
	0A, 1A, 2A, 3A, 4A,	$T_{OA} > 65°F$	*Outdoor air* temperature exceeds 65°F
Differential dry-bulb temperature	0B, 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 [b] or $T_{OA} > 75°F$	*Outdoor air* enthalpy exceeds 28 Btu/lb [b] of dry air [b] 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. Devices with selectable rather than adjustable *set points* shall be capable of being set to within 2°F and 2 Btu/lb of the *set point* listed.
b. 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.

9. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework *systems*.
10. For comfort cooling, where the cooling *efficiency* meets or exceeds the *efficiency* improvement requirements in Table 6.5.1-2.
11. *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*.
12. Dedicated *systems* for *computer rooms*, where a minimum of 75% of the design load serves
    a. those *spaces* classified as an *essential facility*,
    b. those *spaces* having a design of Tier IV as defined by ANSI/TIA-942,
    c. those *spaces* classified under NFPA 70 Article 708—*Critical Operations Power Systems (COPS)*, or
    d. those *spaces* where core clearing and settlement *services* are performed such that their failure to settle pending financial transactions could present systemic risk as described in "The Interagency Paper on Sound Practices to Strengthen the Resilience of the U.S. Financial System" (April 7, 2003).

6.5.1.1 Air Economizers

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

6.5.1.1.2 Control Signal. Economizer controls shall be capable of and configured to sequence the dampers with the *mechanical cooling equipment* and shall not be controlled by only mixed-air temperature.

Exception to 6.5.1.1.2: The use of mixed-air temperature limit control shall be permitted for *systems* controlled from *space* temperature (such as *single-zone systems*).

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for sequencing *air economizers* with *mechanical cooling* using supply air (not mixed air) control loops.

6.5.1.1.3 High-Limit Shutoff. All *air economizers* shall be capable of and configured to *automatically* reduce *outdoor air* intake to the design minimum *outdoor air* quantity when *outdoor air* intake will no longer reduce cooling *energy* use. High-limit shutoff control types and associated *set points* for specific climate zones shall be chosen from Table 6.5.1.1.3.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for disabling *air economizers* using all options of high-limit shutoff options with compliant *set points*.

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6.5.1.1.4 Dampers. Exhaust/relief, and *outdoor air* dampers shall meet the requirements of Table 6.4.3.4.3. Return dampers shall meet the requirements of motorized exhaust/relief dampers in Table 6.4.3.4.3.

Exception to 6.5.1.1.4: Exhaust/relief and *outdoor air* intake dampers on *systems* intended to operate continuously.

6.5.1.1.5 Relief of Excess Outdoor Air

a. *Systems* shall provide one of the following means to relieve excess *outdoor air* during *air economizer* operation to prevent overpressurizing the *building*:
   1. Return or relief fan(s) meeting the requirements of Section 6.5.3.2.4.
   2. Barometric or motorized damper relief path with a total pressure drop at design relief airflow rate less than 0.10 in. of water from the occupied *space* to outdoors. Design relief airflow rate shall be the design supply airflow rate minus any continuous exhaust flows, such as toilet exhaust fans, whose makeup is provided by the economizer *system*.
b. 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 Fluid Economizers

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for enabling and controlling *fluid economizers* in water-cooled chilled-water plants.

6.5.1.2.1 Design Capacity. *Fluid economizer systems* shall be capable of 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 to 6.5.1.2.1:

1. *Systems* primarily serving *computer rooms* in which 100% of the expected *system* cooling load at the dry-bulb and wet-bulb temperatures listed in Table 6.5.1.2.1 is met with water-cooled *fluid 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 air-cooled *fluid 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 water-cooled *fluid economizers*.

6.5.1.2.2 Maximum Hydronic Pressure Drop. Precooling coils and fluid-to-water heat exchangers used as part of a *fluid 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 and configured to provide 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 with a rated capacity no less than 65,000 Btu/h 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.
c. 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.

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Table 6.5.1.2.1 Fluid Economizer Sizing Dry-Bulb and Wet-Bulb Requirements for Computer Rooms

Climate Zone		Water Cooled		Air Cooled
		Dry Bulb, °F	Wet Bulb, °F	Dry Bulb, °F
0	A	NR	NR	NR
0	B	NR	NR	NR
1	A	NR	NR	NR
1	B	NR	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

Table 6.5.1.3 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.

6.5.1.4 Economizer Heating System Impact. *HVAC system* design and economizer controls shall be such that economizer operation does not increase the *building* heating *energy* use during normal operation.

Exception to 6.5.1.4: 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 *fluid economizer* if an economizer is required by Section 6.5.1.

6.5.2 Simultaneous Heating and Cooling Limitation

6.5.2.1 Zone Controls. Zone *thermostatic control* 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.

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Exceptions to 6.5.2.1:

1. Zones for which the volume of air that is reheated, *recooled*, or mixed is less than the larger of the following:
   a. For *systems* without *DDC*, 30% of the zone design peak supply.
   b. For *systems* with *DDC*, the minimum primary airflow rate required to meet the Simplified Procedure *ventilation* requirements of ASHRAE Standard 62.1 for the zone, permitted to be the average airflow rate as allowed by ASHRAE Standard 62.1.
   c. Any higher rate that can be demonstrated to the satisfaction of the *authority having jurisdiction* to reduce overall *system* annual *energy* use by offsetting *reheat*/*recool energy* losses through a reduction in *outdoor air* intake for the *system.*
   d. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.
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. The minimum primary airflow rate required to meet the Simplified Procedure *ventilation* requirements of ASHRAE Standard 62.1 for the zone, permitted to be the average airflow rate as allowed by ASHRAE Standard 62.1.
      ii. Any higher rate that can be demonstrated, to the satisfaction of the *authority having jurisdiction*, to reduce overall *system* annual *energy* use by offsetting *reheat*/*recool energy* losses through a reduction in *outdoor air* intake.
      iii. 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 *set point* up to a maximum *set point* 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 6.5.7.3.
4. Zones where at least 75% of the *energy* for *reheating* or for providing warm air in mixing *systems* is provided from *site-recovered energy* (including condenser heat) or *on-site renewable energy*.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for minimizing simultaneous heating and cooling for most types of *VAV system* zone air *terminal* units including the supply air temperature *reheat* limit.

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 the floor shall not supply heating air more than 20°F above the *space* temperature *set point*.

Exceptions to 6.5.2.1.1:

1. Laboratory exhaust *systems* that comply with Section 6.5.7.3.
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.

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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 and configured to provide 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 cooling 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 cooling tower is used directly in the heat-pump loop, an *automatic* valve shall be installed to bypass all heat-pump water flow around the tower. If an open-circuit cooling 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 to 6.5.2.2.3: 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 to 6.5.2.3:

1. The *system* is capable of and 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 and configured to unload 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* comprising 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 application* needs, such as vivariums; museums; surgical suites; pharmacies; and *buildings* with refrigerating *systems*, such as supermarkets, refrigerated warehouses, and ice arenas, and where the *building* includes *site-recovered energy* or *on-site renewable energy* that provides *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 *site-recovered energy* (including condenser heat) or *on-site renewable energy*.
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 to 6.5.2.4.2: *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.

6.5.2.6 Ventilation Air Heating Control. Units that provide *ventilation* air to multiple zones and operate in conjunction with zone heating and cooling *systems* shall not use heating or heat recovery to warm supply air above 60°F when representative *building* loads or *outdoor air* temperature indicate that the majority of zones require cooling.

Exception to 6.5.2.6: Units that heat the airstream using only series *energy recovery* when representative *building* loads or *outdoor air* temperature indicate that the majority of zones require cooling in Climate Zones 0A, 1A, 2A, 3A, and 4A.

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6.5.3 Air System Design and Control

6.5.3.1 Fan System Power and Efficiency

6.5.3.1.1 Each *HVAC system* having a total *fan system motor nameplate horsepower* exceeding 5 hp at *fan system design conditions* shall not exceed the allowable *fan system motor nameplate horsepower* (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 that operate at *fan system design conditions*. Single-zone *VAV systems* shall comply with the constant-volume fan power limitation.

Exceptions to 6.5.3.1.1:

1. Hospital, vivarium, and laboratory *systems* that use flow *control devices* on exhaust and/or 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 Fan Motor Selection

a. For each fan less than 6 *bhp*, the selected fan motor shall be no larger than the first available motor with a *nameplate rating* greater than 1.5 times the *fan bhp*.
b. For each fan 6 *bhp* and larger, the selected fan motor shall be no larger than the first available motor with a *nameplate rating* greater than 1.3 times the *fan bhp*.

The *fan bhp* must be indicated on the design documents to allow for compliance verification by the *building official*.

Exceptions to 6.5.3.1.2:

1. *Motors* equipped with electronic speed *control devices* to vary the fan airflow as a function of load.
2. *Systems* complying with Section 6.5.3.1.1 Option 1.
3. Fans with motor *nameplate horsepower* of less than 1 hp.
4. Fans with a *fan nameplate electrical input power* of less than 0.89 *kW*.

6.5.3.1.3 Fan Efficiency. Each fan and *fan array* shall have a *fan energy index (FEI)* of 1.00 or higher at its highest design airflow rate. Each fan and *fan array* used for a *variable-air-volume system* that meets the requirements of Section 6.5.3.2.1 shall have an *FEI* of 0.95 or higher at its highest design airflow rate. The *FEI* for *fan arrays* shall be calculated in accordance with AMCA 208 Annex C.

Exceptions to 6.5.3.1.3:

1. Fans that are not *embedded fans* with a motor *nameplate horsepower* of less than 1.0 hp or with a *fan nameplate electrical input power* of less than 0.89 *kW*.
2. *Embedded fans* and *fan arrays* with a combined motor *nameplate horsepower* of 5 hp or less or with a *fan system electrical input power* of 4.1 *kW* or less.
3. *Embedded fans* that are part of *equipment* listed under Section 6.4.1.1.
4. *Embedded fans* included in *equipment* bearing a third-party-certified seal for air performance or *energy* performance of the *equipment* package.
5. Ceiling fans.
6. Fans used for moving gases at temperatures above 482°F.
7. Fans used for operation in explosive atmospheres.
8. Reversible fans used for tunnel *ventilation*.
9. Fans outside the scope of AMCA 208.
10. Fans when operating during emergency conditions.

6.5.3.2 Fan Control

6.5.3.2.1 Supply Fan Airflow Control. Each cooling *system* listed in Table 6.5.3.2.1 shall be designed to vary the supply 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

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Table 6.5.3.1-1 Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan *system* motor *nameplate hp*	Allowable motor *nameplate hp*	$hp \leq cfm_S \times 0.0011$	$hp \leq cfm_S \times 0.0015$
Option 2: *fan system bhp*	Allowable *fan system bhp*	$bhp \leq cfm_S \times 0.00094 + A$	$bhp \leq cfm_S \times 0.0013 + A$

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*

bhp = maximum combined fan brake horsepower

A = sum of ($PD \times cfm_D/4131$)

where

PD = each applicable pressure drop adjustment from Table 6.5.3.1-2 in in. of water

cfm_D = the design airflow through each applicable device from Table 6.5.3.1-2 in cubic feet per minute

Table 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Return or exhaust *systems* required by code or accreditation standards to be fully ducted, or *systems* required to maintain air pressure differentials between adjacent rooms.	0.5 in. of water (2.15 in. of water for laboratory and vivarium *systems*)
Return and/or exhaust airflow *control devices*	0.5 in. of water
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. of water
Particulate Filtration Credit: MERV 13 through 15	0.9 in. of water
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	For each airstream [(2.2 × *Enthalpy Recovery Ratio*) – 0.5] in. of water
Coil runaround loop	0.6 in. of water 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. of water
Exhaust *system* serving fume hoods	0.35 in. of water
Laboratory and vivarium exhaust *systems* in high-rise *buildings*	0.25 in. of water/100 ft of vertical duct exceeding 75 ft
Deductions	
Systems without central cooling device	–0.6 in. of water
Systems without central heating device	–0.3 in. of water
Systems with central *electric resistance* heat	–0.2 in. of water

Table 6.5.3.2.1 Fan Airflow Control

Cooling System Type	Fan Motor Size, hp	Mechanical Cooling Capacity, Btu/h
DX cooling	Any	≥65,000
Chilled-water and evaporative cooling	≥1/4	Any

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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 economizer* to meet the requirements of Section 6.5.1 shall have a minimum of two speeds of fan control during economizer operation.

Exceptions to 6.5.3.2.1:

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 if 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.

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 *set point* is no greater than 1.2 in. of water. 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 to 6.5.3.2.2: *Systems* complying with Section 6.5.3.2.3.

6.5.3.2.3 VAV Set-Point Reset. For multiple-zone *VAV systems* having a total *fan system motor nameplate horsepower* exceeding 5 hp with *DDC* of individual zones reporting to the central control panel, static pressure *set point* shall be *reset* based on the zone requiring the most pressure; i.e., the *set point* is *reset* lower until one zone damper is nearly wide open. 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 zones from the *reset* algorithm.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for resetting static pressure *set point* based on *VAV system* zone damper position and other indicators of zone *demand*, including *automatically* detecting and alarming zones that are excessively driving *reset* logic and readily excluding those zones from *reset* logic.

6.5.3.2.4 Return and Relief Fan Control. Return and relief fans used to meet Section 6.5.1.1.5 shall comply with all of the following:

a. Relief air rate shall be controlled to maintain *building* pressure either directly, or indirectly through differential supply-return airflow tracking. *Systems* with constant speed or multispeed supply fans shall also be allowed to *control* the relief *system* based on *outdoor air* damper position.
b. Fans shall have variable-speed control or other devices that will result in total return/relief fan *system demand* of no more than 30% of total design power at 50% of total design fan flow.

Exceptions to 6.5.3.2.4:

1. Return or relief fans with total motor size less than or equal to 0.5 hp.
2. Staged relief fans with a minimum of four stages.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for controlling *building* pressure using economizer relief *systems* such as relief dampers, relief fans, and return fans.

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 ASHRAE Standard 62.1, Normative Appendix A.

Exceptions to 6.5.3.3:

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

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for dynamically adjusting minimum *ventilation* rate *set points* based on ASHRAE Standard 62.1, Normative Appendix A.

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6.5.3.4 Parallel-Flow Fan-Powered VAV Air Terminal Control. Parallel-flow fan-powered *VAV* air *terminals* shall have *automatic* controls configured to

a. turn off the *terminal* fan except when *space* heating is required or if required for *ventilation*;
b. turn on the *terminal* fan as the first stage of heating before the heating coil is activated; and
c. during heating for *warm-up* or *setback* temperature control, either
   1. operate the *terminal* fan and heating coil without primary air or
   2. reverse the *terminal* damper logic and provide heating from the central air handler through primary air.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for both constant-speed and variable-speed parallel fan-powered *VAV* air *terminal* units.

6.5.3.5 Supply Air Temperature Reset Controls. Multiple zone *HVAC systems* shall include controls that are capable of and configured to *automatically reset* the supply air temperature in response to representative *building* loads or *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 in Climate Zones 0B, 1B, 2B, 3B, 3C, and 4 through 8. *HVAC zones* that are expected to experience relatively constant loads shall have maximum airflow designed to accommodate the fully *reset* supply air temperature.

Exceptions to 6.5.3.5:

1. Systems in Climate Zones 0A, 1A, and 3A with less than 3000 cfm of design *outdoor air*.
2. *Systems* in Climate Zone 2A with less than 10,000 cfm of design *outdoor air*.
3. *Systems* in Climate Zones 0A, 1A, 2A, and 3A with at least 80% *outdoor air* and employing exhaust air *energy* recovery complying with Section 6.5.6.1.
4. *Systems* that prevent *reheating*, *recooling*, or mixing of heated and cooled supply air.
5. *Systems* in which at least 75% of the *energy* for *reheating* (on an annual basis) is from *site recovered energy* or *on-site renewable energy*.

Informative Notes:

1. *HVAC zones* that are expected to experience relatively constant loads typically include electronic *equipment* rooms and interior zones.
2. ASHRAE Guideline 36 includes detailed sequences of control for resetting supply air temperature *set point* on multiple zone air handling units based on both zone air *terminal* unit *demand* and *outdoor air* temperature.

6.5.3.5.1 Dehumidification Control Interaction. In Climate Zones 0A, 1A, 2A, and 3A, the *system* design shall allow supply air temperature *reset* while dehumidification is provided. When dehumidification control is active, *air economizers* shall be locked out.

Informative Note: Examples of *HVAC systems* that can allow supply air temperature *reset* while dehumidifying include cooling of *outdoor air* with a separate cooling coil, bypassing return air around the cooling coil, a dedicated *outdoor air system*, and series *energy* recovery.

6.5.3.6 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 to 6.5.3.6:

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 10.8-3 or 10.8-4.

6.5.3.7 Low Power Fans. Fans that are not covered by Section 6.5.3.6 and having a *fan nameplate electrical input power* of less than 180 W, or having a motor *nameplate horsepower* less than 1/12 hp, shall meet the fan efficacy requirements of Table 6.5.3.7 at one or more rating points.

Exceptions to 6.5.3.7:

1. Fans in *space*-conditioning *equipment*.
2. Intermittently operating dryer exhaust duct power ventilators, domestic range hoods, and domestic range booster fans.
3. Fans in radon mitigation *systems*.
4. Fans not covered within the scope of the test methods referenced in Table 6.5.3.7.
5. Ceiling fans regulated under 10 CFR 430 Appendix U.

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Table 6.5.3.7 Minimum Fan Efficacy for Low-Power Fans

System Type	Minimum Fan Efficacy [a, b], cfm/W	Test Method and Rating Conditions
HRV [c], ERV [d], or other system with exhaust air *energy* recovery	1.2	CAN/CSA 439-18
Transfer fans; in-line [e] supply or exhaust fan	3.8	ASHRAE Standard 51
Other exhaust fan, <90 cfm	2.8	
Other exhaust fan, ≥90 cfm and ≤200 cfm	3.5	
Other exhaust fan, >200 cfm	4.0	

a. Fan efficacy is the volumetric fan airflow rate divided by total fan motor electrical input power at a specified static pressure difference.
b. Fans shall be tested in accordance with the referenced test method. Fan efficacy shall be reported in the product listing or shall be derived from the fan motor electrical input power and airflow values reported in the product listing or on the label. Fan efficacy for fully ducted HRV or ERV, balanced, and in-line fans shall be determined at a static pressure difference not less than 0.2 in. of water for each airstream. Fan efficacy for other ducted fan systems shall be determined at a static pressure difference not less than 0.1 in. of water.
c. A heat recovery ventilator (HRV) is a mechanically powered ventilating device with separate intake and exhaust airstreams and a heat exchanger to transfer a portion of the sensible energy, heat, from one airstream to the other.
d. An energy recovery ventilator (ERV) is a mechanically powered ventilating device with separate intake and exhaust airstreams and a heat exchanger to transfer a portion of the total energy, heat and moisture, from one airstream to the other.
e. An in-line fan is an exhaust or supply fan installed with ductwork on both the fan inlet and outlet.

6.5.3.8 Ventilation Design. The required minimum *outdoor air* rate is the larger of the minimum *outdoor air* rate or the minimum exhaust air rate required by Standard 62.1, Standard 62.2, Standard 170, or applicable codes or accreditation standards. *Outdoor air ventilation systems* shall comply with one of the following:

a. Design minimum *system outdoor air* provided shall not exceed 135% of the required minimum *outdoor air* rate.
b. Dampers, *ductwork*, and controls shall be provided that allow the *system* to supply no more than the required minimum *outdoor air* rate with a single *set-point* adjustment.
c. The *system* includes exhaust air *energy* recovery complying with Section 6.5.6.1.

6.5.3.9 Occupied-Standby Zone Controls. Zones serving only rooms that are required to have *automatic* partial OFF or *automatic* full OFF lighting controls per Section 9.4.1.1, where the ASHRAE Standard 62.1 occupancy category permits *ventilation* air to be reduced to zero when the *space* is in *occupied-standby mode* and when using the Ventilation Rate Procedure, shall meet the following within five minutes of all rooms in that zone entering *occupied-standby mode*.

a. Active heating *set point* shall be *setback* at least 1°F.
b. Active cooling *set point* shall be set up at least 1°F.
c. All airflow supplied to the zone shall be shut off whenever the *space* temperature is between the active heating and cooling *set points*.

Exception to 6.5.3.9: Multiple zone *systems* without *automatic* zone flow control dampers.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for occupied standby controls of zone air *terminal* units.

6.5.3.9.1 Occupied-Standby Control of Multiple-Zone Systems. Multiple-zone *systems* that are capable of resetting the minimum *outdoor air set point* and that serve zones with occupied-standby zone controls shall *reset* the minimum *outdoor air set point* based on a zone *outdoor air* requirement of zero for all zones in *occupied-standby mode*.

Informative Note: ASHRAE Guideline 36 includes sequences for this *reset*.

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.

6.5.4.2 Hydronic Variable Flow Systems. Chilled- and hot-water *distribution systems* that include three or more 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 and configured to reduce *pump* flow rates to no more than the larger of 25% of the design flow rate or the minimum flow required by the heating/cooling *equip-*

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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

Table 6.5.4.2 Pump Flow Control Requirements

Chilled-Water Pumps in These Climate Zones	Heating Water Pumps in These Climate Zones	Motor Nameplate Horsepower
0A, 0B, 1A, 1B, 2B	NR	≥2 hp
2A, 3B	NR	≥3 hp
3A, 3C, 4A, 4B	7, 8	≥5 hp
4C, 5A, 5B, 5C, 6A, 6B	3C, 5A, 5C, 6A, 6B	≥7.5 hp
	4A, 4C, 5B	≥10 hp
7, 8	4B	≥15 hp
	2A, 2B, 3A, 3B	≥25 hp
	1B	≥100 hp
	0A, 0B, 1A	≥200 hp

ment manufacturer for the proper operation of *equipment*. Individual or parallel *pumps* serving variable-flow heating-water or chilled-water *systems*, where the *nameplate horsepower* of the motor or combined parallel motors is at least the power shown in Table 6.5.4.2, shall have controls or devices 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 *set point* 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 *set point* shall be *reset* downward based on valve positions until one valve is nearly wide open.

Exceptions to 6.5.4.2:

1. Differential pressure *set-point reset* is not required where valve position is used to comply with Section 6.5.4.4.
2. Variable-*pump* flow control is not required on heating-water *pumps* where more than 50% of annual heat is generated by an electric *boiler*.
3. Variable flow is not required for primary *pumps* in a primary/secondary *system*.
4. Variable flow is not required for a coil *pump* provided for freeze protection.
5. Variable flow is not required for heat recovery coil runaround loops.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control of variable flow hydronic *systems*, including resetting differential pressure *set point* based on control valve position.

6.5.4.3 Chiller and Boiler Isolation

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for chiller and *boiler* flow isolation and staging.

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

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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 to 24 in. in size	8.5 ft/s	13.0 ft/s	6.5 ft/s	9.5 ft/s	5.0 ft/s	7.5 ft/s

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 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. Where *DDC* is used to *control* valves, the *set point* shall be *reset* based on valve positions until one valve is nearly wide open or *set-point* limits of the *system equipment* or application have been reached.

Exceptions to 6.5.4.4:

1. Where chilled-water supply is already cold, such as chilled water supplied from a district cooling or thermal *energy* storage *system*, such that blending would be required to achieve the *reset* chilled-water supply temperature.
2. Where a specific temperature is required for a *process application*.
3. Water temperature *reset* is not required where valve position is used to comply with Section 6.5.4.2.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for resetting chilled-water and hot-water *system* temperature *set points* based on control valve position.

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 to 6.5.4.5.1: Units employing a *fluid 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 to 6.5.4.6:

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.

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6.5.4.7 Chilled-Water Coil Selection. Chilled-water cooling coils shall be selected to provide a 15°F or higher temperature difference between leaving and entering water temperatures and a minimum of 57°F leaving water temperature at *design conditions*.

Exceptions to 6.5.4.7:

1. Chilled-water cooling coils that have an air-side pressure drop exceeding 0.70 in. of water when rated at 500 fpm face velocity and dry conditions (no condensation).
2. Individual fan-cooling units with a design supply airflow rate 5000 cfm and less.
3. Constant-air-volume *systems*.
4. Coils selected at the maximum temperature difference allowed by the chiller.
5. Passive coils (no mechanically supplied airflow).
6. Coils with design entering chilled-water temperatures of 50°F and higher.
7. Coils with design entering air dry-bulb temperatures of 65°F and lower.

6.5.4.8 Buildings with High-Capacity Space-Heating Gas Boiler Systems. New *buildings* with gas hot-water *boiler systems* for *space* heating with a total *system* input of at least 1,000,000 Btu/h but not more than 10,000,000 Btu/h shall comply with Sections 6.5.4.8.1 and 6.5.4.8.2.

Exceptions to 6.5.4.8:

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

6.5.4.8.1 Boiler Efficiency. Gas hot-water *boilers* shall have a minimum thermal *efficiency* (E_t) of 90% when rated in accordance with the test procedures in Table 6.8.1-6. Systems with multiple *boilers* are allowed to meet this requirement if the *space* 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%. For *boilers* rated only for combustion *efficiency*, the calculation for the input capacity-weighted average thermal *efficiency* shall use the combustion *efficiency* value.

6.5.4.8.2 Hot-Water Distribution System Design. The hot-water *distribution system* shall be designed to meet all of the following:

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

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 to 6.5.5.1: Heat-rejection devices whose *energy* use is included in the *equipment efficiency* ratings listed in Tables 6.8.1-1 through 6.8.1-4, Tables 6.8.1-8 through 6.8.1-14, and Tables 6.8.1-16, 6.8.1-17, and 6.8.1-20.

6.5.5.2 Fan Speed Control

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for staging and controlling variable-speed cooling tower cells and fans.

6.5.5.2.1 The fan *system* on a heat-rejection device powered by an individual motor or an array of motors with a connected power, including the motor service factor, totaling 5 hp or more shall have controls and/or devices (such as variable-speed control) that shall result in fan motor *demand* of no more than 30% of design wattage at 50% of the design airflow and that shall *automatically* modulate the fan speed to *control* the leaving fluid temperature or condensing temperature/pressure of the heat-rejection device.

Exceptions to 6.5.5.2.1:

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

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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 *energy efficiency* requirement for axial fan open-circuit cooling towers listed in Table 6.8.1-7.

Exception to 6.5.5.3: 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

6.5.6.1.1 Nontransient Dwelling Units. *Nontransient dwelling units* shall be provided with *outdoor air energy* recovery *ventilation systems*. For *nontransient dwelling units*, *energy* recovery *systems* shall result in an *enthalpy recovery ratio* of at least 50% at the cooling design condition.

At the heating design condition, *energy* recovery performance shall be as follows:

a. Where active humidification is provided to *spaces* served by the *system*, *energy* recovery *systems* shall result in an *enthalpy recovery ratio* of at least 60%.
b. Where active humidification is not provided to *spaces* served by the *system*, *energy* recovery *systems* shall result in a *sensible energy recovery ratio* of at least 60%.

The *energy* recovery *system* shall provide the required *enthalpy recovery ratio* or *sensible energy recovery ratio* at both heating and cooling *design conditions*, unless one mode is not required for the climate zone by the exceptions below.

Exceptions to 6.5.6.1.1:

1. *Nontransient dwelling units* in Climate Zone 3C.
2. *Nontransient dwelling units* with no more than 500 ft^2 of *gross conditioned floor area* in Climate Zone 0, 1, 2, 3, 4C, and 5C.
3. *Energy* recovery performance requirements at heating design condition in Climate Zones 0, 1, and 2.
4. *Enthalpy recovery ratio* requirements at cooling design condition in Climate Zones 4, 5, 6, 7, 8.

6.5.6.1.2 Spaces Other than Nontransient Dwelling Units. Each fan *system* serving *spaces* other than *nontransient dwelling units* shall have an *energy* recovery *system* where the design supply fan airflow rate exceeds the value listed in Tables 6.5.6.1.2-1 and 6.5.6.1.2-2, based on the climate zone and percentage of *outdoor air* at design airflow conditions. Table 6.5.6.1.2-1 shall be used for all *ventilation systems* that operate less than 8000 hours per year, and Table 6.5.6.1.2-2 shall be used for all *ventilation systems* that operate 8000 or more hours per year.

Exceptions to 6.5.6.1.2:

1. Laboratory *systems* meeting Section 6.5.7.3.
2. *Systems* serving *spaces* that are not cooled and that are heated to less than 60°F.
3. Heating *energy* recovery where more than 60% of the *outdoor air* heating *energy* is provided from *site-recovered energy* or *on-site renewable energy* in Climate Zones 5 through 8.
4. *Enthalpy recovery ratio* requirements at heating design condition in Climate Zones 0, 1, and 2.
5. *Enthalpy recovery ratio* requirements at cooling design condition in Climate Zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
6. Where the sum of the airflow rates exhausted and relieved within 20 ft of each other is less than 75% of the design outdoor airflow rate, excluding exhaust air that is
   a. used for another *energy* recovery *system*,

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Table 6.5.6.1.2-1 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Less than 8000 Hours per Year

	% 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%
Climate Zone	**Design Supply Fan Airflow Rate, cfm**							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B,5C	NR	NR	NR	NR	≥26,000	≥12,000	≥5000	≥4000
6B	≥28,000	≥26,500	≥11,000	≥5500	≥4500	≥3500	≥2500	≥1500
0A, 1A, 2A, 3A, 4A, 5A, 6A	≥26,000	≥16,000	≥5500	≥4500	≥3500	≥2000	≥1000	≥120
7,8	≥4500	≥4000	≥2500	≥1000	≥140	≥120	≥100	≥80

NR—Not required

Table 6.5.6.1.2-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year

	% 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%
Climate Zone	**Design Supply Fan Airflow Rate, cfm**							
3C	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	≥120
0A, 1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	≥140	≥120	≥100	≥80
4A, 5A, 6A, 6B, 7, 8	≥200	≥130	≥100	≥80	≥70	≥60	≥50	≥40

NR—Not required

   b. not allowed by ASHRAE/ASHE Standard 170 for use in *energy* recovery *systems* with leakage potential, or
   c. of Class 4 as defined in ASHRAE Standard 62.1.

7. *Systems* in Climate Zones 0 through 4 requiring dehumidification that employ *series energy recovery* and have a minimum *SERR* of 0.40.
8. *Systems* expected to operate less than 20 hours per week at the *outdoor air* percentage covered by Table 6.5.6.1.2-1.
9. *Indoor pool dehumidifiers* meeting Section 6.5.6.4.

6.5.6.1.2.1 Minimum Enthalpy Recovery Ratio. *Energy* recovery *systems* required by this section shall result in an *enthalpy recovery ratio* of at least 50% at the cooling design condition.

At the heating design condition, *energy* recovery performance shall be as follows:

a. Where active humidification is provided to *spaces* served by the *system*, *energy* recovery *systems* shall result in an *enthalpy recovery ratio* of at least 50%.
b. Where active humidification is not provided to *spaces* served by the *system*, *energy* recovery *systems* shall result in a *sensible energy recovery ratio* of at least 50%.

The *energy* recovery *system* shall provide the required *enthalpy recovery ratio* or *sensible energy recovery ratio* at both heating and cooling *design conditions* unless one mode is not required for the climate zone by the exception to Section 6.5.6.1.2.

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6.5.6.1.2.2 Provision for Air Economizer or Bypass Operation. Provision shall be made for both *outdoor air* and exhaust air to bypass or *control* the *energy* recovery *system* to enable *economizer* operation as required by Section 6.5.1.1. The bypass or *control* shall meet the following criteria:

a. For *energy* recovery *systems* where the transfer of *energy* cannot be stopped, bypass provision shall prevent the total airflow rate of either *outdoor air* or exhaust air through the *energy* recovery exchanger from exceeding 10% of the full design airflow rate.
b. The pressure drop of the *outdoor air* through the *energy* recovery exchanger shall not exceed 0.4 in. of water; the pressure drop of the exhaust air through the *energy* recovery exchanger shall not exceed 0.4 in. of water.

Exception to 6.5.6.1.2.2: *Energy* recovery *systems* with 80% or more *outdoor air* at full design airflow rate and not exceeding 10,000 cfm.

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 to 6.5.6.2.2:

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

6.5.6.3 Heat Recovery for Space Conditioning. Where heating water is used for *space* heating, a heat-pump chiller meeting the requirements of Table 6.8.1-16 for heat recovery that uses the cooling *system* return water as the heat source shall be installed, provided all of the following are true:

a. The *building* is an acute inpatient hospital, where the *building* or portion of a *building* is used on a 24-hour basis for the inpatient medical, obstetric, or surgical care for patients.
b. The total design chilled-water capacity for the acute inpatient hospital, either air cooled or water cooled, required at cooling *design conditions* exceeds 3,600,000 Btu/h of cooling.
c. Simultaneous heating, including *reheat*, and cooling occurs above 60°F *outdoor air temperature.*

The required heat recovery *system* shall have a cooling capacity that is at least 7% of the total design chilled-water capacity of the acute inpatient hospital at peak *design conditions*.

Exception to 6.5.6.3: Buildings in Climate Zones 5C, 6B, 7, and 8.

6.5.6.4 Indoor Pool Dehumidifier Energy Recovery. An *indoor pool dehumidifier* serving a natatorium with a heated indoor *pool* over 500 ft^2 in size shall include one of the following:

a. An exhaust air sensible *energy* recovery *system* with a *sensible energy recovery ratio* of at least 50%
b. A condenser heat recovery *system* capable of and configured to use 100% of the heat generated through dehumidification to heat the *pool* water when there is a *pool* water heating load
c. An exhaust air *energy* recovery *system* that results in an *enthalpy recovery ratio* of at least 50%

Exception to 6.5.6.4: Natatoriums heated by *on-site renewable energy* or *site recovered energy* capable of and configured to provide at least 60% of the annual heating *energy* required.

6.5.7 Exhaust Systems

6.5.7.1 Transfer Air. Conditioned supply air delivered to any *space* with mechanical exhaust shall not exceed the greater of

a. the supply flow required to meet the *space* heating or cooling load;
b. the *ventilation* rate required by the *authority having jurisdiction*, the facility Environmental Health and Safety department, or ASHRAE Standard 62.1; or

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Table 6.5.7.2.2 Maximum Net Exhaust Flow Rate, cfm per Linear Foot of Hood Length

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

NA = Not allowed

c. the mechanical exhaust flow minus the available *transfer air* from *conditioned spaces* or return air *plenums* on the same *story*, not in different smoke or fire compartments, and that at their closest point are within 15 ft of each other. Available *transfer air* is that portion of outdoor *ventilation* air that
   1. is not required to satisfy other exhaust needs,
   2. is not required to maintain pressurization of other *spaces*, and
   3. is transferable according to applicable codes and standards and to the class of air recirculation limitations in ASHRAE Standard 62.1.

Exceptions to 6.5.7.1:

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

6.5.7.2 Kitchen Exhaust Systems

6.5.7.2.1 *Replacement air* introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10% of the hood exhaust airflow rate.

6.5.7.2.2 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5000 cfm then each hood shall have an exhaust rate that complies with Table 6.5.7.2.2. If a single hood or hood section is installed over appliances with different duty ratings then the maximum allowable flow rate for the hood or hood section shall not exceed the Table 6.5.7.2.2 values 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 to 6.5.7.2.2: At least 75% of all the *replacement air* is *transfer air* that would otherwise be exhausted.

6.5.7.2.3 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5000 cfm then it shall have one of the following:

a. At least 50% of all *replacement air* is *transfer air* that would otherwise be exhausted.
b. *Demand ventilation systems* on at least 75% of the exhaust air. Such *systems* shall be capable of and configured to provide at least 50% reduction in exhaust and *replacement air system* airflow rates, including controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent, and combustion products during cooking and idle.
c. Listed *energy* recovery devices that result in a *sensible energy recovery ratio* of not less than 40% on at least 50% of the total exhaust airflow. A 40% *sensible energy recovery ratio* shall mean a change in the dry-bulb temperature of the *outdoor air* supply equal to 40% of the difference between the *outdoor air* and entering exhaust air dry-bulb temperatures at *design conditions*.

6.5.7.2.4 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

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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%

exhaust *systems*. Where *demand ventilation systems* are used to meet Section 6.5.7.2.3, additional performance testing shall be required to demonstrate proper capture and containment at minimum airflow.

6.5.7.3 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 and configured to reduce 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 = *sensible energy recovery ratio*

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 and configured to reduce zone exhaust and makeup airflow rates to the regulated minimum circulation values or the minimum required to maintain pressurization relationship requirements. *Systems* serving nonregulated zones shall be capable of and configured to reduce 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 *set point*, cooled to no cooler than 3°F above room *set point*, 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 to 6.5.8.1: Loading docks equipped with air curtains.

6.5.8.2 Heating Enclosed Spaces. *Radiant heating systems* that are used as primary or supplemental *heating for enclosed spaces* 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. Hot-gas bypass shall not be used on constant-volume units.

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 *set point* to 55°F or lower within five minutes of the *door* opening and
b. disable *mechanical cooling* or *reset* the cooling *set point* to 90°F or greater within five minutes of the *door* opening. *Mechanical cooling* may remain enabled if *outdoor air* temperature is below *space* temperature.

Exceptions to 6.5.10:

1. *Building* entries with *automatic* closing devices.
2. Any *space* without a *thermostat*.

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3. *Alterations* to *existing buildings*.
4. Loading docks.

6.5.11 Refrigeration Systems. Refrigeration *systems* that comprise 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 and 6.5.11.2.

Exception to 6.5.11: *Systems* using 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 *set-point* control logic to *reset* the condensing temperature *set point* in response to ambient dry-bulb temperature.
   2. Refrigeration *system* condenser control for evaporatively cooled condensers shall use variable *set-point* control logic to *reset* the condensing temperature *set point* in response to ambient wet-bulb temperature.
d. Multiple fan condensers shall be controlled in unison.
e. The minimum condensing temperature *set point* 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 to 6.5.11.2(a):
   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 *set point* 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.

6.6 Alternative Compliance Path

6.6.1 Computer Rooms Systems Path. The Computer Room System Path is an optional path for compliance where the following conditions are met:

a. *HVAC systems* that only serve the heating, cooling, or ventilating needs of a *computer room* with IT *equipment* load greater than 10 *kW* shall comply with ASHRAE Standard 90.4, *Energy Standard for Data Centers*.
b. All other *HVAC systems* shall comply with the applicable requirements in Section 6.5.

6.6.2 Mechanical System Performance Path

6.6.2.1 Scope. The Mechanical System Performance Path is an optional path for compliance where the following conditions are met:

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Table 6.6.2.2 Mechanical Performance Factors (MPF)

Building Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium)[a]	0.72	0.71	0.70	0.70	0.68	0.65	0.71	0.66	0.62	0.69	0.64	0.65	0.72	0.66	0.65	0.74	0.70	0.75	0.77
Office (large)[a]	0.83	0.83	0.84	0.84	0.79	0.82	0.72	0.84	0.78	0.69	0.80	0.67	0.72	0.75	0.67	0.73	0.73	0.71	0.70
Retail	0.60	0.57	0.50	0.55	0.46	0.46	0.43	0.46	0.38	0.40	0.45	0.48	0.41	0.50	0.47	0.44	0.39	0.40	0.36
Hotel/motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.71	0.73	0.59	0.66	0.65	0.55	0.59	0.68	0.51	0.54	0.47	0.40
Multifamily/ dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.68	0.54	0.59	0.57	0.52	0.58	0.53	0.48	0.57	0.53	0.55	0.52
School/education	0.82	0.81	0.80	0.79	0.75	0.72	0.71	0.72	0.68	0.67	0.71	0.65	0.72	0.68	0.60	0.75	0.69	0.72	0.68

a. Office sizes defined in Section L1.1.1.1.

a. All *HVAC systems* in the *building* that meet the criteria in Section L1.1.1 shall comply with Section 6.6.2.2.
b. All other HVAC *systems* shall comply with one of the following:
   1. HVAC *systems* shall comply with the applicable requirements in Section 6.5.
   2. *HVAC systems* that only serve the heating, cooling, or ventilating needs of a *computer room* with IT *equipment* load greater than 10 kW shall be permitted to comply with ANSI/ASHRAE Standard 90.4, *Energy Standard for Data Centers*.

6.6.2.2 Criteria. *HVAC systems* in new *buildings*, *additions*, or *alterations* shall comply with the requirements in Section L2, "Mechanical System Performance Rating Method." The *proposed design total system performance ratio* ($TSPR_p$) of the *HVAC systems* using this method shall be greater than or equal to the *total system performance ratio* of the *TSPR reference building design* ($TSPR_r$) divided by the mechanical performance factor (MPF) when calculated in accordance with the following:

$$TSPR_p > TSPR_r/\text{MPF}$$

where

$TSPR_p$ = proposed *TSPR* calculated in accordance with Normative Appendix L
$TSPR_r$ = reference *TSPR* calculated in accordance with Normative Appendix L
MPF = mechanical performance factor from Table 6.6.2.2 based on climate zone and *building* use type

Where a *building* has multiple *building* use types, MPF shall be area weighted as follows:

$$\text{MPF} = (A_1 \times \text{MPF}_1 + A_2 \times \text{MPF}_2 + \ldots + A_n \times \text{MPF}_n)/(A_1 + A_2 + \ldots + A_n)$$

where

$\text{MPF}_1, \text{MPF}_2, \ldots, \text{MPF}_n$ = mechanical performance factors from Table 6.6.2.2 based on climate zone and *building* use types 1 through *n*
$A_1, A_2, \ldots, A_n$ = *gross conditioned floor areas* for *building* use types 1 through *n*

Informative Note: The Mechanical System Performance Rating Method is a simplified performance trade-off approach for *HVAC systems* that does not require using the whole-*building* trade-off approaches in Section 12 or Normative Appendix G. *HVAC systems* that are allowed to use this approach will not need to comply with all of the prescriptive requirements in Section 6.5. For example, an *HVAC system* without a required *outdoor air economizer* can show compliance with Section 6 by demonstrating improved cooling *efficiency* or reduced fan *energy* use compared to a reference *HVAC system* that meets all prescriptive requirements, including *outdoor air economizers*. This approach does not allow *HVAC system efficiency* trade-offs with *building envelope,* plug loads, or *lighting systems*.

6.7 Submittals

6.7.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

6.7.2 Permit Application Documentation (Not Used)

6.7.3 Completion Requirements

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6.7.3.1 Record Documents. *Construction documents* shall require that, within 90 days after the date of *system* acceptance, *record documents* be provided to the *building* owner or the designated representative of the *building* owner. *Record documents* 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.

6.7.3.2 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 *set points* 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 *set points*.

6.7.3.3 System Balancing

6.7.3.3.1 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.

6.7.3.3.2 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.

6.7.3.3.3 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 to 6.7.3.3.3: 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.

6.8 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 Piping Insulation Tables. Hot-water heating, steam heating, and steam condensate *piping* shall be insulated to the minimum thickness required in Tables 6.8.3-1 and 6.8.3-2 and shall either utilize insulation within the *thermal conductivity* ranges in the tables, or, when the insulation *thermal conductivity* is not within the range in the tables, the following equation shall be used to calculate the minimum insulation thickness:

$$t_{alt} = r[(1 + t_{table}/r) \times k_{alt}/k_{upper} - 1]$$

where

t_{alt}	=	minimum insulation thickness of the alternate material, in.
r	=	actual outside radius of pipe, in.
t_{table}	=	insulation thickness listed in Table 6.8.3-1 or Table 6.8.3-2 for applicable fluid temperature and pipe size
k_{alt}	=	*thermal conductivity* of the alternate material at mean rating temperature indicated for the applicable fluid temperature, $Btu \cdot in/h \cdot ft^2 \cdot °F$
k_{upper}	=	upper value of the *thermal conductivity* range listed in this table for the applicable fluid temperature, $Btu \cdot in/h \cdot ft^2 \cdot °F$

Exception to 6.8.3: For nonmetallic *piping* thicker than Schedule 80 and having *thermal resistance* greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is pro-

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vided 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 tables.

6.9 Verification, Testing, and Commissioning

6.9.1 Verification and Testing. HVAC control *systems* shall be tested in accordance with this section and Section 4.2.5.1. Testing shall verify that *systems* and control elements are calibrated, adjusted, configured, and operating in accordance with applicable requirements of Sections 6.3, 6.4, and 6.5. *FPT* and verification documentation shall comply with Section 4.2.5.1.2.

6.9.2 Commissioning. The performance of the *mechanical systems* shall be commissioned in accordance with Section 4.2.5.2. *Commissioning* reporting shall comply with Section 4.2.5.2.2.

Informative Note: See Informative Appendix E for *commissioning* references.

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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*, three phase and applications outside U.S. single phase [b]	13.0 *SEER* before 1/1/2023 13.4 *SEER2* after 1/1/2023	AHRI210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single-package, three phase and applications outside U.S. single phase [b]	14.0 *SEER* before 1/1/2023 13.4 *SEER2* after 1/1/2023	
Space constrained, air cooled	≤30,000 Btu/h[b]	All	Split *system*, three phase and applications outside U.S. single phase [b]	12.0 *SEER* before 1/1/2023 11.7 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase [b]	12.0 *SEER* before 1/1/2023 11.7 *SEER2* after 1/1/2023	
Small duct, high velocity, air cooled	<65,000 Btu/h[b]	All	Split *system*, three phase and applications outside U.S. single phase [b]	12.0 *SEER* before 1/1/2023 12.0 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
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* before 1/1/2023 14.8 *IEER* after 1/1/2023	AHRI 340/360
		All other		11.0 *EER* 12.7 *IEER* before 1/1/2023 14.6 *IEER* after 1/1/2023	
	≥135,000 Btu/h and <240,000 Btu/h	*Electric resistance* (or none)		11.0 *EER* 12.4 *IEER* before 1/1/2023 14.2 *IEER* after 1/1/2023	
		All other		10.8 *EER* 12.2 *IEER* before 1/1/2023 14.0 *IEER* after 1/1/2023	

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, U.S. air-cooled air conditioners <65,000 Btu/h are regulated as consumer products by the U.S. *Code of Federal Regulations* 10 CFR 430. *SEER* and *SEER2* values for single-phase products are set by the U.S. Department of Energy.
Informative Note: See Informative Appendix F for the U.S. Department of Energy minimum *efficiency* requirements of single-phase air conditioners for U.S. applications.

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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 (continued)	≥240,000 Btu/h and <760,000 Btu/h	*Electric resistance* (or none)	Split *system* and single package	10.0 *EER* 11.6 *IEER* before 1/1/2023 13.2 *IEER* after 1/1/2023	AHRI 340/360
		All other		9.8 *EER* 11.4 *IEER* before 1/1/2023 13.0 *IEER* after 1/1/2023	
	≥760,000 Btu/h	*Electric resistance* (or none)		9.7 *EER* 11.2 *IEER* before 1/1/2023 12.5 *IEER* after 1/1/2023	
		All other		9.5 *EER* 11.0 *IEER* before 1/1/2023 12.3 *IEER* after 1/1/2023	
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)		12.1 *EER* 13.9 *IEER*	AHRI 340/360
		All other		11.9 *EER* 13.7 *IEER*	
	≥135,000 Btu/h and <240,000 Btu/h	*Electric resistance* (or none)		12.5 *EER* 13.9 *IEER*	
		All other		12.3 *EER* 13.7 *IEER*	
	≥240,000 Btu/h and <760,000 Btu/h	*Electric resistance* (or none)		12.4 *EER* 13.6 *IEER*	
		All other		12.2 *EER* 13.4 *IEER*	
	≥760,000 Btu/h	*Electric resistance* (or none)		12.2 *EER* 13.5 *IEER*	
		All other		12.0 *EER* 13.3 *IEER*	

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, U.S. air-cooled air conditioners <65,000 Btu/h are regulated as consumer products by the U.S. *Code of Federal Regulations* 10 CFR 430. *SEER* and *SEER2* values for single-phase products are set by the U.S. Department of Energy.
Informative Note: See Informative Appendix F for the U.S. Department of Energy minimum *efficiency* requirements of single-phase air conditioners for U.S. applications.

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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)		12.1 *EER* 12.3 *IEER*	AHRI 340/360
		All other		11.9 *EER* 12.1 *IEER*	
	≥135,000 Btu/h and <240,000 Btu/h	*Electric resistance* (or none)		12.0 *EER* 12.2 *IERR*	
		All other		11.8 *EER* 12.0 *IEER*	
	≥240,000 Btu/h and <760,000 Btu/h	*Electric resistance* (or none)		11.9 *EER* 12.1 *IEER*	
		All other		11.7 *EER* 11.9 *IEER*	
	≥760,000 Btu/h	*Electric resistance* (or none)		11.7 *EER* 11.9 *IEER*	
		All other		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*	AHRI 365
Condensing units, evaporatively cooled	≥135,000 Btu/h			13.5 *EER* 14.0 *IEER*	AHRI 365

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, U.S. air-cooled air conditioners <65,000 Btu/h are regulated as consumer products by the U.S. *Code of Federal Regulations* 10 CFR 430. *SEER* and *SEER2* values for single-phase products are set by the U.S. Department of Energy.

Informative Note: See Informative Appendix F for the U.S. Department of Energy minimum *efficiency* requirements of single-phase air conditioners for U.S. applications.

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Table 6.8.1-2 Electrically Operated Air-Cooled Unitary Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air cooled (cooling mode)	<65,000 Btu/h	All	Split *system*, three phase and applications outside U.S. single phase[b]	14.0 *SEER* before 1/1/2023 14.3 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	14.0 *SEER* before 1/1/2023 13.4 *SEER2* after 1/1/2023	
Space constrained, air cooled (cooling mode)	≤30,000 Btu/h	All	Split *system*, three phase and applications outside U.S. single phase[b]	12.0 *SEER* before 1/1/2023 11.7 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	12.0 *SEER* before 1/1/2023 11.7 *SEER2* after 1/1/2023	
Small duct, high velocity, air cooled (cooling mode)	<65,000 Btu/h	All	Split *System*, three phase and applications outside U.S. single phase[b]	12.0 *SEER* before 1/1/2023 12.0 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Air cooled (cooling mode)	≥65,000 Btu/h and <135,000 Btu/h	*Electric resistance* (or none)	Split *system* and single package	11.0 *EER* 12.2 *IEER* before 1/1/2023 14.1 *IEER* after 1/1/2023	AHRI 340/360
		All other		10.8 *EER* 12.0 *IEER* before 1/1/2023 13.9 *IEER* after 1/1/2023	
	≥135,000 Btu/h and <240,000 Btu/h	*Electric resistance* (or none)		10.6 *EER* 11.6 *IEER* before 1/1/2023 13.5 *IEER* after 1/1/2023	
		All other		10.4 *EER* 11.4 *IEER* before 1/1/2023 13.3 *IEER* after 1/1/2023	
	≥240,000 Btu/h	*Electric resistance* (or none)		9.5 *EER* 10.6 *IEER* before 1/1/2023 12.5 *IEER* after 1/1/2023	
		All other		9.3 *EER* 10.4 *IEER* before 1/1/2023 12.3 *IEER* after 1/1/2023	

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, U.S. air-cooled heat pumps <65,000 Btu/h are regulated as consumer products by the U.S. *Code of Federal Regulations* 10 CFR 430. *SEER, SEER2*, and *HSPF* values for single-phase products are set by the U.S. Department of Energy.
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Table 6.8.1-2 Electrically Operated Air-Cooled Unitary Heat Pumps—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air cooled (heating mode)	<65,000 Btu/h (cooling capacity)		Split *system*, three phase and applications outside U.S. single phase[b]	8.2 *HSPF* before 1/1/2023 7.5 *HSPF2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	8.0 *HSPF* before 1/1/2023 6.7 *HSPF2* after 1/1/2023	
Space constrained, air cooled (heating mode)	≤30,000 Btu/h (cooling capacity)		Split *system*, three phase and applications outside U.S. single phase[b]	7.4 *HSPF* before 1/1/2023 6.3 *HSPF2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	7.4 *HSPF* before 1/1/2023 6.3 *HSPF2* after 1/1/2023	
Small duct high velocity, air cooled (heating mode)	<65,000 Btu/h		Split *system*, three phase and applications outside U.S. single phase[b]	7.2 *HSPF* before 1/1/2023 6.1 *HSPF2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Air cooled (heating mode)	≥65,000 Btu/*h* and <135,000 Btu/h (cooling capacity)		47°F db/43°F wb *outdoor air*	3.30 COP_H before 1/1/2023 3.40 COP_H after 1/1/2023	AHRI 340/360
			17°F db/15°F wb *outdoor air*	2.25 COP_H	
	≥135,000 Btu/*h* (cooling capacity) and <240,000 Btu/h		47°F db/43°F wb *outdoor air*	3.20 COP_H before 1/1/2023 3.30 COP_H after 1/1/2023	
			17°F db/15°F wb *outdoor air*	2.05 COP_H	
	≥240,000 Btu/h (cooling capacity)		47°F db/43°F wb *outdoor air*	3.20 COP_H	
			17°F db/15°F wb *outdoor air*	2.05 COP_H	

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, U.S. air-cooled heat pumps <65,000 Btu/h are regulated as consumer products by the U.S. *Code of Federal Regulations* 10 CFR 430. *SEER, SEER2*, and *HSPF* values for single-phase products are set by the U.S. Department of Energy.

Informative Note: See Informative Appendix F for the U.S. Department of Energy minimum.

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Table 6.8.1-3 Liquid-Chilling Packages—Minimum Efficiency Requirements[a,b,e]

Equipment Type	Size Category	Units	Path A	Path B	Test Procedure[c]
Air-cooled	<150 tons	*EER* (Btu/Wh)	≥10.100 FL	≥9.700 FL	AHRI 550/590
			≥13.700 *IPLV*.IP	≥15.800 *IPLV*.IP	
	≥150 tons		≥10.100 FL	≥9.700 FL	
			≥14.000 *IPLV*.IP	≥16.100 *IPLV*.IP	
Air-cooled without condenser, electrically operated	All capacities	*EER* (Btu/Wh)	Air-cooled without condenser must be rated with matching condensers and comply with air-cooled chiller *efficiency* requirements.		AHRI 550/590
Liquid-cooled, electrically operated positive displacement	<75 tons	*kW*/ton	≤0.750 FL	≤0.780 FL	AHRI 550/590
			≤0.600 *IPLV*.IP	≤0.500 *IPLV*.IP	
	≥75 tons and <150 tons		≤0.720 FL	≤0.750 FL	
			≤0.560 *IPLV*.IP	≤0.490 *IPLV*.IP	
	≥150 tons and <300 tons		≤0.660 FL	≤0.680 FL	
			≤0.540 *IPLV*.IP	≤0.440 *IPLV*.IP	
	≥300 tons and <600 tons		≤0.610 FL	≤0.625 FL	
			≤0.520 *IPLV*.IP	≤0.410 *IPLV*.IP	
	≥600 tons		≤0.560 FL	≤0.585 FL	
			≤0.500 *IPLV*.IP	≤0.380 *IPLV*.IP	
Liquid-cooled, electrically operated centrifugal	<150 tons	*kW*/ton	≤0.610 FL	≤0.695 FL	AHRI 550/590
			≤0.550 *IPLV*.IP	≤0.440 *IPLV*.IP	
	≥150 tons and <300 tons		≤0.610 FL	≤0.635 FL	
			≤0.550 *IPLV*.IP	≤0.400 *IPLV*.IP	
	≥300 tons and <400 tons		≤0.560 FL	≤0.595 FL	
			≤0.520 *IPLV*.IP	≤0.390 *IPLV*.IP	
	≥400 tons and <600 tons		≤0.560 FL	≤0.585 FL	
			≤0.500 *IPLV*.IP	≤0.380 *IPLV*.IP	
	≥600 tons		≤0.560 FL	≤0.585 FL	
			≤0.500 *IPLV*.IP	≤0.380 *IPLV*.IP	
Air-cooled absorption, single effect	All capacities	*COP* (W/W)	≥0.600 FL	NA[d]	AHRI 560
Liquid-cooled absorption, single effect	All capacities	*COP* (W/W)	≥0.700 FL	NA[d]	AHRI 560
Absorption double effect, indirect fired	All capacities	*COP* (W/W)	≥1.000 FL	NA[d]	AHRI 560
			≥1.050 *IPLV*.IP		
Absorption double effect, direct fired	All capacities	*COP* (W/W)	≥1.000 FL	NA[d]	AHRI 560
			≥1.000 *IPLV*		

a. The requirements for centrifugal chilling packages 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, liquid-cooled positive displacement and absorption chilling packages are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and *IPLV*.IP requirements must be met or exceeded to comply with this standard. When there is a Path B, compliance can be with either Path A or Path B for any application.

c. Section 13 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*.IP is for the part-load performance requirements.

f. Electrically operated chilling packages employing a freeze-protection liquid in accordance with Section 6.4.1.2.2 shall be tested or rated with water for the purpose of compliance with the requirements of this table.

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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[d]	Test Procedure[a]
PTAC (cooling mode) standard size	<7000 Btu/h	95°F db/75°F wb *outdoor air*[c]	11.9 *EER*	AHRI 310/380
	≥7000 Btu/h and ≤15,000 Btu/h		14.0 – (0.300 × Cap/1000) *EER*[e]	
	>15,000 Btu/h		9.5 *EER*	
PTAC (cooling mode) nonstandard size[b]	<7000 Btu/h	95°F db/75°F wb *outdoor air*[c]	9.4 *EER*	AHRI 310/380
	≥7000 Btu/h and ≤15,000 Btu/h		10.9 – (0.213 × Cap/1000) *EER*[e]	
	>15,000 Btu/h		7.7 *EER*	
PTHP (cooling mode) standard size	<7000 Btu/h	95°F db/75°F wb *outdoor air*[c]	11.9 *EER*	AHRI 310/380
	≥7000 Btu/h and ≤15,000 Btu/h		14.0 – (0.300 × Cap/1000) *EER*[e]	
	>15,000 Btu/h		9.5 *EER*	
PTHP (cooling mode) nonstandard size[b]	<7000 Btu/h	95°F db/75°F wb *outdoor air*[c]	9.3 *EER*	AHRI 310/380
	≥7000 Btu/h and ≤15,000 Btu/h		10.8 – (0.213 × Cap/1000) *EER*[e]	
	>15,000 Btu/h		7.6 *EER*	
PTHP (heating mode) standard size	<7000 Btu/h	47°F db/43°F wb *outdoor air*	3.3 COP_H	AHRI 310/380
	≥7000 Btu/h and ≤15,000 Btu/h		3.7 – (0.052 × Cap/1000) COP_H[e]	
	>15,000 Btu/h		2.90 COP_H	
PTHP (heating mode) nonstandard size[b]	<7000 Btu/h	47°F db/43°F wb *outdoor air*	2.7 COP_H	AHRI 310/380
	≥7000 Btu/h and ≤15,000 Btu/h		2.9 – (0.026 × Cap/1000) COP_H[e]	
	>15,000 Btu/h		2.5 COP_H	
SPVAC (cooling mode) single and three phase	<65,000 Btu/h	95°F db/75°F wb *outdoor air*[c]	11.0 *EER*	AHRI 390
	≥65,000 Btu/h and <135,000 Btu/h		10.0 *EER*	
	≥135,000 Btu/h and <240,000 Btu/h		10.0 *EER*	
SPVHP (cooling mode)	<65,000 Btu/h	95°F db/75°F wb *outdoor air*[c]	11.0 *EER*	AHRI 390
	≥65,000 Btu/h and <135,000 Btu/h		10.0 *EER*	
	≥135,000 Btu/h and <240,000 Btu/h		10.0 *EER*	
SPVHP (heating mode)	<65,000 Btu/h	47°F db/43°F wb *outdoor air*	3.3 COP_H	AHRI 390
	≥65,000 Btu/h and <135,000 Btu/h		3.0 COP_H	
	≥135,000 Btu/h and <240,000 Btu/h		3.0 COP_H	

a. Section 13 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. The cooling-mode wet bulb temperature requirement only applies for units that reject condensate to the condenser coil.

d. *Room air conditioners* are regulated as consumer products by 10 CFR 430. For U.S. applications of *room air conditioners*, refer to Informative Appendix F, Table F-3, for the U.S. DOE minimum efficiency requirements for U.S. applications.

e. "Cap" in *EER* and COP_H equations for *PTAC*s and *PTHP*s means cooling capacity in Btu/h at 95°F outdoor dry-bulb temperature.

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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[d]	Test Procedure[a]
Room air conditioners without reverse cycle with louvered sides for applications outside U.S. [d]	<6000 Btu/h		11.0 *CEER*	ANSI/AHAM RAC-1
	≥6000 Btu/h and <8000 Btu/h		11.0 *CEER*	
	≥8000 Btu/h and <14,000 Btu/h		10.9 *CEER*	
	≥14,000 Btu/h and <20,000 Btu/h		10.7 *CEER*	
	≥20,000 Btu/h and <28,000 Btu/h		9.4 *CEER*	
	≥28,000 Btu/h		9.0 *CEER*	
Room air conditioners without louvered sides	<6000 Btu/h		10.0 *CEER*	ANSI/AHAM RAC-1
	≥6000 Btu/h and <8000 Btu/h		10.0 *CEER*	
	≥8000 Btu/h and <11,000 Btu/h		9.6 *CEER*	
	≥11,000 Btu/h and <14,000 Btu/h		9.5 *CEER*	
	≥14,000 Btu/h and <20,000 Btu/h		9.3 *CEER*	
	≥20,000 Btu/h		9.4 *CEER*	
Room air conditioners with reverse cycle, with louvered sides for applications outside U.S. [d]	<20,000 Btu/h		9.8 *CEER*	ANSI/AHAM RAC-1
	≥20,000 Btu/h		9.3 *CEER*	
Room air conditioners with reverse cycle without louvered sides for applications outside U.S. [d]	<14,000 Btu/h		9.3 *CEER*	ANSI/AHAM RAC-1
	≥14,000 Btu/h		8.7 *CEER*	
Room air conditioners, casement only for applications outside U.S. [d]	All		9.5 *CEER*	ANSI/AHAM RAC-1
Room air conditioners, casement slider for applications outside U.S. [d]	All		10.4 *CEER*	ANSI/AHAM RAC-1

a. Section 13 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. The cooling-mode wet bulb temperature requirement only applies for units that reject condensate to the condenser coil.

d. *Room air conditioners* are regulated as consumer products by 10 CFR 430. For U.S. applications of *room air conditioners*, refer to Informative Appendix F, Table F-3, for the U.S. DOE minimum efficiency requirements for U.S. applications.

e. "Cap" in *EER* and COP_H equations for *PTAC*s and *PTHP*s means cooling capacity in Btu/h at 95°F outdoor dry-bulb temperature.

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Table 6.8.1-5 Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters—Minimum Efficiency Requirements

Equipment Type								
Description	**Fuel**	**Electric Power Phase**	**Application Location**	**Heating Capacity (input), Btu/h** [b]	**Combo-Unit Cooling Capacity, Btu/h**	**Subtype**	**Minimum Efficiency** [b]	**Test Procedure** [a]
Warm-air furnace	Gas	1	Inside U.S.	<225,000	<65,000	See Informative Appendix F, Table F-4[f]		
Warm-air furnace	Gas	1	Inside U.S.	<225,000	≥65,000	Nonweatherized	80% *AFUE*	Appendix N [g]
						Weatherized	81% *AFUE* or 80% E_t [c]	Appendix N [g] ANSI Z21.47
Warm-air furnace	Gas	1	Outside U.S.	<225,000	All	Nonweatherized	80% *AFUE*	Appendix N [g]
						Weatherized	81% *AFUE* or 80% E_t [c]	Appendix N [g] ANSI Z21.47
Warm-air furnace	Gas	3	All	<225,000	All	Nonweatherized	80% *AFUE*	Appendix N [g]
						Weatherized	81% *AFUE* or 80% E_t [c]	Appendix N [g] ANSI Z21.47
Warm-air furnace	Gas	All	All	≥ 225,000 and ≤ 400,000	All	All	80% E_t [c] before 1/1/2023 81% E_t [c] after 1/1/2023	ANSI Z21.47
Warm-air furnace	Gas	All	Inside U.S.	> 400,000	All	All	80% E_t [c] before 1/1/2023 81% E_t [c] after 1/1/2023	ANSI Z21.47
Warm-air furnace	Gas	All	Outside U.S.	> 400,000	All	All	80% E_t [c] before 1/1/2023 81% E_t [c] after 1/1/2023	ANSI Z21.47 or ANSI Z83.8
Warm-air furnace	Oil	1	Inside U.S.	<225,000	<65,000	See Informative Appendix F, Table F-4 [f]		
Warm-air furnace	Oil	1	Inside U.S.	<225,000	≥65,000	Nonweatherized	83% *AFUE*	Appendix N [g]
						Weatherized	78% *AFUE* or 80% E_t [d]	Appendix N [g] Section 42 UL 727
Warm-air furnace	Oil	1	Outside U.S.	<225,000	All	Nonweatherized	83% *AFUE*	Appendix N [g]
						Weatherized	78% *AFUE* or 80% E_t [d]	Appendix N [g] Section 42 UL 727

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. For this table, the following applies:
- Appendix N = 10 CFR 430 Appendix N
- ANSI Z21.47 = Section 2.39, Thermal *Efficiency*, ANSI Z21.47
- ANSI Z83.3 = Section 2.10, *Efficiency*, ANSI Z83.3
- UL 727 = Section 42, Combustion, UL 727
- UL 731 = Section 40, Combustion, UL 731

b. Compliance of multiple firing rate units shall be at the maximum firing rate.

c. 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*.

d. E_c = combustion *efficiency* (100% less flue losses). See test procedure for detailed discussion.

e. Units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an *automatic flue damper*.

f. Includes combination units with cooling capacity <65,000 Btu/h. For U.S. applications of federally covered <225,000 Btu/h products, see Informative Appendix F, Table F-4.

g. 10 CFR 430 is limited to-single phase equipment that is not contained within the same cabinet with a central air conditioner whose rated cooling capacity is above 65,000 Btu/h but for the test and rating procedures are not impacted for three-phase and can be used for *AFUE* ratings for ASHRAE/IES Standard 90.1 three-phase products and single-phase products with a cooling capacity greater than 65,000 Btu/h.

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Table 6.8.1-5 Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters—Minimum Efficiency Requirements *(Continued)*

Equipment Type								
Description	**Fuel**	**Electric Power Phase**	**Application Location**	**Heating Capacity (input), Btu/h** [b]	**Combo-Unit Cooling Capacity, Btu/h**	**Subtype**	**Minimum Efficiency** [b]	**Test Procedure** [a]
Warm-air furnace	Oil	3	All	<225,000	All	Nonweatherized	83% *AFUE*	Appendix N [g]
						Weatherized	78% *AFUE* or 80% E_t [d]	Appendix N [g]
								Section 42 UL 727
Warm-air furnace	Oil	All	All	≥225,000	All	All	81% E_t [d] before 1/1/2023 82% E_t [d] after 1/1/2023	Section 42 UL 727
Warm-air furnace	Electric	1	Inside U.S.	<225,000	<65,000	See Informative Appendix F, Table F-4 [f]		
Warm-air furnace	Electric	1	Inside U.S.	<225,000	≥65,000	All	96% *AFUE*	Appendix N [g]
Warm-air furnace	Electric	1	Outside U.S.	<225,000	All	All	96% *AFUE*	Appendix N [g]
Warm-air furnace	Electric	3	All	<225,000	All	All	96% *AFUE*	Appendix N [g]
Warm-air duct furnaces	Gas	All	All	All	All	All	80% E_c [d]	ANSI Z83.8
Warm-air unit heaters	Gas	All	All	All	All	All	80% E_c [d,e]	ANSI Z83.8
Warm-air unit heaters	Oil	All	All	All	All	All	80% E_c [d,e]	Section 40 UL 731

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. For this table, the following applies:
- Appendix N = 10 CFR 430 Appendix N
- ANSI Z21.47 = Section 2.39, Thermal *Efficiency*, ANSI Z21.47
- ANSI Z83.3 = Section 2.10, *Efficiency*, ANSI Z83.3
- UL 727 = Section 42, Combustion, UL 727
- UL 731 = Section 40, Combustion, UL 731

b. Compliance of multiple firing rate units shall be at the maximum firing rate.

c. 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*.

d. E_c = combustion *efficiency* (100% less flue losses). See test procedure for detailed discussion.

e. Units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an *automatic flue damper*.

f. Includes combination units with cooling capacity <65,000 Btu/h. For U.S. applications of federally covered <225,000 Btu/h products, see Informative Appendix F, Table F-4.

g. 10 CFR 430 is limited to-single phase equipment that is not contained within the same cabinet with a central air conditioner whose rated cooling capacity is above 65,000 Btu/h but for the test and rating procedures are not impacted for three-phase and can be used for *AFUE* ratings for ASHRAE/IES Standard 90.1 three-phase products and single-phase products with a cooling capacity greater than 65,000 Btu/h.

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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 [i]	Efficiency as of 3/2/2022	Test Procedure
Boilers, hot water	Gas fired [h]	<300,000 Btu/h [f,g] for applications outside U.S. [i]	82% *AFUE*	82% *AFUE*	10 CFR 430 Appendix N
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	80% E_t [c]	80% E_t [c]	10 CFR 431.86
		>2,500,000 Btu/h [d]	82% E_c [b]	82% E_c [b]	
	Oil fired [e]	<300,000 Btu/h [f,g] for applications outside U.S. [i]	84% *AFUE*	84% *AFUE*	10 CFR 430 Appendix N
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	82% E_t [c]	82% E_t [c]	10 CFR 431.86
		>2,500,000 Btu/h [d]	84% E_c [b]	84% E_c [b]	
Boilers, steam	Gas fired	<300,000 Btu/h[f] for applications outside U.S. [i]	80% *AFUE*	80% *AFUE*	10 CFR 430 Appendix N
	Gas fired—all, except natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	79% E_t [c]	79% E_t [c]	10 CFR 431.86
		>2,500,000 Btu/h [d]	79% E_t [c]	79% E_t [c]	
	Gas fired—natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	77% E_t [c]	79% E_t [c]	
		>2,500,000 Btu/h [d]	77% E_t [c]	79% E_t [c]	
	Oil fired [e]	<300,000 Btu/h [f] for applications outside U.S. [i]	82% *AFUE*	82% *AFUE*	10 CFR 430 Appendix N
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	81% E_t [c]	81% E_t [c]	10 CFR 431.86
		>2,500,000 Btu/h [d]	81% E_t [c]	81% E_t [c]	

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.
h. For new construction, refer to Section 6.4.1.1 for additional system compliance requirements.
i. See Informative Appendix F, Table F-4, for U.S. minimum efficiencies for residential products covered by U.S. DOE requirements for U.S. applications.

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Table 6.8.1-7 Performance Requirements for Heat Rejection Equipment—Minimum Efficiency Requirements

Equipment Type	Total System Heat-Rejection Capacity at Rated Conditions	Subcategory or Rating Condition [h]	Performance Required [a,b,c,f,g]	Test Procedure [d,e]
Propeller or axial fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥40.2 gpm/hp	CTI ATC-105 and CTI STD-201 RS
Centrifugal fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥20.0 gpm/hp	CTI ATC-105 and CTI STD-201 RS
Propeller or axial fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥16.1 gpm/hp	CTI ATC-105S and CTI STD-201 RS
Centrifugal fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥7.0 gpm/hp	CTI ATC-105S and CTI STD-201 RS
Propeller or axial fan dry coolers (air-cooled fluid coolers)	All	115°F entering water 105°F leaving water 95°F entering db	≥4.5 gpm/hp	CTI ATC-105DS
Propeller or axial fan evaporative condensers	All	R-448A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥160,000 Btu/h·hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥134,000 Btu/h·hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-448A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥137,000 Btu/h·hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥110,000 Btu/h·hp	CTI ATC-106
Air-cooled condensers	All	125°F condensing temperature 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, dry-cooler performance is defined as the process water flow rating of the unit at the thermal rating condition listed in Table 6.8.1-7 divided by the total fan motor nameplate power of the unit, and air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the total fan motor nameplate power of the unit.
d. Section 13 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-448A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-448A must meet the minimum *efficiency* requirements listed above with R-448A as the test fluid. For ammonia, the condensing temperature is defined as the saturation temperature corresponding to the refrigerant pressure at the condenser entrance. For R-448A, which is a zeotropic refrigerant, the condensing temperature is defined as the arithmetic average of the dew point and the bubble point temperatures corresponding to the refrigerant pressure at the condenser entrance.

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Table 6.8.1-8 Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements

Equipment Type[a]	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF air conditioners, air cooled	<65,000 Btu/h Three-phase for applications in the U.S. and single- and three-phase for applications outside the U.S.	All	*VRF* multisplit *system*	13.0 *SEER* Before 1/1/23 *SEER2* = 13.4 On or after 1/1/23	AHRI 1230-2014 with Addendum 1 before 1/1/2023 AHRI 210/240-2023 on or after 1/1/2023
	≥65,000 Btu/h and <135,000 Btu/h	*Electric resistance* (or none)	*VRF* multisplit *system*	11.2 *EER* 15.5 *IEER* Before 1/1/2024 10.5 *EER* 15.5 *IEER* On or after 1/1/24	AHRI 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
	≥135,000 Btu/h and <240,000 Btu/h	*Electric resistance* (or none)	*VRF* multisplit *system*	11.0 *EER* 14.9 *IEER* Before 1/1/2024 10.3 *EER* 14.9 *IEER* On or after 1/1/24	
	≥240,000 Btu/h	*Electric resistance* (or none)	*VRF* multisplit *system*	10.0 *EER* 13.9 *IEER* Before 1/1/2024 9.5 *EER* 13.9 *IEER* On or after 1/1/24	

a. *VRF* outdoor units can be combined with innumerable indoor unit combinations, which will vary by application, building type, building size, operating conditions, and comfort level goals. Selection of indoor units tested during the test is considered to be representative of commonly sold applications and is detailed in AHRI 1230.

Informative Note: For single-phase *VRF* air conditioners, air-cooled *systems* less than 65,000 Btu/h see Informative Appendix F, Table F-1 for the U.S. Department of Energy minimum.

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Table 6.8.1-9 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 Three-phase for applications in the U.S. and single- and three-phase for applications outside the U.S.	All	*VRF* multisplit *system*	13.0 *SEER* Before 1/1/2023 *SEER2* = 13.4 On or after 1/1/2023	AHRI 1230-2014 with Addendum 1 before 1/1/2023 AHRI 210/240-2023 on or after 1/1/2023
	≥65,000 Btu/h and <135,000 Btu/h	*Electric resistance* (or none)		11.0 *EER* 14.6 *IEER* Before 1/1/2024 10.3 *EER* 14.6 *IEER* On or after 1/1/24	AHRI 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
			VRF multisplit *system* with heat recovery	10.8 *EER* 14.4 *IEER* Before 1/1/2024 10.1 *EER* 14.4 *IEER* On or after 1/1/24	
	≥135,000 Btu/h and <240,000 Btu/h		*VRF* multisplit *system*	10.6 *EER* 13.9 *IEER* Before 1/1/2024 9.9 *EER* 13.9 *IEER* On or after 1/1/24	
			VRF multisplit *system* with heat recovery	10.4 *EER* 13.7 *IEER* Before 1/1/2024 9.7 *EER* 13.7 *IEER* On or after 1/1/24	
	≥240,000 Btu/h		*VRF* multisplit *system*	9.5 *EER* 12.7 *IEER* Before 1/1/2024 9.1 *EER* 12.7 *IEER* On or after 1/1/24	
			VRF multisplit *system* with heat recovery	9.3 *EER* 12.5 *IEER* Before 1/1/2024 8.9 *EER* 12.5 *IEER* On or after 1/1/24	

a. *VRF* outdoor units can be combined with innumerable indoor unit combinations, which will vary by application, building type, building size, operating conditions, and comfort level goals. Selection of indoor units tested during the test is considered to be representative of commonly sold applications and is detailed in AHRI 1230.

Informative Note: For single-phase *VRF* multisplit *system* less than 65,000 Btu/h, see Informative Appendix F, Table F-1 for the U.S. Department of Energy minimum.

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Table 6.8.1-9 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 water source (cooling mode)	<65,000 Btu/h	All	*VRF* multisplit *systems* 86°F entering water	12.0 *EER* 16.0 *IEER*	AHRI 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
			VRF multisplit *systems* with heat recovery 86°F entering water	11.8 *EER* 15.8 *IEER*	
	≥65,000 Btu/h and <135,000 Btu/h		*VRF* multisplit *system* 86°F entering water	12.0 *EER* 16.0 *IEER*	
			VRF multisplit *system* with heat recovery 86°F entering water	11.8 *EER* 15.8 *IEER*	
	≥135,000 Btu/h and <240,000 Btu/h		*VRF* multisplit *system* 86°F entering water	10.0 *EER* 14.0 *IEER*	
			VRF multisplit *system* with heat recovery 86°F entering water	9.8 *EER* 13.8 *IEER*	
	≥240,000 Btu/h		*VRF* multisplit *system* 86°F entering water	10.0 *EER* 12.0 *IEER*	
			VRF multisplit *system* with heat recovery 86°F entering water	9.8 *EER* 11.8 *IEER*	
VRF groundwater source (cooling mode)	<135,000 Btu/h	All	*VRF* multisplit *system* 59°F entering water	16.2 *EER*	AHRI 1230- 2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
			VRF multisplit *system* with heat recovery 59°F entering water	16.0 *EER*	
	≥135,000 Btu/h		*VRF* multisplit *system* 59°F entering water	13.8 *EER*	
			VRF multisplit *system* with heat recovery 59°F entering water	13.6 *EER*	
VRF ground source (cooling mode)	<135,000 Btu/h	All	*VRF* multisplit *system* 77°F entering water	13.4 *EER*	AHRI 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
			VRF multisplit *system* with heat recovery 77°F entering water	13.2 *EER*	
	≥135,000 Btu/h		*VRF* multisplit *system* 77°F entering water	11.0 *EER*	
			VRF multisplit *system* with heat recovery 77°F entering water	10.8 *EER*	

a. *VRF* outdoor units can be combined with innumerable indoor unit combinations, which will vary by application, building type, building size, operating conditions, and comfort level goals. Selection of indoor units tested during the test is considered to be representative of commonly sold applications and is detailed in AHRI 1230.

Informative Note: For single-phase *VRF* multisplit *system* less than 65,000 Btu/h, see Informative Appendix F, Table F-1 for the U.S. Department of Energy minimum.

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Table 6.8.1-9 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 air cooled (heating mode)	<65,000 Btu/h (cooling capacity) Three-phase for applications in the U.S. and single- and three-phase for applications outside the U.S.		*VRF* multisplit *system*	7.7 *HSPF* Before 1/1/2023 On or after 1/1/2023 *HSPF2* = 7.5	AHRI 1230-2014 with Addendum 1 before 1/1/2023 AHRI 210/240-2023 on or after 1/1/2023
	≥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	AHRI 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
			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)	<65,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 68°F entering water	4.3 COP_H	AHRI 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
	≥65,000 Btu/h and <135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 68°F entering water	4.3 COP_H	
	≥135,000 Btu/h and <240,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 68°F entering water	4.0 COP_H	
	≥240,000 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 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
	≥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 1230-2014 with Addendum 1 before 1/1/2024 AHRI 1230-2021 on or after 1/1/2024
	≥135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 32°F entering water	2.8 COP_H	

a. *VRF* outdoor units can be combined with innumerable indoor unit combinations, which will vary by application, building type, building size, operating conditions, and comfort level goals. Selection of indoor units tested during the test is considered to be representative of commonly sold applications and is detailed in AHRI 1230.

Informative Note: For single-phase *VRF* multisplit *system* less than 65,000 Btu/h, see Informative Appendix F, Table F-1 for the U.S. Department of Energy minimum.

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Table 6.8.1-10 Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements

Equipment Type	Standard Model	Net Sensible Cooling Capacity	Minimum Net Sensible COP	Rating Conditions Return Air (dry-bulb/dew-point)	Test Procedure
Air cooled	Downflow	<80,000 Btu/h	2.70	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and <295,000 Btu/h	2.58		
		≥295,000 Btu/h	2.36		
	Upflow—ducted	<80,000 Btu/h	2.67		
		≥80,000 Btu/h and <295,000 Btu/h	2.55		
		≥295,000 Btu/h	2.33		
	Upflow—nonducted	<65,000 Btu/h	2.16	75°F/52°F (Class 1)	
		≥65,000 Btu/h and <240,000 Btu/h	2.04		
		≥240,000 Btu/h	1.89		
	Horizontal	<65,000 Btu/h	2.65	95°F/52°F (Class 3)	
		≥65,000 Btu/h and <240,000 Btu/h	2.55		
		≥240,000 Btu/h	2.47		
Air cooled with *fluid economizer*	Downflow	<80,000 Btu/h	2.70	85°F/52°F (Class 1)	AHRI 1360
		≥80,000 Btu/h and <295,000 Btu/h	2.58		
		≥295,000 Btu/h	2.36		
	Upflow—ducted	<80,000 Btu/h	2.67		
		≥80,000 Btu/h and <295,000 Btu/h	2.55		
		≥295,000 Btu/h	2.33		
	Upflow—nonducted	<65,000 Btu/h	2.09	75°F/52°F (Class 1)	
		≥65,000 Btu/h and <240,000 Btu/h	1.99		
		≥240,000 Btu/h	1.81		
	Horizontal	<65,000 Btu/h	2.65	95°F/52°F (Class 3)	
		≥65,000 Btu/h and <240,000 Btu/h	2.55		
		≥240,000 Btu/h	2.47		

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Table 6.8.1-10 Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements *(Continued)*

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

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Table 6.8.1-10 Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements *(Continued)*

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

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Table 6.8.1-11 Commercial Refrigerators, Commercial Freezers, and Refrigeration—Minimum Efficiency Requirements

Equipment Category	Condensing Unit Configuration	Equipment Family	Rating Temp., °F	Operating Temp., °F	Equipment Classification[c]	Maximum Daily Energy Consumption, kWh/day[d,e]	Test Procedure
Remote condensing commercial refrigerators and commercial freezers	Remote (RC)	Vertical open (VOP)	38 (M)	≥32	VOP.RC.M	0.64 × TDA + 4.07	AHRI 1200
			0 (L)	<32	VOP.RC.L	2.20 × TDA + 6.85	
		Semivertical open (SVO)	38 (M)	≥32	SVO.RC.M	0.66 × TDA + 3.18	
			0 (L)	<32	SVO.RC.L	2.20 × TDA + 6.85	
		Horizontal open (HZO)	38 (M)	≥32	HZO.RC.M	0.35 × TDA + 2.88	
			0 (L)	<32	HZO.RC.L	0.55 × TDA + 6.88	
		Vertical closed transparent (VCT)	38 (M)	≥32	VCT.RC.M	0.15 × TDA + 1.95	
			0 (L)	<32	VCT.RC.L	0.49 × TDA + 2.61	
		Horizontal closed transparent (HCT)	38 (M)	≥32	HCT.RC.M	0.16 × TDA + 0.13	
			0 (L)	<32	HCT.RC.L	0.34 × TDA + 0.26	
		Vertical closed solid (VCS)	38 (M)	≥32	VCS.RC.M	0.10 × V + 0.26	
			0 (L)	<32	VCS.RC.L	0.21 × V + 0.54	
		Horizontal closed solid (HCS)	38 (M)	≥32	HCS.RC.M	0.10 × V + 0.26	
			0 (L)	<32	HCS.RC.L	0.21 × V + 0.54	
		Service over counter (SOC)	38 (M)	≥32	SOC.RC.M	0.44 × TDA + 0.11	
			0 (L)	<32	SOC.RC.L	0.93 × TDA + 0.22	
Self-contained commercial refrigerators and commercial freezers with and without doors	Self-contained (SC)	Vertical open (VOP)	38 (M)	≥32	VOP.SC.M	1.69 × TDA + 4.71	AHRI 1200
			0 (L)	<32	VOP.SC.L	4.25 × TDA + 11.82	
		Semivertical open (SVO)	38 (M)	≥32	SVO.SC.M	1.70 × TDA + 4.59	
			0 (L)	<32	SVO.SC.L	4.26 × TDA + 11.51	
		Horizontal open (HZO)	38 (M)	≥32	HZO.SC.M	0.72 × TDA + 5.55	
			0 (L)	<32	HZO.SC.L	1.90 × TDA + 7.08	
		Vertical closed transparent (VCT)	38 (M)	≥32	VCT.SC.M	0.10 × V + 0.86	
			0 (L)	<32	VCT.SC.L	0.29 × V + 2.95	
		Vertical closed solid (VCS)	38 (M)	≥32	VCS.SC.M	0.05 × V + 1.36	
			0 (L)	<32	VCS.SC.L	0.22 × V + 1.38	
		Horizontal closed transparent (HCT)	38 (M)	≥32	HCT.SC.M	0.06 × V + 0.37	
			0 (L)	<32	HCT.SC.L	0.08 × V + 1.23	
		Horizontal closed solid (HCS)	38 (M)	≥32	HCS.SC.M	0.05 × V + 0.91	
			0 (L)	<32	HCS.SC.L	0.06 × V + 1.12	
		Service over counter (SOC)	38 (M)	≥32	SOC.SC.M	0.52 × TDA + 1.00	
			0 (L)	<32	SOC.SC.L	1.10 × TDA + 2.10	

a. The meaning of the letters in this column is indicated in the columns to the left.

b. "Ice-cream freezer" is defined in 10 CFR 431.62 as a commercial freezer that is designed to operate at or below –5°F and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream.

c. Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of the following: (AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical closed transparent doors, VCS = vertical closed solid doors, HCT = horizontal closed transparent doors, HCS = horizontal closed 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.

d. V is the volume of the case (ft^3) as measured in AHRI Standard 1200, Appendix C.

e. TDA is the total display area of the case (ft^2) as measured in AHRI Standard 1200, Appendix D.

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Table 6.8.1-11 Commercial Refrigerators, Commercial Freezers, and Refrigeration—Minimum Efficiency Requirements *(Continued)*

Equipment Category	Condensing Unit Configuration	Equipment Family	Rating Temp., °F	Operating Temp., °F	Equipment Classification[c]	Maximum Daily Energy Consumption, kWh/day[d,e]	Test Procedure
Self-contained commercial refrigerators with transparent doors for pull-down temperature applications	Self-contained (SC)	Pull-down (PD)	38 (M)	≥32	PD.SC.M	$0.11 \times V + 0.81$	AHRI 1200
Commercial ice-cream freezers	Remote (RC)	Vertical open (VOP)	–15 (I)	≤–5[b]	VOP.RC.I	2.79 × TDA + 8.70	AHRI 1200
		Semivertical open (SVO)			SVO.RC.I	2.79 × TDA + 8.70	
		Horizontal open (HZO)			HZO.RC.I	0.70 × TDA + 8.74	
		Vertical closed transparent (VCT)			VCT.RC.I	0.58 × TDA + 3.05	
		Horizontal closed transparent (HCT)			HCT.RC.I	0.40 × TDA + 0.31	
		Vertical closed solid (VCS)			VCS.RC.I	0.25 × V + 0.63	
		Horizontal closed solid (HCS)			HCS.RC.I	0.25 × V + 0.63	
		Service over counter (SOC)			SOC.RC.I	1.09 × TDA + 0.26	
	Self-contained (SC)	Vertical open (VOP)			VOP.SC.I	5.40 × TDA + 15.02	AHRI 1200
		Semivertical open (SVO)			SVO.SC.I	5.41 × TDA + 14.63	
		Horizontal open (HZO)			HZO.SC.I	2.42 × TDA + 9.00	
		Vertical closed transparent (VCT)			VCT.SC.I	0.62 × TDA + 3.29	
		Horizontal closed transparent (HCT)			HCT.SC.I	0.56 × TDA + 0.43	
		Vertical closed solid (VCS)			VCS.SC.I	0.34 × V + 0.88	
		Horizontal closed solid (HCS)			HCS.SC.I	0.34 × V + 0.88	
		Service over counter (SOC)			SOC.SC.I	1.53 × TDA + 0.36	

a. The meaning of the letters in this column is indicated in the columns to the left.
b. "Ice-cream freezer" is defined in 10 CFR 431.62 as a commercial freezer that is designed to operate at or below –5°F and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream.
c. Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of the following: (AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical closed transparent doors, VCS = vertical closed solid doors, HCT = horizontal closed transparent doors, HCS = horizontal closed 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.
d. V is the volume of the case (ft^3) as measured in AHRI Standard 1200, Appendix C.
e. TDA is the total display area of the case (ft^2) as measured in AHRI Standard 1200, Appendix D.

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Table 6.8.1-12 Vapor-Compression-Based Indoor Pool Dehumidifiers—Minimum Efficiency Requirements

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

Table 6.8.1-13 Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, without Energy Recovery—Minimum Efficiency Requirements

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

Table 6.8.1-14 Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, with Energy Recovery—Minimum Efficiency Requirements

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

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Table 6.8.1-15 Electrically Operated Water-Source Heat Pumps—Minimum Efficiency Requirements [b]

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Water-to-air, water loop (cooling mode)	<17,000 Btu/h	All	86°F entering water	12.2 *EER*	ISO 13256-1
	≥17,000 Btu/h and <65,000 Btu/h			13.0 *EER*	
	≥65,000 Btu/h and <135,000 Btu/h			13.0 *EER*	
Water-to-air, groundwater (cooling mode)	<135,000 Btu/h	All	59°F entering water	18.0 *EER*	ISO 13256-1
Brine-to-air, ground loop (cooling mode)	<135,000 Btu/h	All	77°F entering water	14.1 *EER*	ISO 13256-1
Water-to-water, water loop (cooling mode)	<135,000 Btu/h	All	86°F entering water	10.6 *EER*	ISO 13256-2
Water-to-water, groundwater (cooling mode)	<135,000 Btu/h	All	59°F entering water	16.3 *EER*	ISO 13256-2
Brine-to-water, ground loop (cooling mode)	<135,000 Btu/h	All	77°F entering water	12.1 *EER*	ISO 13256-2
Water-to-air, water loop (heating mode)	<135,000 Btu/h (cooling capacity)		68°F entering water	4.3 COP_H	ISO 13256-1
Water-to-air, groundwater (heating mode)	<135,000 Btu/h (cooling capacity)		50°F entering water	3.7 COP_H	ISO 13256-1
Brine-to-air, ground loop (heating mode)	<135,000 Btu/h (cooling capacity)		32°F entering water	3.2 COP_H	ISO 13256-1
Water-to-water, water loop (heating mode)	<135,000 Btu/h (cooling capacity)		68°F entering water	3.7 COP_H	ISO 13256-1
Water-to-water, groundwater (heating mode)	<135,000 Btu/h (cooling capacity)		50°F entering water	3.1 COP_H	ISO 13256-2
Brine-to-water, ground loop (heating mode)	<135,000 Btu/h (cooling capacity)		32°F entering water	2.5 COP_H	ISO 13256-2

a. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, U.S. air-cooled heat pumps <65,000 Btu/h are regulated as consumer products by 10 CFR 430. *SEER*, *SEER2*, *HPSF* and *HPSF2* values for single-phase products are set by the U.S. DOE.

Informative Note: See Informative Appendix F for the U.S. DOE minimum.

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Table 6.8.1-16 Heat Pump and Heat Recovery Water-Chilling Packages—Minimum Efficiency Requirements

Equipment Type	Size Category Refrigerating Capacity[n], ton_R	Cooling Operation Efficiency[a,d,e,j] Air Source EER (FL/IPLV), Btu/W·h Liquid-Source Power Input per Capacity (FL/IPLV), kW/ton_R		Heating Source Conditions (leaving liquid) or OAT (db/wb)[g], °F	Heating Operation Efficiency,[b,e,j] Heat Pump Heating Full-Load Heating Efficiency (COP_H)[f,h], W/W				Simultaneous Cooling and Heating Full-Load Efficiency (COP_{SHC})[b,i], W/W				Heat Recovery Heating Full-Load Efficiency (COP_{HR})[c,j], W/W				Test Procedure
					Entering/Leaving Heating Liquid Temperature				Entering/Leaving Heating Liquid Temperature				Entering/Leaving Heating Liquid Temperature				
					Low	Medium	High	Boost	Low	Medium	High	Boost	Low	Medium	Hot-Water 1	Hot-Water 2	
		Path A	Path B		95.00°F/105.00°F	105.00°F/120.00°F	120.00°F/140.00°F	120.00°F/140.00°F	95.00°F/105.00°F	105.00°F/120.00°F	120.00°F/140.00°F	120.00°F/140.00°F	95.00°F/105.00°F	105.00°F/120.00°F	90.00°F/140.00°F	120.00°F/140.00°F	
Air source	<150.0	≥9.595 FL ≥13.02 *IPLV*.IP	≥9.215 FL ≥15.01 *IPLV*.IP	47.00 db 43.00 wb[l]	≥3.290	≥2.770	≥2.310	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	AHRI 550/590
				17.00 db 15.00 wb[l]	≥2.029	≥1.775	≥1.483	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	
	≥150.0	≥9.595 FL ≥13.30 *IPLV*.IP	≥9.215 FL ≥15.30 *IPLV*.IP	47.00 db 43.00 wb[l]	≥3.290	≥2.770	≥2.310	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	
				17.00 db 15.00 wb[l]	≥2.029	≥1.775	≥1.483	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	NA[p]	
Liquid-source electrically operated positive displacement	≥11.25[q] and <150.00	≤ 0.7895 FL ≤0.6316 *IPLV*.IP	≤0.8211FL ≤0.5263 *IPLV*.IP	44.00[m]	≥4.640	≥3.680	≥2.680	NA[p]	≥8.330	≥6.410	≥4.420	NA[p]	≥8.330	≥6.410	≥4.862	≥4.420	AHRI 550/590
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.550	NA[p]	NA[p]	NA[p]	≥6.150	NA[p]	NA[p]	NA[p]	NA[p]	
	≥150.0 and <300.0	≤0.7579 FL ≤0.5895 *IPLV*.IP	≤0.7895 FL ≤0.5158 *IPLV*.IP	44.00[m]	≥4.640	≥3.680	≥2.680	NA[p]	≥8.330	≥6.410	≥4.420	NA[p]	≥8.330	≥6.410	≥4.862	≥4.420	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.550	NA[p]	NA[p]	NA[p]	≥6.150	NA[p]	NA[p]	NA[p]	NA[p]	
	≥300.0 and <400.0	≤0.6947 FL ≤0.5684 *IPLV*.IP	≤0.7158 FL ≤0.4632 *IPLV*.IP	44.00[m]	≥4.640	≥3.680	≥2.680	NA[p]	≥8.330	≥6.410	≥4.420	NA[p]	≥8.330	≥6.410	≥4.862	≥4.420	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.550	NA[p]	NA[p]	NA[p]	≥6.150	NA[p]	NA[p]	NA[p]	NA[p]	
	≥400.0 and <600.0	≤0.6421 FL ≤0.5474 *IPLV*.IP	≤0.6579 FL ≤0.4316 *IPLV*.IP	44.00[m]	≥4.930	≥3.960	≥2.970	NA[p]	≥8.900	≥6.980	≥5.000	NA[p]	≥8.900	≥6.980	≥5.500	≥5.000	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.900	NA[p]	NA[p]	NA[p]	≥6.850	NA[p]	NA[p]	NA[p]	NA[p]	
	≥600.0	≤0.5895 FL ≤0.5263 *IPLV*.IP	≤0.6158 FL ≤0.4000 *IPLV*.IP	44.00[m]	≥4.930	≥3.960	≥2.970	NA[p]	≥8.900	≥6.980	≥5.000	NA[p]	≥8.900	≥6.980	≥5.500	≥5.000	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.900	NA[p]	NA[p]	NA[p]	≥6.850	NA[p]	NA[p]	NA[p]	NA[p]	

a. Cooling rating conditions are standard rating conditions defined in AHRI 550/590 (I-P), Table 4, except for liquid-cooled centrifugal chilling packages which can adjust cooling *efficiency* for nonstandard rating conditions using K_{adj} procedure in accordance with Section 6.4.1.2.1.
b. Heating full-load rating conditions are at standard rating conditions defined in AHRI 550/590 (I-P), Table 4; includes the impact of defrost for air source heating ratings.
c. For liquid-source heat recovery chilling packages that have capabilities for heat rejection to a heat recovery condenser and a tower condenser the COP_{HR} applies to operation at full load with 100% heat recovery (no tower rejection). Units that only have capabilities for partial heat recovery shall meet the requirements of Table 6.8.1-3.
d. For cooling operation, compliance with both the FL and *IPLV* is required, but only compliance with Path A or Path B cooling *efficiency* is required.
e. For units that operate in both cooling and heating, compliance with both the cooling and heating *efficiency* is required.
f. For applications where the chilling package is installed to operate only in heating, compliance only with the heating performance COP_H is required at only one of the heating AHRI 550/590 (I-P) standard rating conditions of Low, Medium, High, or Boost. Compliance with cooling performance is not required.
g. For air source heat pumps, compliance with both the 47.00°F and 17.00°F heating source *outdoor air* temperature (OAT) rating *efficiency* is required for heating.
h. For heat-pump chilling package applications where the cooling capacity is not being used for conditioning, compliance with the heating performance COP_H is only required at one of the four heating AHRI 550/590 standard ratings conditions of Low, Medium, High, or Boost. Compliance with the cooling performance is required as defined in footnotes (a) and (d), except as noted in footnote (f).
i. For simultaneous cooling and heating chillers applications where there is simultaneous cooling and heating, compliance with the simultaneous cooling performance heat recovery COP_{SHC} is only required at one of the four simultaneous cooling and heating AHRI 550/590 (I-P) standard ratings conditions of Low, Medium, High, or Boost. Compliance with the cooling only performance is required as defined in footnotes (a) and (d).
j. For heat recovery heating chilling package applications where there is simultaneous cooling and heating, compliance with the heating performance heat recovery COP_{HR} is only required at one of the four heating AHRI 550/590 (I-P) standard ratings conditions of Low, Medium, Hot-Water 1, or Hot-Water 2. Compliance with the cooling only performance is required as defined in footnotes a and d.
k. Chilling packages employing a freeze-protection liquid in accordance with Section 6.4.1.2.2 shall be tested or rated with water for the purpose of compliance with the requirements of this table.
l. Outdoor air entering dry-bulb (db) temperature and wet-bulb (wb) temperature.
m. Source-leaving liquid temperature.
- The cooling evaporator liquid flow rate used for the heating rating for a reverse cycle air-to-water heat pump shall be the flow rate determined during the full-load cooling rating.
- The cooling evaporator liquid flow rate for the simultaneous cooling and heating and heat recovery liquid cooled chilling packages rating shall be the liquid flow rates from the cooling operation full load rating.
- For heating-only fluid-to-fluid chiller packages, the evaporator flow rate obtained with an entering liquid temperature of 54.00°F and a leaving liquid temperature of 44.00°F shall be used.

n. The size category is the full-load net refrigerating cooling mode capacity, which is the capacity of the evaporator available for cooling of the thermal load external to the chilling package.
o A heat recovery condenser at its maximum load point must remove enough heat from the refrigerant to cool the refrigerant to remove all superheat energy and begin condensation of the refrigerant. A heat recovery system where only the superheat is reduced is not covered by Table 6.8.1-16 and is considered a desuperheater, and the chiller package must comply with Table 6.8.1-3.
p. "NA" means the requirements are not applicable.
q. Water-to-water heat pumps with a capacity less than 135,000 Btu/h are covered by Table 6.8.1-15.

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Table 6.8.1-16 Heat Pump and Heat Recovery Water-Chilling Packages—Minimum Efficiency Requirements

Equipment Type	Size Category Refrigerating Capacity[n], ton_R	Cooling Operation Efficiency[a,d,e,j] Air Source EER (FL/IPLV), Btu/W·h Liquid-Source Power Input per Capacity (FL/IPLV), kW/ton_R		Heating Operation Efficiency,[b,e,j] Heating Source Conditions (leaving liquid) or OAT (db/wb)[g], °F	Heat Pump Heating Full-Load Heating Efficiency (COP_H)[f,h], W/W — Entering/Leaving Heating Liquid Temperature				Simultaneous Cooling and Heating Full-Load Efficiency (COP_{SHC})[b,i], W/W — Entering/Leaving Heating Liquid Temperature				Heat Recovery Heating Full-Load Efficiency (COP_{HR})[c,j], W/W — Entering/Leaving Heating Liquid Temperature				Test Procedure
		Path A	Path B		Low 95.00°F/105.00°F	Medium 105.00°F/120.00°F	High 120.00°F/140.00°F	Boost 120.00°F/140.00°F	Low 95.00°F/105.00°F	Medium 105.00°F/120.00°F	High 120.00°F/140.00°F	Boost 120.00°F/140.00°F	Low 95.00°F/105.00°F	Medium 105.00°F/120.00°F	Hot-Water 1 90.00°F/140.00°F	Hot-Water 2 120.00°F/140.00°F	
Liquid-source electrically operated centrifugal	≥11.25[q] and <150.0	≤0.6421 FL ≤0.5789 *IPLV*.IP	≤0.7316 FL ≤0.4632 *IPLV*.IP	44.00[m]	≥4.640	≥3.680	≥2.680	NA[p]	≥8.330	≥6.410	≥4.420	NA[p]	≥8.330	≥6.410	≥4.862	≥4.420	AHRI 550/590
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.550	NA[p]	NA[p]	NA[p]	≥6.150	NA[p]	NA[p]	NA[p]	NA[p]	
	≥150.0 and <300.0	≤0.6190 FL ≤0.5748 *IPLV*.IP	≤0.6684 FL ≤0.4211 *IPLV*.IP	44.00[m]	≥4.640	≥3.680	≥2.680	NA[p]	≥8.330	≥6.410	≥4.420	NA[p]	≥8.330	≥6.410	≥4.862	≥4.420	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.550	NA[p]	NA[p]	NA[p]	≥6.150	NA[p]	NA[p]	NA[p]	NA[p]	
	≥300.0 and <400.0	≤0.5895 FL ≤0.5526 *IPLV*.IP	≤0.6263 FL ≤0.4105 *IPLV*.IP	44.00[m]	≥4.640	≥3.680	≥2.680	NA[p]	≥8.330	≥6.410	≥4.420	NA[p]	≥8.330	≥6.410	≥4.862	≥4.420	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.550	NA[p]	NA[p]	NA[p]	≥6.150	NA[p]	NA[p]	NA[p]	NA[p]	
	≥400.0 and <600.0	≤0.5895 FL ≤0.5263 *IPLV*.IP	≤0.6158 FL ≤0.4000 *IPLV*.IP	44.00[m]	≥4.930	≥3.960	≥2.970	NA[p]	≥8.900	≥6.980	≥5.000	NA[p]	≥8.900	≥6.980	≥5.500	≥5.000	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.900	NA[p]	NA[p]	NA[p]	≥6.850	NA[p]	NA[p]	NA[p]	NA[p]	
	≥600.0	≤0.5895 FL ≤0.5263 *IPLV*.IP	≤0.6158 FL ≤0.4000 *IPLV*.IP	44.00[m]	≥4.930	≥3.960	≥2.970	NA[p]	≥8.900	≥6.980	≥5.000	NA[p]	≥8.900	≥6.980	≥5.500	≥5.000	
				65.00[m]	NA[p]	NA[p]	NA[p]	≥3.900	NA[p]	NA[p]	NA[p]	≥6.850	NA[p]	NA[p]	NA[p]	NA[p]	

a. Cooling rating conditions are standard rating conditions defined in AHRI 550/590 (I-P), Table 4, except for liquid-cooled centrifugal chilling packages which can adjust cooling *efficiency* for nonstandard rating conditions using K_{adj} procedure in accordance with Section 6.4.1.2.1.
b. Heating full-load rating conditions are at standard rating conditions defined in AHRI 550/590 (I-P), Table 4; includes the impact of defrost for air source heating ratings.
c. For liquid-source heat recovery chilling packages that have capabilities for heat rejection to a heat recovery condenser and a tower condenser the COP_{HR} applies to operation at full load with 100% heat recovery (no tower rejection). Units that only have capabilities for partial heat recovery shall meet the requirements of Table 6.8.1-3.
d. For cooling operation, compliance with both the FL and *IPLV* is required, but only compliance with Path A or Path B cooling *efficiency* is required.
e. For units that operate in both cooling and heating, compliance with both the cooling and heating *efficiency* is required.
f. For applications where the chilling package is installed to operate only in heating, compliance only with the heating performance COP_H is required at only one of the heating AHRI 550/590 (I-P) standard rating conditions of Low, Medium, High, or Boost. Compliance with cooling performance is not required.
g. For air source heat pumps, compliance with both the 47.00°F and 17.00°F heating source *outdoor air* temperature (OAT) rating *efficiency* is required for heating.
h. For heat-pump chilling package applications where the cooling capacity is not being used for conditioning, compliance with the heating performance COP_H is only required at one of the four heating AHRI 550/590 standard ratings conditions of Low, Medium, High, or Boost. Compliance with the cooling performance is required as defined in footnotes (a) and (d), except as noted in footnote (f).
i. For simultaneous cooling and heating chillers applications where there is simultaneous cooling and heating, compliance with the simultaneous cooling performance heat recovery COP_{SHC} is only required at one of the four simultaneous cooling and heating AHRI 550/590 (I-P) standard ratings conditions of Low, Medium, High, or Boost. Compliance with the cooling only performance is required as defined in footnotes (a) and (d).
j. For heat recovery heating chilling package applications where there is simultaneous cooling and heating, compliance with the heating performance heat recovery COP_{HR} is only required at one of the four heating AHRI 550/590 (I-P) standard ratings conditions of Low, Medium, Hot-Water 1, or Hot-Water 2. Compliance with the cooling only performance is required as defined in footnotes a and d.
k. Chilling packages employing a freeze-protection liquid in accordance with Section 6.4.1.2.2 shall be tested or rated with water for the purpose of compliance with the requirements of this table.
l. Outdoor air entering dry-bulb (db) temperature and wet-bulb (wb) temperature.
m. Source-leaving liquid temperature.
- The cooling evaporator liquid flow rate used for the heating rating for a reverse cycle air-to-water heat pump shall be the flow rate determined during the full-load cooling rating.
- The cooling evaporator liquid flow rate for the simultaneous cooling and heating and heat recovery liquid cooled chilling packages rating shall be the liquid flow rates from the cooling operation full load rating.
- For heating-only fluid-to-fluid chiller packages, the evaporator flow rate obtained with an entering liquid temperature of 54.00°F and a leaving liquid temperature of 44.00°F shall be used.

n. The size category is the full-load net refrigerating cooling mode capacity, which is the capacity of the evaporator available for cooling of the thermal load external to the chilling package.
o A heat recovery condenser at its maximum load point must remove enough heat from the refrigerant to cool the refrigerant to remove all superheat energy and begin condensation of the refrigerant. A heat recovery system where only the superheat is reduced is not covered by Table 6.8.1-16 and is considered a desuperheater, and the chiller package must comply with Table 6.8.1-3.
p. "NA" means the requirements are not applicable.
q. Water-to-water heat pumps with a capacity less than 135,000 Btu/h are covered by Table 6.8.1-15.

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Table 6.8.1-17 Ceiling-Mounted Computer-Room Air Conditioners—Minimum Efficiency Requirements

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

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Table 6.8.1-17 Ceiling-Mounted Computer-Room Air Conditioners—Minimum Efficiency Requirements *(Continued)*

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

Table 6.8.1-18 Walk-In Cooler and Freezer Display Door Efficiency Requirements

Class Descriptor	Class	Maximum Energy Consumption, kWh/day[a]	Test Procedure
Display door, medium temperature	DD, M	$0.04 \times A_{dd} + 0.41$	10 CFR 431
Display door, low temperature	DD, L	$0.15 \times A_{dd} + 0.29$	10 CFR 431

a. A_{dd} is the surface area (ft^2) of the display door.

Table 6.8.1-19 Walk-In Cooler and Freezer Nondisplay Door Efficiency Requirements

Class Descriptor	Class	Maximum Energy Consumption, kWh/day[a]	Test Procedure
Passage door, medium temperature	PD, M	$0.05 \times A_{nd} + 1.7$	10 CFR 431
Passage door, low temperature	PD, L	$0.14 \times A_{nd} + 4.8$	10 CFR 431
Freight door, medium temperature	FD, M	$0.04 \times A_{nd} + 1.9$	10 CFR 431
Freight door, low temperature	FD, L	$0.12\ A_{nd} + 5.6$	10 CFR 431

a. A_{nd} is the surface area (ft^2) of the non-display door.

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Table 6.8.1-20 Walk-In Cooler and Freezer Refrigeration System Efficiency Requirements

Class Descriptor	Class	Minimum Annual Walk-In Energy Factor AWEF, Btu/W·h [a]	Test Procedure	Compliance Date: Equipment Manufactured Starting On
Dedicated condensing, medium temperature, indoor system	DC.M.I	5.61	AHRI 1250	June 5, 2017
Dedicated condensing, medium temperature, outdoor system	DC.M.O	7.60	AHRI 1250	June 5, 2017
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) < 6500 Btu/h	DC.L.I <6500 Btu/h	$9.091 \times 10^{-5} \times q_{net} + 1.81$	AHRI 1250	July 10, 2020
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) ≥ 6500 Btu/h	DC.L.I, ≥6500 Btu/h	2.40	AHRI 1250	July 10, 2020
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) < 6500 Btu/h	DC.L.O, <6500 Btu/h	$6.522 \times 10^{-5} \times q_{net} + 2.73$	AHRI 1250	July 10, 2020
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) ≥ 6500 Btu/h	DC.L.O, ≥6500 Btu/h	3.15	AHRI 1250	July 10, 2020
Unit cooler, medium	UC.M	9.00	AHRI 1250	July 10, 2020
Unit cooler, low temperature, net capacity (q_{net}) < 15,500 Btu/h	UC.L, <15,500 Btu/h	$1.575 \times 10^{-5} \times q_{net} + 3.91$	AHRI 1250	July 10, 2020
Unit cooler, low temperature, net capacity (q_{net}) ≥ 15,500 Btu/h	UC.L, ≥15,500 Btu/h	4.15	AHRI 1250	July 10, 2020

a. q_{net} is net capacity (Btu/h) as determined in accordance with AHRI 1250.

Table 6.8.1-21 Ceiling Fan Efficiency Requirements [a]

Equipment Type	Size Category	Minimum Efficiency[b]	Test Procedure[c]
Large-diameter ceiling fan for applications outside the U.S.	Blade span ≥ 84.5 in.	*CFEI* ≥ 1.00 at high (maximum) speed; and *CFEI* ≥ 1.31 at 40% of high speed or the nearest speed that is not less than 40% of high speed	10 CFR 430 Appendix U or AMCA Standard 230 and AMCA Standard 208

a. The minimum *efficiency* requirements at both high speed and 40% of maximum speed must be met or exceeded to comply with this standard.
b. *Ceiling fans* are regulated in the U.S. as consumer products under 10 CFR 430. For U.S. applications of large-diameter ceiling fans, refer to Informative Appendix F, Table F-6, for the U.S. DOE minimum *efficiency* requirements.
c. Section 13 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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Table 6.8.2 Minimum Duct Insulation R-Value[a]

Climate Zone	Duct Location		
	Exterior [b]	Unconditioned Space and Buried Ducts	Indirectly Conditioned Space [c,d]
Supply and Return Ducts for Heating and Cooling			
0 to 4	R-8	R-6	R-1.9
5 to 8	R-12	R-6	R-1.9
Supply and Return Ducts for Heating Only			
0 to 1	None	None	None
2 to 4	R-6	R-6	R-1.9
5 to 8	R-12	R-6	R-1.9
Supply and Return Ducts for Cooling Only			
0 to 6	R-8	R-6	R-1.9
7 to 8	R-1.9	R-1.9	R-1.9

a. Insulation *R-values*, measured in h·ft^2·°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 portions of the *building envelope* are used as a *plenum* enclosure, *building envelope* insulation shall be as required by the most restrictive condition of Section 6.4.4.1 or Section 5, depending on whether the *plenum* is located in the *roof*, *wall*, or *floor*. 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 attics above insulated ceilings, parking garages and crawl *spaces*.

c. Includes return air *plenums* with or without exposed *roofs* above.

d. Return ducts in this duct location do not require insulation.

Table 6.8.3-1 Minimum Piping Insulation Thickness Heating and Hot-Water Systems[a,b,c,d] (Steam, Steam Condensate, Hot-Water Heating and Domestic Water Systems)

Fluid Operating Temperature Range (°F) and Usage	Insulation Thermal Conductivity		≥Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in/h·ft^2·°F	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
>350	0.32 to 0.34	250	4.5	5.0	5.0	5.0	5.0
251 to 350	0.29 to 0.32	200	3.0	4.0	4.5	4.5	4.5
201 to 250	0.27 to 0.30	150	2.5	2.5	2.5	3.0	3.0
141 to 200	0.25 to 0.29	125	1.5	1.5	2.0	2.0	2.0
105 to 140	0.22 to 0.28	100	1.0	1.0	1.5	1.5	1.5
For *service water heating systems*, see Table 7.4-2.							

a. These thicknesses are based on *energy efficiency* considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

b. 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.

c. 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.

d. *Piping* that also serves *service water heating systems* shall comply with Section 7.4.

Table 6.8.3-2 Minimum Piping Insulation Thickness Cooling Systems (Chilled Water, Brine, and Refrigerant)[a,b]

Fluid Operating Temperature Range (°F) and Usage	Insulation Thermal Conductivity		Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in/h·ft^2·°F	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
40 to 60	0.21 to 0.27	75	0.5	0.5	1.0	1.0	1.0
<40	0.20 to 0.26	50	0.5	1.0	1.0	1.0	1.5

a. 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.

b. For direct-buried cooling *system piping*, insulation is not required.

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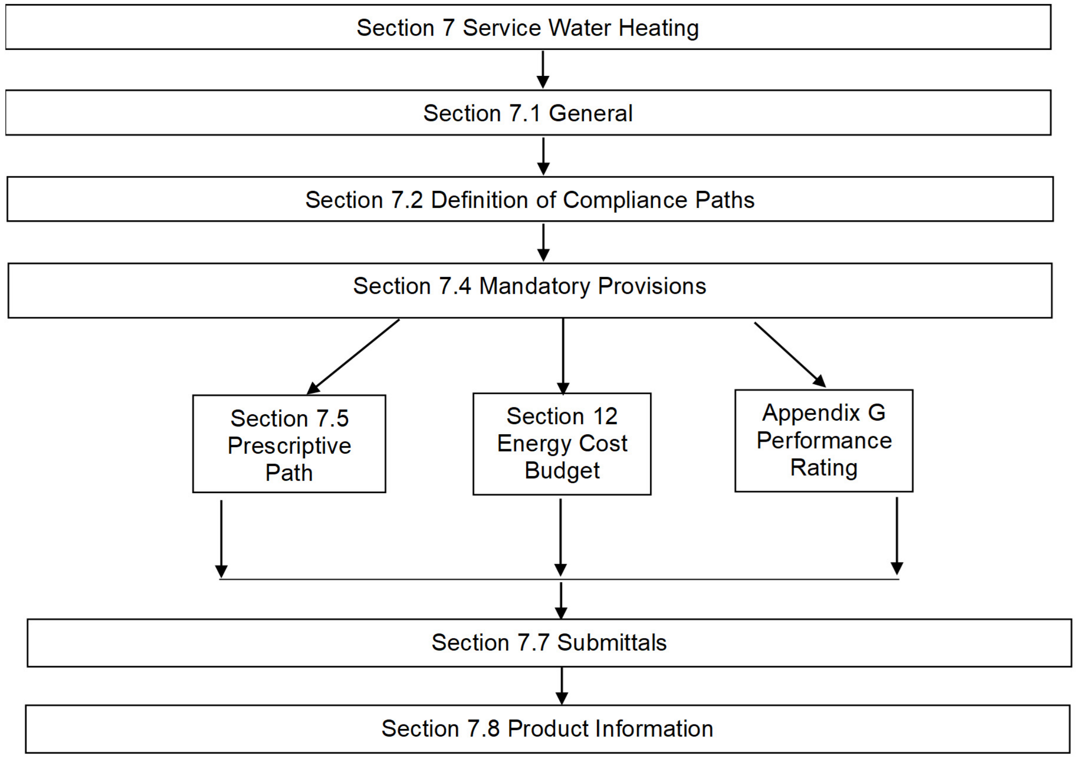

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7. SERVICE WATER HEATING

7.1 General

7.1.1 Service Water-Heating Scope. Section 7 specifies requirements for *service water-heating systems* and *equipment.*

7.1.2 New Buildings. *Service water-heating systems* and *equipment* shall comply with the requirements of Section 7.2.

7.1.3 Additions to Existing Buildings. *Service water-heating systems* and *equipment* shall comply with the requirements of Section 7.2.

Exception to 7.1.3: 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*.

7.1.4 Alterations to Service Water-Heating Systems and Equipment. *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 to 7.1.4: Compliance shall not be required where there is insufficient *space* or access to meet these requirements.

7.2 Compliance Paths.

Service water heating systems and *equipment* shall comply with Sections 7.2.1 and 7.2.2.

7.2.1 Requirements for All Compliance Paths. *Service water heating systems* and *equipment* shall comply with Sections 7.1, “General”; 7.4, “Mandatory Provisions”; 7.7, “Submittals”; and 7.8, “Product Information.”

7.2.2 Additional Requirements to Comply with Section 7. *Service water heating systems* and *equipment* shall comply with Section 7.5, “Prescriptive Compliance Path.”

7.3 Simplified Building Compliance Path (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 the *manufacturer*’s published sizing guidelines or

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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 7.4-1. 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 7.4-1 has no minimum performance requirements.

Exceptions to 7.4.2: 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 7.4-1 when

1. the tank surface is thermally insulated to R-12.5,
2. a standing pilot light is not installed, and
3. gas- or oil-fired storage *water heaters* have a *flue damper* or fan-assisted combustion.

7.4.3 Service Water Heating System Piping Insulation. *Service water heating system piping* shall be surrounded by uncompressed insulation of the thickness shown in Table 7.4-2. When the insulation thermal conductivity is not within the range in the table, the following equation shall be used to calculate the minimum insulation thickness:

$$t_{alt} = r[(1 + t_{table}/r) \times k_{alt}/k_{upper} - 1]$$

where

t_{alt} = minimum insulation thickness of the alternate material, in.

r = actual outside radius of pipe, in.

t_{table} = insulation thickness listed in Table 7.4-2 for applicable fluid temperature and pipe size

k_{alt} = *thermal conductivity* of the alternate material at mean rating temperature indicated for the applicable fluid temperature, $Btu \cdot in/h \cdot ft^2 \cdot °F$

k_{upper} = upper value of the *thermal conductivity* range listed in this table for the applicable fluid temperature, $Btu \cdot in/h \cdot ft^2 \cdot °F$

Exception to 7.4.3: For nonmetallic *piping* thicker than Schedule 80 and 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.

7.4.3.1 The following *piping* shall be insulated per the requirements of this section:

a. *Recirculating system piping*, including the supply and return *piping*
b. The first 8 ft of outlet *piping* from
   1. storage *water heaters*,
   2. hot-water storage tanks, and
   3. any *water heater* and *hot-water supply boiler* containing 10 gal or more of water heated by a direct heat source, an indirect heat source, or both a direct heat source and an indirect heat source.
c. The first 8 ft of branch *piping* connecting to recirculated, *heat traced*, or impedance heated *piping*.
d. The make-up water inlet *piping* between heat traps (see Section 7.4.6) and the storage *water heaters* and the storage tank they are serving, in a *nonrecirculating service water heating system*.
e. Hot-water *piping* between multiple *water heaters*, between multiple hot-water storage tanks, and between *water heaters* and hot-water storage tanks.
f. *Piping* that is externally heated (such as *heat trace* or impedance heating).

Exceptions to 7.4.3.1:

1. Factory-installed *piping* within *water heaters* and hot-water storage tanks tested and rated in accordance with Section 6.4.1.
2. *Piping* that conveys hot water that has not been heated through the use of *fossil fuels* or electricity.
3. For *piping* 1 in. or less, insulation is not required for valves or strainers.
4. *Piping* in *existing buildings* where *alterations* are made to existing *service water heating systems* where there is insufficient space or access to meet the requirements.
5. Insulation is not required at the point where *piping* passes through a framing member if it requires increasing the size of the framing member.
6. Insulation is not required on *piping* at the point where a vertical support of the *piping* is installed.

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Table 7.4-1 Performance Requirements for Water-Heating Equipment—Minimum Efficiency Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure[b,c]
Electric table-top *water heaters*	≤12 *kW*	<4000 (Btu/h)/gal ≥20 gal and ≤120 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
Electric storage *water heaters*	≤12 *kW*	<4000 (Btu/h)/gal ≥20 gal and ≤55 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
		<4000 (Btu/h)/gal >55 gal and ≤120 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
	>12 *kW*	<4000 (Btu/h)/gal	$SL \le 0.3 + 27/V_m$ %/h	10 CFR 431.106
Electric instantaneous *water heaters*	≤12 *kW*	≥4000 (Btu/h)/gal <2 gal	For applications outside US, see footnote (h). For US applications, see footnote (g).	10 CFR 430 Appendix E
	>12 *kW* and ≤58.6 *kW* [c]	≥4000 (Btu/h)/gal ≤2 gal ≤180°F	Very small DP: UEF = 0.80 Low DP: UEF = 0.80 Medium DP: UEF = 0.80 High DP: UEF = 0.80	10 CFR 430 Appendix E
	>58.6 *kW* [c]	≥4000 (Btu/h)/gal <10 gal	No requirement	
		≥4000 (Btu/h)/gal ≥10 gal	No requirement	
Gas storage water heaters	≤75,000 Btu/h	<4000 (Btu/h)/gal ≥20 gal and ≤55 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
		<4000 (Btu/h)/gal >55 gal and ≤100 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
	>75,000 Btu/h and ≤105,000 Btu/h [d]	<4000 (Btu/h)/gal ≤120 gal ≤180°F	Very small DP: $UEF = 0.2674 - (0.0009 \times V_r)$ Low DP: $UEF = 0.5362 - (0.0012 \times V_r)$ Medium DP: $UEF = 0.6002 - (0.0011 \times V_r)$ High DP: $UEF = 0.6597 - (0.0009 \times V_r)$	10 CFR 430 Appendix E
	>105,000 Btu/h [d,f]	<4000 (Btu/h)/gal	80% E_t $SL \le (Q/800 + 110\sqrt{V})$, Btu/h	10 CFR 431.106
Gas instantaneous water heaters	>50,000 Btu/h and ≤200,000 Btu/h	≥4000 (Btu/h)/gal <2 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
	≥200,000 Btu/h [d,f]	≥4000 (Btu/h)/gal <10 gal	80% E_t	10 CFR 431.106
	≥200,000 Btu/h [f]	≥4000 (Btu/h)/gal ≥10 gal	80% E_t $SL \le (Q/800 + 110\sqrt{V})$, Btu/h	

a. Thermal *efficiency* (E_t) is a minimum requirement, while standby loss is a maximum requirement. In the standby loss equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h. V_m is the measured volume in the tank in gallons. Standby loss for electric water heaters is in terms of %/h and denoted by the term "S," and standby loss for gas and oil water heaters is in terms of Btu/h and denoted by the term "SL." Draw pattern (DP) refers to the water draw profile in the uniform *energy factor* (UEF) test. UEF and *energy factor* (*EF*) are minimum requirements. In the UEF standard equations, V_r refers to the rated volume in gallons.

b. Section 13 contains a complete specification, including the year version, of the referenced test procedure.

c. Electric instantaneous water heaters with input capacity >12 kW and ≤58.6 kW must comply with the requirements for the 58.6 kW if the water heater either (1) has a storage volume >2 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power.

d. Gas storage water heaters with input capacity >75,000 Btu/h and ≤105,000 Btu/h must comply with the requirements for the >105,000 Btu/h if the water heater either (1) has a storage volume >120 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power

e. Oil storage water heaters with input capacity >105,000 Btu/h and ≤140,000 Btu/h must comply with the requirements for the >140,000 Btu/h if the water heater either (1) has a storage volume >120 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power

f. Refer to Section 7.5.3 for additional requirements for gas storage and instantaneous *water heaters* and gas *hot-water supply boilers*.

g. *Water heaters* or gas *pool* heaters in this category or subcategory are regulated as consumer products by the U.S. DOE as defined in 10 CFR 430.

h. Where this standard is being applied to a building outside the U.S. and Canada and water heaters in this subcategory are being installed in that building, those water heaters shall meet the local efficiency requirements. If there are no local efficiency standards for residential water heaters, consideration should be given to using the U.S. DOE efficiency requirements shown in Informative Appendix F, Table F-2.

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Table 7.4-1 Performance Requirements for Water-Heating Equipment—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure[b,c]
Oil storage water heaters	≤105,000 Btu/h	<4000(Btu/h)/gal ≤50 gal	For applications outside U.S., see footnote (h). For U.S. applications, see footnote (g).	10 CFR 430 Appendix E
	>105,000 Btu/h and ≤140,000 Btu/h [e]	≤120 gal <4000 (Btu/h)/gal ≤180°F	Very small DP: UEF = 0.2932 – (0.0015 × V_r) Low DP: UEF = 0.5596 – (0.0018 × V_r) Medium DP: UEF = 0.6194 – (0.0016 × V_r) High DP: UEF = 0.6740 – (0.0013 × V_r)	10 CFR 430 Appendix E
	>140,000 Btu/h	<4000 (Btu/h)/gal	80% E_t SL ≤ (Q/800 + 110 $\sqrt{V}$), Btu/h	10 CFR 431.106
Oil instantaneous water heaters	≤210,000 Btu/h	≥4000 (Btu/h)/gal <2 gal	80% E_t $EF \geq 0.59 - 0.0005 \times V$	10 CFR 430 Appendix E
	>210,000 Btu/h	≥4000 (Btu/h)/gal <10 gal	80% E_t	10 CFR 431.106
	>210,000 Btu/h	≥4000 (Btu/h)/gal ≥10 gal	78% E_t SL ≤ (Q/800 + 110 $\sqrt{V}$), Btu/h	
Hot-water supply boilers, gas and oil [f]	≥300,000 Btu/h and <12,500,000 Btu/h	≥4000 (Btu/h)/gal <10 gal	80% E_t	10 CFR 431.106
Hot-water supply boilers, gas [f]	≥300,000 Btu/h and <12,500,000 Btu/h	≥4000 (Btu/h)/gal ≥10 gal	80% E_t SL ≤ (Q/800 + 110 $\sqrt{V}$), Btu/h	10 CFR 431.106
Hot-water supply boilers, oil	≥300,000 Btu/h and <12,500,000 Btu/h	≥4000 (Btu/h)/gal ≥10 gal	78% E_t SL ≤ (Q/800 + 110 $\sqrt{V}$), Btu/h	10 CFR 431.106
Pool heaters, gas	All		82% E_t for commercial *pool* heaters and for applications outside U.S. For U.S. applications, see footnote (g).	10 CFR 430 Appendix P
Heat pump *pool* heaters	All	50°F db 44.2°F wb *outdoor air* 80.0°F entering water	4.0 *COP*	10 CFR 430 Appendix P
Unfired storage tanks	All		R-12.5	(none)

a. Thermal *efficiency* (E_t) is a minimum requirement, while standby loss is a maximum requirement. In the standby loss equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h. V_m is the measured volume in the tank in gallons. Standby loss for electric water heaters is in terms of %/h and denoted by the term "S," and standby loss for gas and oil water heaters is in terms of Btu/h and denoted by the term "SL." Draw pattern (DP) refers to the water draw profile in the uniform *energy factor* (UEF) test. UEF and *energy factor* (*EF*) are minimum requirements. In the UEF standard equations, V_r refers to the rated volume in gallons.

b. Section 13 contains a complete specification, including the year version, of the referenced test procedure.

c. Electric instantaneous water heaters with input capacity >12 kW and ≤58.6 kW must comply with the requirements for the 58.6 kW if the water heater either (1) has a storage volume >2 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power.

d. Gas storage water heaters with input capacity >75,000 Btu/h and ≤105,000 Btu/h must comply with the requirements for the >105,000 Btu/h if the water heater either (1) has a storage volume >120 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power

e. Oil storage water heaters with input capacity >105,000 Btu/h and ≤140,000 Btu/h must comply with the requirements for the >140,000 Btu/h if the water heater either (1) has a storage volume >120 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power

f. Refer to Section 7.5.3 for additional requirements for gas storage and instantaneous *water heaters* and gas *hot-water supply boilers*.

g. *Water heaters* or gas *pool* heaters in this category or subcategory are regulated as consumer products by the U.S. DOE as defined in 10 CFR 430.

h. Where this standard is being applied to a building outside the U.S. and Canada and water heaters in this subcategory are being installed in that building, those water heaters shall meet the local efficiency requirements. If there are no local efficiency standards for residential water heaters, consideration should be given to using the U.S. DOE efficiency requirements shown in Informative Appendix F, Table F-2.

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Table 7.4-2 Minimum Piping Insulation Thickness for Service Water Heating Systems [a,b]

Service Hot-Water Temperature Range	Insulation Thermal 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.				
Service Water Heating System Piping not Located in Partitions within *Conditioned Spaces*							
105°F to 140°F	0.22 to 0.28	100	1.0	1.0	1.5	2.0	2.0
>140°F to 200°F	0.25 to 0.29	125	1.5	1.5	2.5	2.5	2.5
>200°F	0.27 to 0.30	150	2.5	2.5	3.0	3.0	3.0
Service Water Heating System Piping Located in Partitions within *Conditioned Spaces*							
105°F to 140°F	0.22 to 0.28	100	1.0	1.0	1.5	1.5	1.5
>140°F to 200°F	0.25 to 0.29	125	1.0	1.0	2.0	2.0	2.0
>200°F	0.27 to 0.30	150	1.5	1.5	2.5	3.0	3.0

a. These thicknesses are based on *energy efficiency* considerations only. Additional insulation may be necessary for safety.
b. For direct-buried *service water heating system piping*, reduction of these thicknesses by 1.5 in. shall be permitted (before thickness adjustment required in Section 7.4.3 but not to thicknesses less than 1 in.).

7.4.4 Service Water-Heating System Controls

Informative Note: *Service water heating system* control settings and operating temperatures should be determined in accordance with the ASHRAE Standard 188 *building* water *systems* water management program for the *building*, or with *generally accepted engineering standards* and guidance (e.g., ASHRAE Guideline 12).

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 to 7.4.4.1: 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 to 7.4.5.2: *Pools* deriving over 60% of the *energy* for heating from *site-recovered energy* or *on-site renewable energy*.

7.4.5.3 Time Switches. Time switches shall be installed on swimming *pool* heaters and *pumps*.

Exceptions to 7.4.5.3:

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) a device specifically designed for the purpose or an

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arrangement of tubing that forms a loop of 360 degrees, or (b) *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 Compliance Path

7.5.1 Space Heating and Service 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 *service 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 Large Service Water-Heating Systems. New *buildings* with *service water-heating systems* with a total installed input capacity of 1,000,000 Btu/h or greater, provided by high-capacity gas-fired *service water-heating equipment*, shall meet either or both of the following requirements:

a. Where a single unit of high-capacity gas-fired *service water-heating equipment* is installed, it shall have a minimum thermal *efficiency* (E_t) of 92%.

b. Multiple units of high-capacity gas-fired *service water-heating equipment* connected to the same *service water-heating system* shall have a total input capacity-weighted average thermal *efficiency* (E_t) of at least 90%, and a minimum of 30% of the input of the high-capacity gas-fired *service water-heating equipment* in the *service water heating-system* shall have a thermal *efficiency* (E_t) of at least 92%.

High-capacity gas-fired *service water-heating equipment* comprises gas-fired instantaneous *water heaters* with a rated input both greater than 200,000 Btu/h and not less than 4000 Btu/h per gallon of stored water, and gas-fired storage *water heaters* with a rated input both greater than 105,000 Btu/h and less than 4000 Btu/h per gallon of stored water.

Exceptions to 7.5.3:

1. *Water heaters* installed in individual *dwelling units*.
2. 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. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

7.7.2 Permit Application Documentation (Not Used)

7.7.3 Completion Requirements

7.7.3.1 Record Documents. *Construction documents* shall require that, within 90 days after the date of *building envelope* acceptance, *record documents* be provided to the *building* owner or the designated representative of the *building* owner.

7.7.3.2 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 and shall include, at a minimum, operation manuals and maintenance manuals for each component of the *system* requiring maintenance, except components not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

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7.8 Product Information

7.9 Verification, Testing, and Commissioning

7.9.1 Verification and Testing. Service hot-water controls shall be verified and tested in accordance with this section and Section 4.2.5.1. Testing shall verify that *systems* and controls are configured and operating in accordance with applicable requirements of

a. *service water heating system* temperature controls (Sections 7.4.4.1 and 7.4.4.3),
b. recirculation *pump* or *heat trace* controls (Section 7.4.4.2), or
c. *pool* time switch controls (Section 7.4.5.3).

Verification and *FPT* documentation shall comply with Section 4.2.5.1.2.

7.9.2 Commissioning. The *energy* performance of the *service water heating systems* shall be *commissioned* in accordance with Section 4.2.5.2, and reporting shall comply with Section 4.2.5.2.2.

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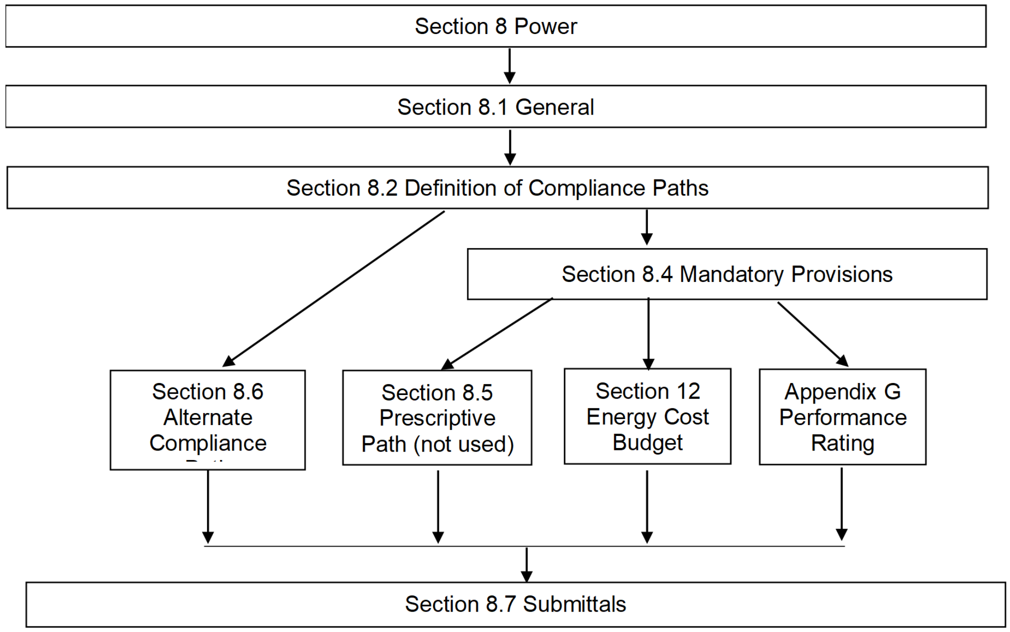

8. POWER

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 Building or Site System or Equipment. *Building power distribution equipment* installed shall comply with the requirements of Section 8.2.

8.1.3 Addition to Existing Systems and Equipment. *Building power distribution equipment* installed in *addition* to *existing buildings* and *existing sites* shall comply with the requirements of Section 8.2.

8.1.4 Alterations to Existing Service Equipment or Systems

Exception to 8.1.4: 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* shall comply with the requirements of Section 8, as applicable to those specific portions of the *building* that are being altered.

8.1.4.2 *Alterations* to *systems* shall comply with the requirements of Section 8, as applicable to those specific portions that are being altered.

8.1.4.3 Any new *equipment* subject to the requirements of Section 8 that is installed in conjunction with the *alterations* as a direct replacement of *existing equipment* shall comply with the specific requirements, as applicable to that *equipment*.

8.2 Compliance Paths. Power *distribution systems* and *equipment* shall comply with Sections 8.2.1 and 8.2.2.

8.2.1 Requirements for All Compliance Paths. Power *distribution systems* and *equipment* only shall comply with Sections 8.1, "General"; 8.4, "Mandatory Provisions"; and 8.7, "Submittals."

Exception to 8.2.1: Power *distribution systems* and *equipment* only serving a *computer room* with IT *equipment* load greater than 10 *kW* shall be permitted to comply with Section 8.6, "Alternative Compliance Path."

8.2.2 Additional Requirements to Comply with Section 8 (Not Used)

8.3 Simplified Building Compliance Path (Not Used)

8.4 Mandatory Provisions

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8.4.1 Voltage Drop. The *feeder conductors* and *branch circuits* combined shall be sized for a maximum of 5% *voltage drop* total.

8.4.2 Automatic Receptacle Control. The following shall be *automatically* controlled:

a. At least 50% of all 125 V, 15 and 20 amp receptacles in all private offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, classrooms, and individual workstations.
b. At least 25% of *branch circuit* feeders installed for modular furniture not shown on the *construction documents*.

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 *occupancy 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 to 8.4.2: Receptacles for the following shall not require an *automatic control device*:

1. Receptacles specifically designated for *equipment* requiring continuous operation (24/day, 365 days/year).
2. *Spaces* where an *automatic* control would endanger the safety or security of the room or *building* occupants.

8.4.3 Electrical Energy Monitoring

8.4.3.1 Monitoring. Measurement devices shall be installed in new *buildings* to monitor the electrical *energy* use for each of the following separately:

a. Total electrical *energy*
b. *HVAC systems*
c. Interior lighting
d. Exterior lighting
e. Receptacle circuits
f. Refrigeration *systems*

For *buildings* with tenants, these *systems* shall be separately monitored for the total *building* and (excluding shared *systems*) for each individual tenant.

Exception to 8.4.3.1: Where the design load of any of the categories (b) through (f) are less than 10% of the whole-building load, these categories shall be allowed to be combined with other categories.

8.4.3.2 Recording and Reporting. The electrical *energy* use for all loads specified in Section 8.4.3.1 shall be recorded a minimum of every 15 minutes and reported at least hourly, daily, monthly, and annually. The data for each tenant *space* shall be made available to that tenant. In *buildings* with a digital control *system* installed to comply with Section 6.4.3.10, the *energy* use data shall be transmitted to the digital control *system* and graphically displayed. The *system* shall be capable of maintaining all data collected for a minimum of 36 months.

Exceptions to 8.4.3.1 and 8.4.3.2:

1. *Building* 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. Critical *equipment* and life-safety branches of NFPA 70, Article 517.

8.4.4 Low-Voltage Dry-Type Distribution Transformers. Low-voltage dry-type distribution *transformers* shall comply with the requirements shown in Table 8.4.4. *Transformers* that are not included in the definition of distribution *transformers* as defined in 10 CFR 431.192 have no performance requirements in this section and are listed for ease of reference as exceptions.

Exception to 8.4.4: *Transformers* that meet any of the following exclusions in the U.S. DOE definition of "distribution transformers" found in 10 CFR 431.192:

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Table 8.4.4 Minimum Nominal Efficiency Levels for Low-Voltage Dry-Type Distribution Transformers [a,b]

Single-Phase Transformers		Three-Phase Transformers	
kVA [c]	**Efficiency,% [d]**	**kVA [c]**	**Efficiency,% [d]**
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.60	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
		750	99.23
		1000	99.28

a. A low-voltage dry-type 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. A low-voltage dry-type distribution *transformer* with a *kVA* rating not listed in the table shall have its minimum efficiency level determined by linear interpolation of the *kVA* and efficiency values listed in the table immediately above and below its *kVA* rating. Extrapolation shall not be used below the minimum values or above the maximum values shown for single-phase *transformers* and three-phase *transformers*.
b. *Kilovolt-ampere* rating.
c. Nominal efficiencies shall be established in accordance with the 10 CFR 431.193 test procedure for low-voltage dry-type distribution *transformers*.

1. *Transformers* with tap range of 20% or more.
2. Drive (isolation) *transformer*.
3. Rectifier *transformer*.
4. Auto-*transformer*.
5. Uninterruptible power supply *transformer*.
6. Special impedance *transformer*.
7. Regulating *transformer*.
8. Sealed and nonventilating *transformer*.
9. Machine-tool (control) *transformer*.
10. Welding *transformer*.
11. Grounding *transformer*.
12. Testing *transformer*.
13. Nonventilated *transformer*.

8.5 Prescriptive Path (Not Used)

8.6 Alternative Compliance Path

8.6.1 Computer Room Systems. Power *distribution systems* and *equipment* only serving a *computer room* with IT *equipment* load greater than 10 *kW* shall comply with ASHRAE Standard 90.4, *Energy Standard for Data Centers.*

8.7 Submittals

8.7.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

8.7.2 Permit Application Documentation (Not Used)

8.7.3 Completion Requirements

8.7.3.1 Record Documents. *Construction documents* shall require that within 90 days after the date of *system* acceptance, *record documents* shall be provided to the *property* owner, including

a. a *single-line diagram* of the *property* electrical *distribution system*,
b. *floor* plans indicating location and area served for all distribution, and
c. *site* plans indicating location and area served for all distribution.

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8.7.3.2 Manuals. *Construction documents* shall require that an operating manual and maintenance manual be provided to the *property* 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)

8.9 Verification, Testing, and Commissioning

8.9.1 Verification and Testing. *Building* power *distribution systems* and applicable *equipment* shall be verified and tested in accordance with this section and provisions of Section 4.2.5.1. Testing shall verify that control elements are configured and operating in accordance with applicable requirements of

a. *automatic* receptacles controls (Section 8.4.2) and
b. *energy* monitoring (Section 8.4.3).

Verification and *FPT* documentation shall comply with Section 4.2.5.1.

8.9.2 Commissioning. The *energy* performance of the power *systems* shall be *commissioned* in accordance with Section 4.2.5.2, and reporting shall comply with Section 4.2.5.2.2.

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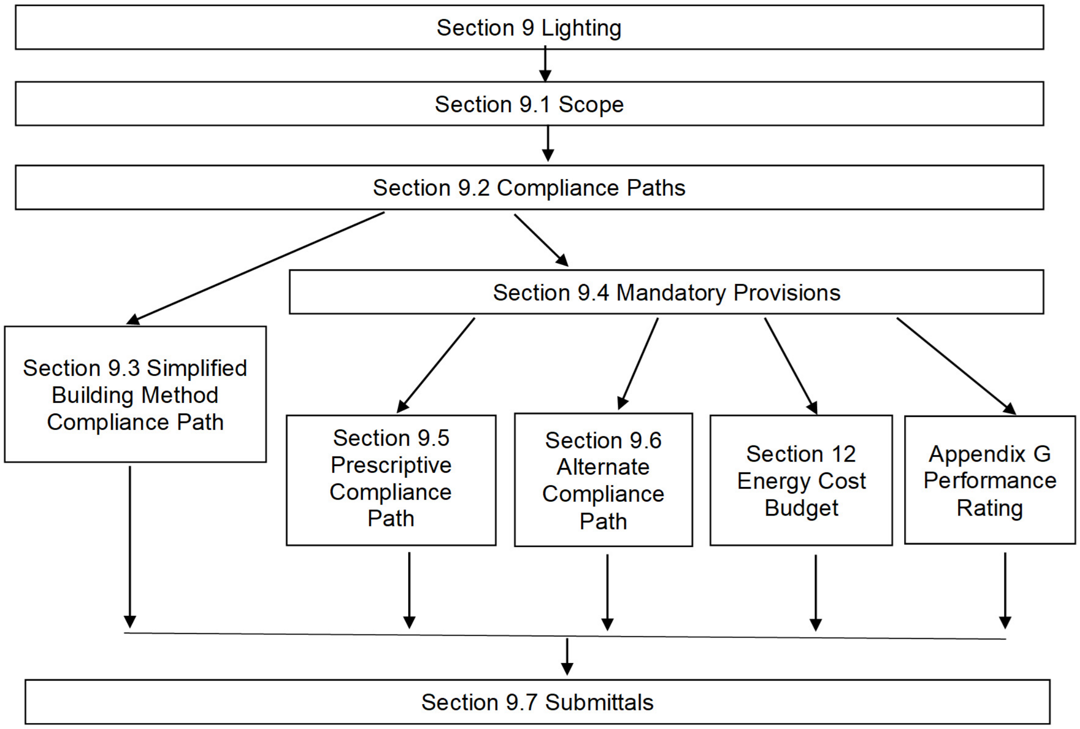

9. LIGHTING

9.1 General

9.1.1 Scope

9.1.1.1 New Building or Site System or Equipment. Lighting *equipment* and *systems* serving the lighting needs of new *buildings* or new ***site*** *systems* and *equipment* shall comply with the requirements of this section as described in Section 9.2.

This section shall apply to the following:

a. Lighting *equipment* and *systems* serving interior *spaces* of *buildings*.
b. Lighting *equipment* and *systems* serving exterior applications.

Exceptions to 9.1.1.1:

1. Emergency lighting that is *automatically* off during normal operation.
2. Lighting, including exit signs, that is specifically designated as required by a health or life safety statute, ordinance, or regulation.
3. Decorative gas *lighting systems*.

9.1.1.2 Additions to Existing Systems and Equipment. Lighting *equipment* and *systems* installed in *addition* to *existing buildings* and *existing sites* shall comply with the requirements of Section 9.1.1.1.

9.1.1.3 Alterations to Existing Systems and Equipment. The *alteration* of *lighting equipment* and *systems* in an interior *space* shall comply with Section 9.1.1.3.1. The *alteration* of a *lighting system* in an exterior application shall comply with Section 9.1.1.3.2.

The maintenance of an existing *lighting system* to return it to working order shall not be considered an *alteration*. Retrofitting a *luminaire* for which the original *lamps* and *ballast/driver* are replaced with a new *lamp/light source* and *driver/ballast* that was not a component of the original *luminaire* shall be considered an *alteration*.

9.1.1.3.1 Alterations for Interior Building Spaces. The *alteration* of a *lighting system* in an interior *space* shall meet one of the following requirements:

a. The *alteration* shall comply with Section 9.2 when the total wattage of all new and retrofitted *luminaires* is greater than 2000 W.
b. When the total wattage of all new and retrofitted *luminaires* is 2000 W or less, each altered *space* shall comply with the *LPA* of Tables 9.5.2.1-1 and 9.5.2.1-2 and Section 9.5.2.2, or the *alteration* shall result

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in a new wattage at least 50% below the original wattage of each altered *lighting system*. Additionally, the new and retrofitted lighting shall comply with the control requirements of Sections 9.4.1.1(a), 9.4.1.1(h), 9.4.1.1(i) as applicable to each altered *space* as shown in Tables 9.5.2.1-1 and 9.5.2.1-2 and Section 9.5.2.2.

9.1.1.3.2 Lighting Alterations for Exterior Building Areas. The *alteration* of a *lighting system* for an exterior area shall use only the area-specific allowances in Table 9.4.2-2 and shall not use the base *site* allowances to determine the *LPA*. Additionally, the exterior *alteration* shall meet one of the following:

a. The *alteration* shall comply with Section 9.2 when the total number of new and retrofitted *luminaires* is greater than 10 or where the combined length of new and retrofitted linear *luminaires* is greater than 20 linear feet.
b. Where the total number of new and retrofitted *luminaires* is not greater than 10, or where the combined length of new and retrofitted linear *luminaires* is not greater than 20 linear feet of linear *luminaires*, the total wattage of the *alteration* shall be no greater than the maximum *LPA* permitted by Table 9.4.2-2, or the total new wattage shall be at least 50% below the total original wattage of that *lighting system*. Additionally, the new and retrofitted lighting shall comply with the control requirements of Section 9.4.1.4(a).

9.1.2 Climate. Climate zones shall be determined in accordance with Section 5.1.5.

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/drivers*, *transformers*, and *control devices*, except as specifically exempted in Section 9.1.1, 9.2.2.1, or 9.2.2.2.

Exception to 9.1.3: 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. The wattage of lighting *equipment*, 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 lighting *equipment* connected to line voltage shall be the *manufacturers*' *labeled* maximum wattage.
b. The wattage of line voltage lighting *equipment* with remote *ballasts/drivers* or similar devices shall be the total input wattage of all line voltage components in the *system*.

   Exception to 9.1.4(b): 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 field-changeable.
c. The wattage of line-voltage lighting track and plug-in busway designed to allow the addition and/or relocation of lighting *equipment* without altering the wiring of the *system* shall be the lesser of
   1. the specified wattage of the lighting *equipment* included in the *system* with a minimum of 10 W/lin ft or
   2. the wattage limit of permanent current-limiting devices 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 lighting *equipment* without altering the wiring of the *system* shall be the specified wattage of the *ballast/driver* or *transformer* supplying the *system*.
e. The wattage of a DC low-voltage *lighting system* that employs flexible cabling for plug-in connection of the lighting *equipment* and a remote power supply shall be *labeled* maximum wattage of the *system* power supply. For *systems* that also provide power to *equipment* other than lighting, the wattage shall be *labeled* maximum wattage of the *system* power supply reduced by the wattage of the nonlighting *equipment* connected to the *system*.
f. The wattage of a retrofitted *luminaire* shall be the *manufacturer's labeled* input power of the new *light source* plus *driver.*
g. The wattage of all other miscellaneous lighting *equipment* shall be the specified wattage of the lighting *equipment*.

9.2 Compliance Paths. *Lighting systems* and *equipment* shall comply with Section 9.2.1.

9.2.1 Requirements for All Compliance Paths. *Lighting systems* and *equipment* shall comply with Sections 9.1 "General"; 9.7, "Submittals"; 9.9, "Verification, Testing, and Commissioning"; and one of the following:

a. Section 9.3, "Simplified Building Method Compliance Path" or
b. Section 9.4, "Mandatory Provisions", and Section 9.5.1, "Building Area Method Compliance Path" or

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c. Section 9.4, "Mandatory Provisions," and Section 9.5.2, "Space-by-Space Method Compliance Path" or
d. Section 9.4, "Mandatory Provisions," and Section 9.6 "Alternative Compliance Path," or
e. Section 9.4, "Mandatory Provisions," and Section 12, "Energy Cost Budget Method," or
f. Section 9.4, "Mandatory Provisions," and Normative Appendix G, "Performance Rating Method."

The installed lighting power identified in accordance with Section 9.1.3 shall not exceed the *lighting power allowance* developed in accordance with Section 9.2.1(a), (b), or (c).

9.2.2 Prescriptive Requirements

9.2.2.1 Interior Lighting Power Allowance. The *interior lighting power allowance* for a *building* or a separately metered or permitted portion of a *building* shall be determined by either Simplified Building Method described in Section 9.3, the Building Area Method described in Section 9.5.1, or the Space-by-Space Method described in Section 9.5.2.

Trade-offs of *lighting power allowance* among portions of the *building* for which a different calculation method has been used for compliance are not permitted.

Exception to 9.2.2.1: When using the compliance methods in Section 9.5.1 or 9.5.2 only, the lighting *equipment* and applications listed in Table 9.2.2.1 shall not be considered when determining the *interior lighting power allowance* developed in accordance with Section 9.5.1 or 9.5.2, nor shall the wattage for such lighting be included in the *installed interior lighting power* identified in accordance with Section 9.1.3. This exemption shall only apply when the lighting and controls are in compliance with the requirements of Table 9.2.2.1. Lighting controls noted in this table are the only required controls for this *equipment* and these applications.

9.2.2.2 Exterior Lighting Power Allowance. The *exterior lighting power allowance* shall be determined by

a. Section 9.3.2, "Simplified Building Method of Calculating Exterior Lighting Power Allowance," when using Section 9.3 to determine the *interior lighting power allowance*, or
b. Section 9.4.2, "Exterior Lighting Power."

9.3 Simplified Building Method Compliance Path. The Simplified Building Method contains the requirements for interior lighting in Section 9.3.1 and exterior lighting in Section 9.3.2 and shall be allowed to be used where at least 80% of the *floor* area supports either office *buildings*, retail *buildings*, or school *buildings*. The Simplified Building Method shall be used for new *buildings* or tenants improvements of less than 25,000 ft^2. Interior and exterior wattage allowances shall be calculated and complied with separately.

9.3.1 Simplified Building Method of Calculating Interior Lighting Power Allowance. *Buildings* (new and *alterations*) shall comply with the *lighting power allowance* and control requirements of Table 9.3.1-1, Table 9.3.1-2, or Table 9.3.1-3.

9.3.2 Simplified Building Method of Calculating Exterior Lighting Power Allowance. For all *building* types listed in Section 9.3, exterior areas (new and *alterations*) shall comply with the *lighting power allowance* and control requirements of Table 9.3.2.

9.4 Mandatory Provisions

9.4.1 Lighting Control. Lighting controls shall be installed to meet the provisions of Section 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 Tables 9.5.2.1-1 and 9.5.2.1-2, for the appropriate *space* type in the first column, and as described below, shall be implemented. All control functions indicated as "REQ" are mandatory and shall be implemented. If a *space* type has control functions indicated as "ADD1," then at least one of those functions shall be implemented. If a *space* type has control functions indicated as "ADD2," then at least one of those functions shall be implemented. For *space* types not listed, select a reasonably equivalent type.

If using the Space-by-Space Method, the *space* type used for determining control requirements shall be the same *space* type that is used for determining the *LPD* allowance.

a. Local control: There shall be one or more *manual* lighting *control device* that provides ON and OFF control of all lighting in the *space*. Each *control device* shall control an area (1) no larger than 2500 ft^2 if the *space* is ≤10,000 ft^2 and (2) no larger than 10,000 ft^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 to 9.4.1.1(a): 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 *control device* is clearly *labeled* to identify the controlled lighting.

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Table 9.2.2.1 Exceptions to Interior Lighting Power and Minimum Control Requirements

Item #	Equipment/Application	In Addition to and Controlled Separately from General Lighting	Required Controls
1	Lighting that is integral to *equipment*, medical *equipment* or instrumentation, and is installed by its *manufacturer*	YES	No control requirements
2	Power for only the germicidal function in *luminaires* or sources	YES	No control requirements
3	Lighting specifically designed for use only during medical or dental procedures	YES	9.4.1.1(a)—Local control
4	Lighting specifically designed for the research or support of nonhuman life forms except for horticultural production or cultivation	YES	9.4.1.1(a)—Local control
5	Lighting for video broadcasting, video or film production, or live performance	YES	9.4.1.1(a)—Local control
6	Lighting that is an integral part of advertising or directional signage	YES	9.4.1.1(i)—Scheduled shutoff
7	Lighting integral to both open and glass-enclosed refrigerator and freezer cases	YES	9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
8	Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions	YES	9.4.1.1(a)—Local control and 9.4.1.1(i)—Scheduled shutoff
9	Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments	YES	9.4.1.1(a)—Local control and either 9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
10	Lighting integral to food warming and food preparation *equipment*	YES	9.4.1.1(a)—Local control and either 9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
11	Lighting that is for sale or lighting educational demonstration *systems*	YES	9.4.1.1(a)—Local control and either 9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
12	Mirror lighting in makeup or dressing areas used for theatrical or broadcast functions	YES	9.4.1.1(a)—Local control and either 9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
13	Accent lighting in religious pulpit and choir areas	YES	9.4.1.1(a)—Local control and either 9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
14	Lighting in interior *spaces* that have been specifically designated as a registered interior *historic* landmark	NO	9.4.1.1(a)—Local control and either 9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
15	Furniture-mounted supplemental *task lighting*	YES	9.4.1.1(a)—Local control and 9.4.1.1(h)—Automatic full OFF

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Table 9.2.2.2 Exceptions to Exterior Lighting Power and Minimum Control Zones

Item #	Equipment/Application	Controlled Separately from General Lighting	Required Controls
1	Specialized signal, directional, and marker lighting associated with transportation	Yes	9.4.1.4(a)
2	Lighting integral to *equipment* or instrumentation and installed by its *manufacturer*	Yes	9.4.1.4(a)
3	Temporary lighting	Yes	9.4.1.4(a)
4	Searchlights	Yes	9.4.1.4(a)
5	Lighting for hazardous locations	Yes	9.4.1.4(a)
6	Lighting integral to public art [a]	Yes	9.4.1.4(a)
7	Lighting used to highlight features of public monuments, public art [a] displays, and registered *historic* landmark *structure* or *buildings*.	Yes	9.4.1.4(b)
8	Lighting for theatrical purposes, including performance, stage, film production, and video production	Yes	9.4.1.4(a)
9	Lighting for athletic playing areas for colleges and professional sports venues	Yes	9.4.1.4(a)
10	Lighting for athletic playing areas	Yes	9.4.1.4(a), (b), or (c)
11	Lighting for swimming *pools*	Yes	9.4.1.4(a)
12	Lighting for water features	Yes	9.4.1.4(b) or (c)
13	Theme elements in theme/amusement parks	Yes	9.4.1.4(c)
14	Lighting that is integral to signage and installed in the signage by the *manufacturer*	Yes	9.4.1.4(d)
15	Lighting for industrial production, material handling, transportation sites, and associated storage areas	Yes	9.4.1.4(b), (d), or (e)

a. ***Informative Note:*** "Public art" means art funded either with public or private funds but intended and accessible for the general public.

b. Restricted to *manual* ON: None of the lighting shall be *automatically* turned on.
   Exception to 9.4.1.1(b): *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.

   Offices greater than 300 ft^2, shall have the following requirements:

   1. Control zones for *general lighting* shall be limited to 600 ft^2.
   2. Control zones for *general lighting* shall be permitted to *automatically* turn on, up to full power upon occupancy.
   3. *General lighting* in other unoccupied control zones shall be permitted to *automatically* turn on to no more than 20% of full power.
d. Multilevel lighting control: The *general lighting* in the *space* shall be *manually* controlled with *continuous dimming* to 10% or less of full lighting power in addition to full ON and full OFF.
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 sidelighted areas* is 75 W or greater, the *general lighting* in the *primary sidelighted areas* shall be controlled by photocontrols.

   In any *space* where the combined input power of all *general lighting* completely or partially within the *primary sidelighted area* and *secondary sidelighted area* is 150 W or greater, the *general lighting* in the *primary sidelighted area* and *secondary sidelighted area* shall be controlled by photocontrols. *General lighting* in the *secondary sidelighted area* shall be controlled independently of the *general lighting* in the *primary sidelighted area*.

   The control *system* shall have the following characteristics:

   1. The calibration adjustment control shall be located no higher than 11 ft above the finished *floor*. Calibration shall not require the physical presence of a person at the sensor while it is processing.

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Table 9.3.1-1 Simplified Building Method for Office Buildings

Interior Space Type and LPA	Controls
All *spaces* in office *buildings* other than parking garages The total *LPA* for the *building* other than parking garages shall not exceed 0.56 W/ft^2.	All lighting shall be *automatically* controlled to turn off when individual *spaces* are either unoccupied or scheduled to be unoccupied. (**Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the *space* shall be permitted to operate at all times.) Each *space* shall have a *manual control device* that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Office *spaces* ≤150 ft^2, classrooms, conference rooms, meeting rooms, training rooms, storage rooms, and break rooms	These *spaces* shall also be controlled by *manual*-ON *occupant sensors*.
Office *spaces* >150 ft^2 and restrooms	These *spaces* shall also be controlled by *occupant sensors*.
Stairwells and corridors in office *buildings*	These *spaces* shall also be controlled by *occupant sensors* that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 15 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages: The *LPA* shall not exceed 0.14 W/ft^2 for the interior parking floors. Uncovered floors of a garage shall use *LPA* and control requirements in Table 9.3.2 for parking lots.	All lighting shall be controlled by *occupant sensors*. Controls shall reduce the power by a minimum of 50% when no activity is detected for not longer than 15 minutes. No device shall *control* more than 3600 ft^2.

Table 9.3.1-2 Simplified Building Method for Retail Buildings

Interior Space Type	Controls
All *spaces* in retail *buildings* other than parking garages The total *LPA* for the *building* other than parking garages shall not exceed 0.70 W/ft^2.	All lighting shall be *automatically* controlled to turn off when individual *spaces* are either unoccupied or scheduled to be unoccupied. (**Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the *space* shall be permitted to operate at all times.) Each *space* shall have a *manual control device* that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Sales area	These *spaces* shall also be *automatically* controlled to • reduce the *general lighting* power by a minimum of 75% during nonbusiness hours, • to turn off all lighting other than *general lighting* during nonbusiness hours, and • by *continuous daylight dimming* controls in *spaces* with *toplighting*.
Stock rooms, dressing/fitting rooms, locker rooms, and restrooms	These *spaces* shall also be controlled by; auto-ON or *manual*-ON *occupant sensors*, and *continuous daylight dimming* controls in *spaces* with *toplighting*.
Office *spaces*, conference rooms, meeting rooms, training rooms, storage rooms, break rooms, and utility *spaces*	These *spaces* shall also be controlled by; *manual*-ON *occupant sensors*, and *continuous daylight dimming* controls in *spaces* with *toplighting*.
Stairwells and corridors in retail *buildings*	These *spaces* shall also be controlled by *occupant sensors* that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 15 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages: The *LPA* shall not exceed 0.14 W/ft^2 for the interior parking floors. Uncovered floors of a garage shall use *LPA* and control requirements in Table 9.3.2 for parking lots.	All lighting shall be controlled by *occupant sensors*. Controls shall reduce the power by a minimum of 50% when no activity is detected for not longer than 15 minutes. No device shall *control* a more than 3600 ft^2.

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Table 9.3.1-3 Simplified Building Method for School Buildings

Interior Space Type	**Controls**
All *spaces* in school *buildings* other than parking garages The total *LPA* for the *building* other than parking garages shall not exceed 0.63 W/ft^2	All lighting shall be *automatically* controlled to turn off when individual *spaces* are either unoccupied or scheduled to be unoccupied. (**Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the *space* shall be permitted to operate at all times.) Each *space* shall have a *manual control device* that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Classrooms, offices *spaces*, conference rooms, meeting rooms, library, storage rooms, and break rooms	These *spaces* shall also be controlled by *manual*-ON *occupant sensors*.
Gymnasiums and cafeterias	These *spaces* shall also be controlled by *occupant sensors*.
Restrooms	These *spaces* shall also be controlled by *occupant sensors*.
Stairwells and corridors in school *buildings* and parking garages	These *spaces* shall also be controlled by *occupant sensors* that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 15 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking Garages: The *LPA* shall not exceed 0.14 W/ft^2 for the interior parking floors. Uncovered floors of a garage shall use *LPA* and control requirements in Table 9.3.2 for parking lots.	All lighting shall be controlled by *occupant sensors*. Controls shall reduce the power by a minimum of 50% when no activity is detected for not longer than 15 minutes. No device shall *control* a more than 3600 ft^2.

Table 9.3.2 Simplified Building Method for Building Exteriors

Exterior Area Type	**Exterior Lighting Power Allowance** [a,b]	**Controls**
All exterior areas		All lighting shall be *automatically* controlled to shut off the lighting when daylight is available.
Base allowance	200 W	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Façade lighting	0.10 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Roof terraces, special feature areas, walkways, plazas and ramps	0.07 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Landscape	0.036 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Entry doors	14 W/linear ft	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Stairs	Exempt	No additional controls required.
Parking lots and drives	0.037 W/ft^2	*Luminaires* mounted 25 ft or less above *grade* shall be controlled to reduce the power by at least 50% when no activity is detected for not longer than 15 minutes.
All other areas not listed	0.20 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.

a. To calculate the exterior allowance, multiply the *space* or area square footage by the allowed W/ft^2 and sum the exterior allowances and the base allowance. Façade lighting shall be calculated separately by multiplying the facade area by the allowed W/ft^2. Façade allowance shall not be traded with other exterior areas or between separate *facade areas*.

b. For *buildings* in Lighting Zone 2, as defined in Table 9.4.2-1, multiply exterior allowances by 0.7. For *buildings* in Lighting Zone 4, as defined in Table 9.4.2-1, multiply exterior allowances by 1.4.

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2. The photocontrol shall reduce electric lighting power in response to available daylight using *continuous daylight dimming* to 20% or less and off.
3. When an *automatic* reduction control has reduced the lighting power to the unoccupied *set point* in accordance with Section 9.4.1.1(g), the daylight responsive control shall adjust the electric light in response to available daylight, but it shall not allow the lighting power to be above the unoccupied *set point*.

Exceptions to 9.4.1.1(e): The following areas are exempted from Section 9.4.1.1(e):

1. *Primary sidelighted areas* where the top of any existing adjacent *structure* or natural object is at least twice as high above the windows as its horizontal distance away from the windows.
2. Sidelighted areas where the total glazing area is less than 20 ft^2.
3. *Primary sidelighted areas* adjacent to *vertical fenestration* that have external projections and no *vertical fenestration* above the external projection, where the external projection has a *projection factor* greater than 1.0 for *north-oriented* projections or where the external projection has a *projection factor* greater than 1.5 for all other *orientations* (see Figure 3.2-6).

f. Automatic daylight responsive controls for *toplighting*: In any *space* where the combined input power for all *general lighting* completely or partially within *daylight area under skylights* and *daylight area under roof monitors* is 75 W or greater, *general lighting* in the *daylight area* shall be controlled by photocontrols. The control *system* shall have the following characteristics:

1. The calibration adjustment control shall be located no higher than 11 ft above the finished *floor*. Calibration shall not require the physical presence of a person at the sensor while it is processing.
2. The photocontrol shall reduce lighting power in response to available daylight using *continuous daylight dimming* to 20% or less and off.
3. When an *automatic* reduction control has reduced the lighting power to the unoccupied *set point* in accordance with Section 9.4.1.1(g) the daylight responsive control shall adjust the electric light in response to available daylight, but it shall not allow the lighting power to be above the unoccupied *set point*.
4. *General lighting* in overlapping toplighted and sidelighted *daylight areas* shall be controlled together with *general lighting* in the *daylight area under skylights* or *daylight area under roof monitors*.

Exceptions to 9.4.1.1(f): The following areas are exempted from Section 9.4.1.1(f):

1. *Daylight area under skylights* where it is documented that existing adjacent *structures* or natural objects block direct sunlight for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
2. *Daylight area under skylights* where the overall *skylight effective aperture* for the *enclosed space* is less than 0.006.
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.

g. Automatic reduction control (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*.

In offices greater than 300 ft^2, control zones for *general lighting* shall

1. be limited to 600 ft^2 and
2. *automatically* reduce *general lighting* by at least 80% of full power within 20 minutes of all occupants leaving a control zone.

h. Automatic full OFF control: All lighting in the *space*, including lighting connected to emergency circuits, shall be *automatically* shut off within 20 minutes of all occupants leaving the *space*. A *control device* meeting this requirement shall control no more than 5000 ft^2.

Exceptions to 9.4.1.1(h): The following lighting is not required to be *automatically* shut off:

1. Lighting required for 24/7 continuous operation.
2. Lighting in *spaces* where patient care is rendered.
3. *General lighting* and *task lighting* in *spaces* where *automatic* shutoff would endanger the safety or security of the room or *building* occupants.
4. Lighting load not exceeding 0.02 W/ft^2 multiplied by the *gross lighted floor area* of the *building*.

i. Scheduled shutoff*:* All lighting in the *space*, including lighting connected to emergency circuits, 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

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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 to 9.4.1.1(i): The following lighting is not required to be on scheduled shutoff:

1. Lighting required for 24/7 continuous operation.
2. Lighting in *spaces* where patient care is rendered.
3. *General lighting* and *task lighting* in *spaces* where *automatic* shutoff would endanger the safety or security of the room or *building* occupants.
4. Lighting load not exceeding 0.02 W/ft^2 multiplied by the *gross lighted floor area* of the *building*.

j. Scheduled OFF during nonbusiness hours*:* Lighting shall be scheduled to provide *automatic* OFF control so that lights are turned off at the end of business hours, 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*. Any *manual* control installed to provide override of the scheduled control shall not turn the lighting on for more than two hours per activation during scheduled off periods.

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 50% when there is no activity detected within a lighting zone for 10 minutes. Lighting zones for this requirement shall be no larger than 3600 ft^2.
c. *Parking garage daylight transition zone* lighting shall be separately controlled to *automatically* reduce the lighting to no more than the general light level from sunset to sunrise.
d. The power to any *luminaire* within 20 ft of perimeter *wall* openings totaling at least 24 ft^2 shall be *automatically* reduced through *continuous dimming* in response to available daylight.

Exceptions to 9.4.1.2(d):

1. *Parking garage daylight transition zone* lighting.
2. Where permanent screens or architectural elements obstruct more than 50% of the opening.
3. Where the top of any existing adjacent *structure* or natural object is at least twice as high above the openings as its horizontal distance from the opening.

9.4.1.3 Special Applications. Lighting controls noted in this section are the only required controls for this *equipment* and these applications. Lighting exempt from interior lighting power shall be controlled in accordance with Table 9.2.2.1. Lighting using additional interior lighting power applications shall be controlled in accordance with Section 9.5.2.2.

a. Lighting used for the following applications shall be equipped with a local control independent of the control of the *general lighting* in accordance with Section 9.4.1.1(a). In addition, such lighting shall be controlled in accordance with Section 9.4.1.1(h) or Section 9.4.1.1(i).
   1. Display or accent lighting
   2. Lighting in display cases
b. Guestrooms
   1. All lighting and 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*. Card key controls shall not be used to comply with this provision.
   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 to 9.4.1.3(b)(2): Night lighting of up to 5 W per bathroom is exempt.
c. 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. a local control independent of the control of the *general lighting* in accordance with Section 9.4.1.1(a).

   In addition, such lighting shall be controlled in accordance with Section 9.4.1.1(h) or Section 9.4.1.1(i).

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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

9.4.1.4 Exterior Lighting Control. For each surface or area, all of the lighting control functions indicated in Table 9.4.2-2 shall be implemented. Lighting for exterior applications not exempted in Section 9.1 shall meet the requirements defined here and listed in Table 9.4.2-2:

a. OFF control: There shall be one or more lighting control(s) that turns off all of the lighting in the area or surface.
b. Daylight OFF control: Lighting shall *automatically* turn off when sufficient daylight is available or within 30 minutes of sunrise.
c. Scheduled OFF control: 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*.
d. Scheduled light reduction control: Lighting and signage shall be controlled to *automatically* reduce the connected lighting power by at least 50% from midnight or within one hour of the end of business operations, whichever is later, until 6 a.m. or the beginning of business operations, whichever is earlier.
e. Occupancy-sensing light reduction control: Lighting shall be *controlled* to *automatically* reduce the connected lighting power by a minimum of 50% when no activity has been detected in the area illuminated by the controlled *luminaires* for a time of no longer than 15 minutes. No more than 1500 W of lighting power shall be controlled together.

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.

9.4.2 Exterior Lighting Power. The total *exterior lighting power allowance* for all exterior 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 in Table 9.4.2-1. 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. Trade-offs are allowed only among exterior lighting applications listed in the Table 9.4.2-2 “Tradable Surfaces” section. The lighting zone for exterior applications is determined from Table 9.4.2-1 unless otherwise specified by the local jurisdiction.

9.4.3 Dwelling Units. *Dwelling unit lamps*, *luminaires*, and lighting controls shall be installed to meet the provisions of Sections 9.4.3.1, 9.4.3.2, and 9.4.3.3. No other provisions of Section 9 apply to *dwelling units*.

9.4.3.1 Lamp and Luminaire Efficacy. At least 75% of the *permanently installed luminaires* shall use *lamps* with an *efficacy* of at least 75 lm/W or have a total *luminaire efficacy* of at least 50 lm/W.

9.4.3.2 Interior Lighting Controls. Fifty percent (50%) of *permanently installed* interior *luminaires* shall be controlled with *dimmers* or shall *automatically* be shut off within 20 minutes of all occupants leaving a *space*.

9.4.3.3 Exterior Lighting Controls. *Permanently installed* exterior *luminaires* dedicated to a *dwelling unit* shall be provided with *manual* controls and be *automatically* shut off through time of day, available daylight, or when no activity has been detected for 15 minutes.

Exception to 9.4.3.3: Applications with a total rated *luminaire* wattage of no greater than 8 W.

9.4.4 Horticultural Lighting. *Greenhouse horticultural lighting* shall follow the requirements of Section 9.4.4.1. *Indoor grow horticultural lighting* shall follow the requirements of Section 9.4.4.2.

9.4.4.1 *Luminaires* in *greenhouse buildings* with at least 40 *kW* of connected load for *horticultural lighting* shall have a *photosynthetic photon efficacy* (*PPE*) of at least 1.7 µmol/J for integrated, nonserviceable *luminaires*, or a *PPE* of at least 1.7 µmol/J for *lamps* in *luminaires* with removable or serviceable *lamps*.

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Table 9.4.2-2 Individual Lighting Power Allowances for Building Exteriors Applications

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4	Section 9.4.1.4 Required Controls
Base Site Allowance (Base allowance may be used in tradable or non-tradable surfaces.)						
	No allowance	160 W	280 W	400 W	560 W	
Tradable Surfaces (*LPD* 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	0.015 W/ft^2	0.026W/ft^2	0.037 W/ft^2	0.052 W/ft^2	(b) and either (d) or (e)
Parking areas and drives with *luminaires* >78W and mounting height <24 ft	No allowance	0.015 W/ft^2	0.026 W/ft^2	0.037 W/ft^2	0.052 W/ft^2	(b) and (e)
Grounds						
Walkways/ramps	No allowance	0.5 W/linear ft	0.5 W/linear ft	0.55W/linear ft	0.60 W/linear ft	(b) and either (d) or (e)
Plaza areas	No allowance	0.028 W/ft^2	0.049 W/ft^2	0.070 W/ft^2	0.098 W/ft^2	(b) and either (d) or (e)
Roof terraces and special features	No allowance	0.04 W/ft^2	0.07 W/ft^2	0.10 W/ft^2	0.140 W/ft^2	(b) and either (d) or (e)
Dining areas	No allowance	0.156 W/ft^2	0.273 W/ft^2	0.390 W/ft^2	0.546 W/ft^2	(b) and either (d) or (e)
Pedestrian tunnels	No allowance	0.063 W/ft^2	0.110 W/ft^2	0.157 W/ft^2	0.220 W/ft^2	(d) or (e)
Landscaping	No allowance	0.014 W/ft^2	0.025 W/ft^2	0.036 W/ft^2	0.050 W/ft^2	(b) and (c)
Building Entrances, Exits, and Loading Docks						
Pedestrian and vehicular entrances and exits	No allowance	5.6 W/linear ft of opening	9.8W/linear ft of opening	14.0 W/linear ft of opening	19.6 W/linear ft of opening	(b) and either (d) or (e)
Entry canopies	No allowance	0.072 W/ft^2	0.126 W/ft^2	0.180 W/ft^2	0.252 W/ft^2	(b) and either (d) or (e)
Loading docks	No allowance	0.104 W/ft^2	0.182 W/ft^2	0.260 W/ft^2	0.364 W/ft^2	(b) and either (d) or (e)
Sales Canopies						
Free standing and attached	No allowance	0.20 W/ft^2	0.35 W/ft^2	0.50 W/ft^2	0.70 W/ft^2	(b) and either (d) or (e)
Outdoor Sales						
Open areas (including vehicle sales lots)	No allowance	0.072 W/ft^2	0.126 W/ft^2	0.180 W/ft^2	0.252 W/ft^2	(b) and either (d) or (e)
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	No allowance	7.2 W/linear ft	10.3 W/linear ft	14.4 W/linear ft	(b) and either (d) or (e)
Nontradable Surfaces (*LPD* 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.)						
Stairways	Exempt	Exempt	Exempt	Exempt	Exempt	(b)

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Table 9.4.2-2 Individual Lighting Power Allowances for Building Exteriors Applications *(Continued)*

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4	Section 9.4.1.4 Required Controls
Building facades (The allowance for each illuminated facade *orientation* shall be calculated by multiplying the allowable value by the entire *facade area* or facades length for that *orientation*.)	No allowance	0.056 /ft^2 of *facade area* or 1.4 W/linear ft of facade length	0.098 W/ft^2 of *facade area* or 2.4 W/linear ft of facade length	0.140 W/ft^2 of *facade area* or 3.4 W/ linear ft of facade length	0.196 W/ft^2 of *facade area* or 4.8 W/linear ft of facade length	(b) and (c)
Automated teller machines and night depositories	No allowance	90 W per location plus 35 W per additional ATM per location	90 W per location plus 35 W per additional ATM per location	90 W per location plus 35 W per additional ATM per location	90 W per location plus 35 W per additional ATM per location	(b)
Uncovered entrances and gatehouse inspection stations at guarded facilities	No allowance	0.144 W/ft^2	0.252 W/ft^2	0.360 W/ft^2	0.504 W/ft^2	(b) and either (d) or (e)
Uncovered loading areas for law enforcement, fire, ambulance, and other emergency service vehicles	No allowance	0.104 W/ft^2	0.182 W/ft^2	0.260 W/ft^2	0.364 W/ft^2	(b) and either (d) or (e)
Drive-through windows/doors	No allowance	53 W per drive-through	92 W per drive-through	132 W per drive-through	185 W per drive-through	(b) and either (d) or (e)
Parking near 24-hour retail entrances	No allowance	80 W per main entry	140 W per main entry	200 W per main entry	280 W per main entry	(b) and either (d) or (e)
For areas that are not listed in this table or are not comparable to areas listed in this table, use the comparable interior *space* type from Tables 9.5.2.1-1 and 9.5.2.1-2 as modified by factors in this row.	No allowance	22% of the *interior lighting power allowance* value	39% of the *interior lighting power allowance* value	55% of the *interior lighting power allowance* value	77% of the *interior lighting power allowance* value	(b) and either (d) or (e)
Roadway/parking entry, trail head, and toilet facility, or other locations approved by the *authority having jurisdiction*.	A single *luminaire* of 10 W or less	No additional allowance	No additional allowance	No additional allowance	No additional allowance	(b) and either (d) or (e)

Horticultural lighting in *greenhouse spaces* shall be controlled by a device that *automatically* turns off the *horticultural lighting* at specific programmed times.

9.4.4.2 *Luminaires* in *indoor grow spaces* used for *horticultural lighting* shall have a *PPE* of at least 1.9 µmol/J for integrated, nonserviceable *luminaires*, or a *PPE* of at least 1.9 µmol/J for *lamps* in *luminaires* with removable or serviceable *lamps*. *Horticultural lighting* in *indoor grow spaces* shall be controlled by a device that *automatically* turns off the *horticultural lighting* at specific programmed times.

Exception to 9.4.4.2: *Indoor grow buildings* with less than 40 *kW* of connected load for *horticultural lighting* shall have a *PPE* of at least 1.7 µmol/J for integrated, nonserviceable *luminaires*, or a *PPE* of at least 1.7 µmol/J for *lamps* in *luminaires* with removable or serviceable *lamps*.

9.5 Prescriptive Compliance Path. *Interior lighting power* shall comply with either Section 9.5.1 or 9.5.2. Lighting control requirements shall comply with Section 9.4.1 and Tables 9.5.2.1-1 and 9.5.2.1-2.

9.5.1 Building Area Method Compliance Path. 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 corresponding *LPD* allowance. For *building* area types not listed, selection of a reasonably equivalent type shall be permitted.
b. Determine the *gross lighted floor area* in ft^2 of the *building* area type.
c. Multiply the *gross lighted floor areas* of the *building* area types times the *LPD*.

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Table 9.5.1 Lighting Power Density Allowances Using the Building Area Method

Building Area Type[a]	LPD, W/ft^2
Automotive facility	0.73
Convention center	0.64
Courthouse	0.75
Dining: Bar lounge/leisure	0.74
Dining: Cafeteria/fast food	0.70
Dining: Family	0.65
Dormitory	0.52
Exercise center	0.72
Fire station	0.56
Gymnasium	0.75
Health care clinic	0.77
Hospital	0.92
Hotel/motel	0.53
Library	0.83
Manufacturing facility	0.82
Motion picture theater	0.43
Multifamily	0.46
Museum	0.56
Office	0.62
Parking garage	0.17
Penitentiary	0.65
Performing arts theater	0.82
Police station	0.62
Post office	0.64
Religious facility	0.66
Retail	0.78
School/university	0.70
Sports arena	0.73
Town hall	0.67
Transportation	0.56
Warehouse	0.45
Workshop	0.86

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.

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 Space-by-Space Method Compliance Path

9.5.2.1 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:

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a. For each *space* enclosed by partitions that are 80% of the ceiling height or taller, determine the appropriate *space* type and the corresponding *LPD* allowance from Tables 9.5.2.1-1 and 9.5.2.1-2. If a *space* has multiple functions, where more than one *space* type is applicable, that *space* shall be broken up into smaller subspaces, each using its own *space* type from Tables 9.5.2.1-1 and 9.5.2.1-2. 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. 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* or *semiexterior walls*. For the purposes of this section, *semiexterior walls* that separate *semiheated space* from *conditioned space* shall be considered interior 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* allowance determined in Section 9.5.2.1(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. Trade-offs among *spaces* and subspaces are permitted, provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

9.5.2.2 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 controlled independently of the *general lighting* in accordance with Table 9.5.2.2. This additional power shall be used only for the specified *luminaires* and shall not be used for any other purpose unless otherwise indicated. Lighting control requirements referenced in Section 9.5.2.2 are the only required controls for these applications.

An increase in the *interior lighting power allowance* is permitted in the following cases:

a. For each *space* in which lighting is installed in addition to the *general lighting* for the purpose of decorative appearance or for highlighting art or exhibits not exempted in Table 9.2.2.1, provided that the additional lighting power shall not exceed the value in Table 9.5.2.2.
b. For lighting *equipment* installed in sales areas and specifically designed and directed to highlight merchandise, provided that the additional lighting power shall not exceed the value in Table 9.5.2.2.
c. For *spaces* in which lighting is installed for the purpose of videoconferencing and the lighting in that *space* meets ANSI/IES/AVIXA RP-38, additional lighting power shall be allowed per Table 9.5.2.2.

Exception to 9.5.2.2: 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*.

9.5.2.3 Additional Interior Lighting Power Using Nonmandatory Controls. An additional lighting power allowance shall be permitted for *space* types with nonmandatory controls installed as identified in Table 9.5.2.3 when all mandatory controls are used according to Section 9.4. This allowance is added to the *interior lighting power allowance* and is calculated as follows:

Additional *Interior Lighting Power Allowance* = Lighting Power Under Control × Control Factor

where

Lighting Power Under Control	=	the total input watts of all *lamps* being controlled using the control method indicated
Control Factor	=	the value given in Table 9.5.2.3 for the corresponding *space* type and control method

9.5.2.4 Room Geometry Adjustment. When using the Space-by-Space Method, an adjustment of the *space LPD* allowance is permitted 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 Tables 9.5.2.1-1 and 9.5.2.1-2.

$$RCR = 2.5 \times \text{Room Cavity Height} \times \text{Room Perimeter Length/Room Area}$$

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:

$$LPD \text{ Increase} = \text{Base } Space\ LPD \times 0.20$$

where Base *Space LPD* = the applicable *LPD* allowance from Tables 9.5.2.1-1 and 9.5.2.1-2.

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9.6 Alternate Compliance Path (Reserved)

9.7 Submittals

9.7.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2.

9.7.2 Permit Application Documentation (Not Used)

9.7.3 Completion Requirements

9.7.3.1 Record Documents. *Construction documents* shall require that within 90 days after the date of *system* acceptance, *record documents* be provided to the *property* owner or the designated representative of the *property* owner. *Record documents* shall include, as a minimum, the location, *luminaire* identifier, control, and circuiting for each piece of lighting *equipment*.

9.7.3.2 Manuals. *Construction documents* shall require for all lighting *equipment* and lighting controls that an operating manual and maintenance manual be provided to the *property* owner or the designated representative of the *property* 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.

9.7.3.3 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*, and *primary sidelighted area* and *secondary sidelighted areas*.

9.8 Product Information (Not Used)

9.9 Verification, Testing, and Commissioning

9.9.1 Verification and Testing. Lighting *control devices* and control *systems* shall be tested in accordance with this section and Section 4.2.5.1 to verify that control hardware and software are calibrated, adjusted, programmed, and in proper working condition in accordance with the *construction documents* and *manufacturer*'s installation instructions. The following procedures shall be performed for the type of controls listed:

a. *Occupancy 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 performed for each unique combination of sensor type and *space* geometry.
      i. For each sensor to be tested, verify the following:
         (a) Status indicator (as applicable) operates correctly.
         (b) *Controlled* lights turn off or down to the permitted level within the required time.
         (c) For auto-ON *occupancy sensors*, the lights turn on to the permitted level when someone enters the *space.*
         (d) For *manual*-ON sensors, the lights turn on only when *manually* activated.
         (e) 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 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:
      i. All lights can be turned on and off by their respective area control switch.

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ii. The switch only operates lighting in the *enclosed space* in which the switch is located.

7. Simulate unoccupied condition. Verify and document the following:
   i. All nonexempt lighting turns off.
   ii. *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.

c. Daylight Controls
   1. All *control devices* (photocontrols) have been properly located and field-calibrated, to *set points* and threshold light levels.
   2. Daylight *controlled* lighting loads adjust in response to available daylight.
   3. The location where calibration adjustments are made is *readily accessible* only to authorized personnel.

d. *High-End Trim* and *Lumen Maintenance* Controls
   1. The initial maximum *set point* for power or light output for each control group of *luminaires* shall be documented.
   2. The tuned maximum *set point* for power or light output for each control group of *luminaires* shall be documented.
   3. Measurement of *high-end trim* in *daylight areas* shall be conducted at night.
   4. Where *lumen maintenance* controls are included, the *automatic* rate of increase in lighting power shall be no more than 1.0% per year.
   5. The *high-end trim* and *lumen maintenance* control documentation shall show the initial and tuned *set point* and area for each control group and summarize the overall percentage of lighting output or power reduction from tuning. The rate of increase for *lumen maintenance* shall be shown for each control group.

e. Verification and *FPT* documentation shall comply with Section 4.2.5.1.2.

9.9.2 Commissioning. The *energy* performance of the *lighting systems* shall be *commissioned* in accordance with Section 4.2.5.2, and reporting shall comply with Section 4.2.5.2.2.

Informative Note: See Informative Appendix E and Informative Appendix H for *commissioning* references and guidance.

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Table 9.5.2.1-1 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers common *space* types typically found in multiple *building* types. Table 9.5.2.1-2 covers *building*-specific *space* types typically found in a single *building* type.

The control functions below shall be implemented in accordance with the descriptions found 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[a]	LPD, W/ft²	RCR	Local Control	Manual ON	Partial Auto ON	Multilevel Lighting Control	Daylight Response Sidelight	Daylight Response Toplight	Auto Reduction (Full OFF complies)	Auto Full OFF	Scheduled Shutoff
			9.4.1.1(a)	9.4.1.1(b)	9.4.1.1(c)	9.4.1.1(d)	9.4.1.1(e) [b]	9.4.1.1(f) [b]	9.4.1.1(g)	9.4.1.1(h)	9.4.1.1(i)
Atrium											
<20 ft in height	0.32	NA	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
≥20 ft and ≤40 ft in height	0.41	NA	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
>40 ft in height	0.51	11	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Audience Seating Area											
Auditorium	0.57	6	REQ	ADD1	ADD1	REQ	REQ			ADD2	ADD2
Gymnasium	0.23	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Motion picture theater	0.27	4	REQ	ADD1	ADD1	REQ				ADD2	ADD2
Performing arts theater	1.10	8	REQ	ADD1	ADD1	REQ				ADD2	ADD2
Sports arena	0.27	4	REQ	ADD1	ADD1	REQ		REQ		ADD2	ADD2
All other audience seating areas	0.23	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Banking Activity Area	0.56	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Classroom/Lecture Hall/Training Room											
Shop classroom	1.17	6	REQ	ADD1	ADD1		REQ	REQ			REQ
All other classrooms/lecture halls/training rooms	0.72	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Computer Room	0.75	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Conference/Meeting/Multipurpose Rooms	0.88	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Control/Editing Room or Booth	0.73	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Copy/Print Room	0.56	6	REQ	ADD1	ADD1		REQ	REQ		REQ	
Corridor	0.44	width <8 ft	REQ				REQ	REQ	REQ	ADD2	ADD2
Courtroom	1.08	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Dining Areas											
Bar/lounge or leisure dining	0.76	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2

a. Where both a common *space* type and a *building*-specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-2 for *building*-specific *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.1-1 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers common *space* types typically found in multiple *building* types. Table 9.5.2.1-2 covers *building*-specific *space* types typically found in a single *building* type.

The control functions below shall be implemented in accordance with the descriptions found 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[a]	LPD, W/ft²	RCR	Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e)[b]	Daylight Response Toplight 9.4.1.1(f)[b]	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)	Scheduled Shutoff 9.4.1.1(i)
Cafeteria or fast-food dining	0.36	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Family dining	0.52	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
All other dining areas	0.42	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Electrical/Mechanical Room	0.71	6	REQ								
Emergency Vehicle Garage	0.51	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Equipment Room	0.73	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Food Preparation Area	1.19	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Guest Room	0.41	6	See Section 9.4.1.3(b).								
Laboratory											
In or as a classroom	1.05	6	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
All other laboratories	1.21	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Laundry/Washing Area	0.51	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Loading Dock, Interior	0.87	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Lobby											
Elevator	0.64	6	REQ				REQ	REQ		ADD2	ADD2
Hotel	0.48	4	REQ				REQ	REQ		ADD2	ADD2
Motion picture theater	0.20	4	REQ				REQ	REQ		ADD2	ADD2
Performing arts theater	1.21	6	REQ				REQ	REQ		ADD2	ADD2
All other lobbies	0.80	4	REQ				REQ	REQ	REQ	ADD2	ADD2
Locker Room	0.43	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Lounge/Breakroom											
Mother's/wellness room	0.68	6	REQ	ADD1	ADD1	REQ				REQ	
All other lounges/breakrooms	0.55	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	

a. Where both a common *space* type and a *building*-specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-2 for *building*-specific *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.1-1 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers common *space* types typically found in multiple *building* types. Table 9.5.2.1-2 covers *building*-specific *space* types typically found in a single *building* type.

The control functions below shall be implemented in accordance with the descriptions found 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[a]	LPD, W/ft^2	RCR	Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e)[b]	Daylight Response Toplight 9.4.1.1(f)[b]	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)	Scheduled Shutoff 9.4.1.1(i)
Office											
Office ≤150 ft^2	0.73	8	REQ	ADD1	ADD1	REQ				REQ	
Office >150 and ≤300 ft^2	0.66	8	REQ	ADD1	ADD1	REQ				REQ	
Offices >300 ft^2	0.56	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	REQ	
Parking Garage											
Daylight transition zone	1.06	4	See Section 9.4.1.2.								
All other parking and drive areas	0.11	4	See Section 9.4.1.2.								
Pharmacy Area	1.59	6	REQ	ADD1	ADD1	REQ				ADD2	ADD2
Restroom	0.74	8								REQ	
Sales Area (For accent lighting, see Section 9.5.2.2[b].)	0.85	6	REQ	ADD1	ADD1	REQ		REQ		ADD2	ADD2
Seating Area, General	0.21	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Security Screening											
Airport/bus/ship/train/transportation screening	0.93	6	REQ				REQ	REQ		ADD2	ADD2
Airport/bus/ship/train/transportation screening queue	0.56	6	REQ				REQ	REQ		ADD2	ADD2
General security screening	0.64	6	REQ				REQ	REQ		ADD2	ADD2
Stairway	The *space* containing the stairway shall determine the *LPD* and control requirements for the stairway.										
Stairwell	0.47	10					REQ	REQ	REQ	ADD2	ADD2
Storage Room											
<50 ft^2	0.49	9	REQ	REQ						REQ	
≥50 ft^2	0.35	6	REQ							REQ	
Vehicular Maintenance Area	0.59	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Workshop (including workshop classrooms)	1.17	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2

a. Where both a common *space* type and a *building*-specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-2 for *building*-specific *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.1-2 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers *building*-specific *space* types typically found in a single *building* type. Table 9.5.2.1-1 covers common *space* types typically found in multiple *building* types.

The control functions below shall be implemented in accordance with the descriptions found 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-Specific Space Types[a]	LPD, W/ft²	RCR	Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e)[b]	Daylight Response Toplight 9.4.1.1(f)[b]	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)	Scheduled Shutoff 9.4.1.1(i)
Casino—Gaming Area											
Betting/sportsbook/keno/bingo area	0.82	5				REQ				ADD2	ADD2
High-limit game area	1.68	4				REQ				ADD2	ADD2
Slot machine/digital gaming area	0.54	5				REQ				ADD2	ADD2
Table games area	1.09	5				REQ				ADD2	ADD2
Convention Center—Exhibit Space	0.50	4	REQ	ADD1	ADD1	REQ	REQ	REQ			REQ
Correctional Facilities											
Audience seating area	0.56	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Classroom/lecture hall/training room	0.74	4	REQ	ADD1	ADD1	REQ	REQ	REQ			
Confinement cells	0.60	6	REQ								REQ
Dining area	0.35	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Dormitory—Living Quarters	0.48	8	REQ								
Facility for the Visually Impaired (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 that is or will be licensed by local/state authorities for senior long-term care, adult daycare, senior support, and/or people with special visual needs.)											
Chapel (used primarily by residents)	0.58	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Corridor (used primarily by residents)	0.71	width <8 ft	REQ				REQ	REQ	REQ	ADD2	ADD2
Dining (used primarily by residents)	1.22	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Lobby	1.44	4	REQ				REQ	REQ	REQ	ADD2	ADD2
Recreation room/common living room (used primarily by residents)	1.20	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Restroom (used primarily by residents)	0.96	8					REQ	REQ		REQ	
Fire Station—Sleeping Quarters	0.22	6	REQ								

a. Where both a common *space* type and a *building* specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-1 for common *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.1-2 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers *building*-specific *space* types typically found in a single *building* type. Table 9.5.2.1-1 covers common *space* types typically found in multiple *building* types.

The control functions below shall be implemented in accordance with the descriptions found 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-Specific Space Types[a]	LPD, W/ft²	RCR	Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e)[b]	Daylight Response Toplight 9.4.1.1(f)[b]	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)	Scheduled Shutoff 9.4.1.1(i)
Gymnasium/Fitness Center											
Exercise area	0.82	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Playing area	0.82	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Health Care Facility											
Control room (MRI/CT/radiology/PET)	0.78	8	REQ	REQ		REQ				REQ	
Exam/treatment room	1.33	8	REQ			REQ	REQ	REQ		ADD2	ADD2
Hospital corridor	0.61	width <8 ft	REQ				REQ	REQ	ADD2	ADD2	ADD2
Imaging room	0.94	6	REQ			REQ				ADD2	ADD2
Lounge	0.77	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Medical supply room	0.56	6	REQ	ADD1	ADD1					REQ	
Nursery	0.87	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Nurse's station	1.07	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Operating room	2.31	6	REQ			REQ					
Patient room	0.78	6	REQ			REQ					
Physical therapy room	0.82	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Recovery room	1.18	6	REQ			REQ				ADD2	ADD2
Telemedicine	1.44	8	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Library											
Reading area	0.86	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Stacks	1.18	4	REQ	ADD1	ADD1				REQ	ADD2	ADD2
Manufacturing Facility											
Detailed manufacturing area	0.75	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Extra-high bay area (>50 ft *floor*-to-ceiling height)	1.36	8	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2

a. Where both a common *space* type and a *building* specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-1 for common *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.1-2 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers *building*-specific *space* types typically found in a single *building* type. Table 9.5.2.1-1 covers common *space* types typically found in multiple *building* types.

The control functions below shall be implemented in accordance with the descriptions found 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-Specific Space Types[a]	LPD, W/ft^2	RCR	Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e)[b]	Daylight Response Toplight 9.4.1.1(f)[b]	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)	Scheduled Shutoff 9.4.1.1(i)
High bay area (25 to 50 ft *floor*-to-ceiling height)	1.24	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Low bay area (<25 ft *floor*-to-ceiling height)	0.85	3	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Museum											
General exhibition area	0.31	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Restoration area	1.24	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Performing Arts Theater—Dressing Room	0.39	6	REQ	ADD1	ADD1	REQ				REQ	
Post Office—Sorting Area	0.71	4	REQ	ADD1	ADD1		REQ	REQ	REQ	ADD2	ADD2
Religious Facility											
Audience seating area	0.72	4	REQ			REQ	REQ	REQ		ADD2	ADD2
Fellowship hall	0.50	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Worship/pulpit/choir area	0.75	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Retail Facilities											
Dressing/fitting room	0.45	8								ADD2	ADD2
Hair care	0.65	6	REQ	ADD1	ADD1					ADD2	ADD2
Mall concourse	0.57	4	REQ	ADD1	ADD1	REQ		REQ		ADD2	ADD2
Massage	0.81	8	REQ	ADD1	ADD1	REQ				ADD2	ADD2
Nail care	0.75	6	REQ	ADD1	ADD1					ADD2	ADD2
Sports Arena—Playing Area (Class of play as defined by ANSI/IES RP-6)											
Class I facility	2.86	4	REQ	REQ			REQ	REQ			REQ
Class II facility	1.98	4	REQ	REQ			REQ	REQ			REQ
Class III facility	1.29	4	REQ	REQ			REQ	REQ			REQ
Class IV facility	0.85	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2

a. Where both a common *space* type and a *building* specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-1 for common *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.1-2 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Informative Note: This table covers *building*-specific *space* types typically found in a single *building* type. Table 9.5.2.1-1 covers common *space* types typically found in multiple *building* types.

The control functions below shall be implemented in accordance with the descriptions found 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-Specific Space Types[a]	LPD, W/ft²	RCR	Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e) [b]	Daylight Response Toplight 9.4.1.1(f) [b]	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)	Scheduled Shutoff 9.4.1.1(i)
Natatorium (Class of play as defined by IES RP-6)											
Class I facility	2.20	4	REQ	REQ			REQ	REQ			REQ
Class II facility	1.47	4	REQ	REQ			REQ	REQ			REQ
Class III facility	0.99	4	REQ	REQ			REQ	REQ			REQ
Class IV facility	0.59	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Transportation Facility											
Airport hanger	1.36	4	REQ	REQ			REQ	REQ			REQ
Baggage/carousel area	0.28	4					REQ	REQ		ADD2	ADD2
Concourse	0.49	4					REQ	REQ		ADD2	ADD2
Passenger loading area	0.71	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Ticket counter	0.40	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Warehouse—Storage Area											
Medium-to-bulky, palletized items	0.33	4	REQ	ADD1	ADD1		REQ	REQ	REQ	ADD2	ADD2
Smaller items, picking areas	0.69	6	REQ	ADD1	ADD1		REQ	REQ	REQ	ADD2	ADD2

a. Where both a common *space* type and a *building* specific *space* type are listed, the *building* specific *space* type shall apply (see Table 9.5.2.1-1 for common *space* types).
b. *Automatic* daylight responsive controls are mandatory only if the *space* meets the requirements of the specified sections.

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Table 9.5.2.2 Additional Lighting Power

Section	Description	Additional Lighting Power	Required Controls
9.5.2.2(a)	Decorative	0.70 W/ft^2	Section 9.4.1.1(j)
9.5.2.2(b)	Retail sales	750 W + (Retail Area 1 × 0.40 W/ft^2) + (Retail Area 2 × 0.40 W/ft^2) + (Retail Area 3 × 0.70 W/ft^2) + (Retail Area 4 × 1.00 W/ft^2)	Section 9.4.1.1(j)
9.5.2.2(c)	Video conferencing	0.50 W/ft^2	See Tables 9.5.2.1-1 and 9.5.2.1-2 space types for required controls.

Notes:
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

Table 9.5.2.3 Control Factors Used in Calculating Additional Interior Lighting Power Allowance

	Space Type				
Additional Control Method (in Addition to Mandatory Requirements)	**Open Office**	**Private Office**	**Conference Room, Meeting Room, Classroom (Lecture/ Training)**	**Retail Sales Area**	**Lobby, Atrium, Dining Area, Corridors/ Stairways, Gym/ Pool, Mall Concourse, Parking Garage**
Programmable multilevel dimming control using programmable time scheduling	0.05	0.05	0.10	0.10	0.10
Occupancy sensors controlling the downlight component of workstation specific *luminaires* with continuous dimming to off capabilities	0.25[a]	0	0	0	0
Occupancy sensors controlling the downlight component of workstation specific *luminaires* with continuous dimming to off operation, in combination with personal continuous dimming control of downlight illumination by workstation occupant	0.30[a,b]	0	0	0	0

a. Control factor is limited to workstation-specific *luminaires* in partitioned single occupant work *spaces* contained within an open office environment (i.e. direct-indirect *luminaires* with separately controlled downlight and uplight components, with the downward component providing illumination to a single occupant in an open plan workstation). Within 30 minutes of the occupant leaving the *space*, the downward component shall continuously dim to off over a minimum of two minutes. Upon the occupant entering the *space*, the downward component shall turn on at the minimum level and continuously raise the illumination to a preset level over a minimum of 30 seconds. The uplight component of workstation specific *luminaire* shall comply with Section 9.4.1.1(h) (*automatic* full OFF).

b. In addition to the requirements described in footnote (a), the control shall allow the occupant to select their preferred light level via a personal computer, handheld device, or similarly accessible device located within the workstation.

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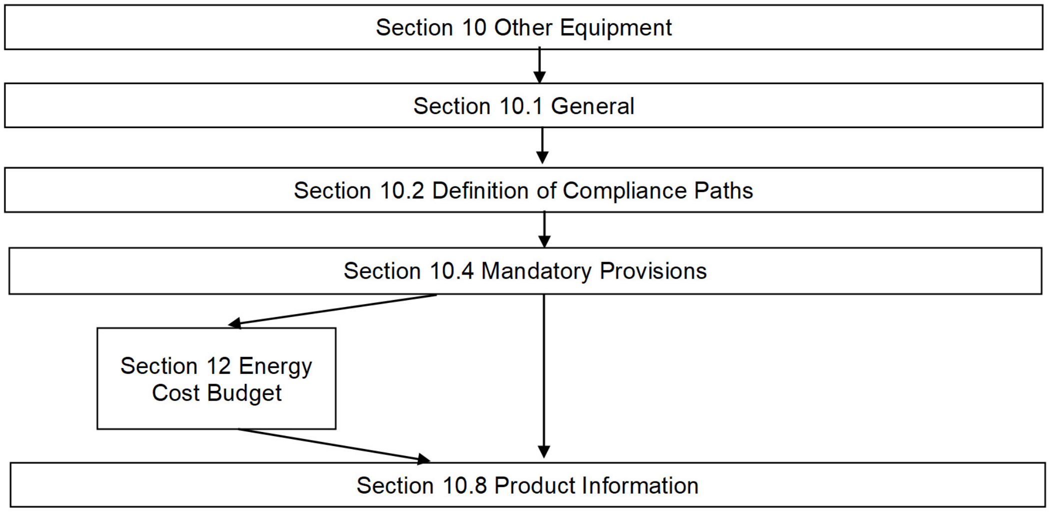

10. OTHER EQUIPMENT

10.1 General

10.1.1 Scope. This section applies to other *equipment* as described in Section 10.4.

10.1.2 New Building or Site System or Equipment. Other *equipment* installed in new *buildings* shall comply with the requirements of Section 10.2.

10.1.3 Additions to Existing Systems and Equipment. Other *equipment* installed in *additions* to *existing buildings* and *existing sites* shall comply with the requirements of Section 10.2.

10.1.4 Alterations to Existing Service Equipment or Systems

10.1.4.1 *Alterations* to other *building service equipment* shall comply with the requirements of Section 10.2 as applicable to those specific portions of the *building* that are being altered.

10.1.4.2 *Alterations* to *systems* shall comply with the requirements of Section 10.2, as applicable to those specific portions that are being altered.

10.1.4.3 Any new *equipment* subject to the requirements of Section 10 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 to 10.1.4.3:** Compliance shall not be required for the relocation or reuse of *existing equipment*.

10.1.5 Climate. Climate zones shall be determined in accordance with Section 5.1.5.

10.2 Compliance Paths.

Other *equipment* shall comply with Sections 10.2.1 and 10.2.2.

10.2.1 Requirements for All Compliance Paths. Other *equipment* shall comply with Sections 10.1, "General"; 10.4, "Mandatory Provisions"; 10.5, "Prescriptive Path", and 10.8, "Product Information."

10.2.2 Additional Requirements to Comply with Section 10 (Not Used)

10.3 Simplified Building Compliance Path (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 *rated motor power* of 1 hp or more, and less than or equal to 200 hp, shall comply with the requirements shown in Table 10.8-1 for *NEMA Design A motors*, *NEMA Design B motors*, and *IEC Design N motors*, and Table 10.8-2 for *NEMA Design C motors* and *IEC Design H motors*.

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General purpose *small electric motors* with an *rated motor power* of 0.25 hp or more, and less than or equal to 3 hp, shall have a minimum average full-load *efficiency* that is not less than as shown in Table 10.8-3 for polyphase *small electric motors* and Table 10.8-4 for capacitor-start capacitor-run *small electric motors* and capacitor-start induction-run *small electric motors*.

Fire *pump* electric motors shall have a minimum nominal full-load *efficiency* that is not less than that shown in Table 10.8-5.

Exception to 10.4.1: The standards in this section do not apply to the following exempt electric motors:

1. Air-over electric motors.
2. Component sets of an electric motor.
3. Liquid-cooled electric motors.
4. Submersible electric motors.
5. Inverter-only electric motors.

10.4.2 Service Water Pressure Booster Systems. Service water pressure booster *systems* shall be designed such that the following apply:

a. One or more pressure sensors shall be used to vary *pump* speed and/or start and stop *pumps*. The sensors shall either be located near the critical fixtures that determine the pressure required, or logic shall be employed that adjusts the *set point* to simulate operation of remote sensors.
b. No devices shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster *system pump* or booster *system*, except for safety devices.
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 Cab Lighting Power. For the *luminaires* in each elevator cab, not including power for germicidal function, 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 50 lm/W.

Exception to 10.4.3.1: This requirement does not apply to elevators in an *essential facility* where special lighting needs are required.

10.4.3.2 Ventilation Efficacy. Cab *ventilation* for elevators, except elevators with air conditioning or MERV 13 or greater filters, shall have an efficacy of at least 4.0 cfm/W at maximum speed.

10.4.3.3 Standby Mode. The elevator cab lighting shall be *automatically* de-energized in accordance with ASME A17.1/CSA B44 Requirement 2.14.7.2.2. Cab *ventilation* fans for elevators without air conditioning shall also be de-energized.

When stopped and unoccupied with *doors* closed for over 15 minutes, cab interior lighting and *ventilation* shall be de-energized until required for operation.

Exception to 10.4.3.3: Forced *ventilation* shall meet the requirements of ASME A17.1/CSA B44 Requirement 2.14.2.3.3.

10.4.3.4 Energy Use. New elevators shall meet the following requirements:

a. Usage category as defined in ISO 25745-2 between 1 and 6. The usage category shall be in accordance with Annex B.
b. The *energy efficiency* class shall be E or better per ISO 25745-2, Table 7.

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 Air Curtains. Air curtain unit performance shall be tested in accordance with ANSI/AMCA 220 or ISO 27327-1 and shall have a jet speed of not less than 6.6 ft/s at 6.0 in. above the *floor*. Automatic controls shall be provided that will operate the air curtain unit with the opening and closing of the *door* and comply with Section 6.4.3.9. To ensure proper operation, each air curtain unit shall be commissioned in accordance with the *manufacturer*'s instructions, including airstream split location and direction.

10.4.6 Compressed Air Systems. All compressed air *systems* in factory industrial occupancies shall meet the requirements of Sections 10.4.6.1 through 10.4.6.5. These requirements apply to the compressors, related *piping systems*, and controls that provide compressed air. This section does not apply to any *equipment* or controls that use or process the compressed air.

Exception to 10.4.6: Medical air *systems*.

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10.4.6.1 Part-Load Controls and Efficiency. Compressed air *systems* where the total motor power is 25 hp or more shall be equipped with appropriately sized *trim compressor(s)* and primary storage. The compressed air *system* shall comply with either of the following:

a. The compressed air *system* shall include one or more variable-speed-drive (VSD) compressors. For *systems* with more than one compressor, the total combined capacity of the VSD compressor(s) acting as *trim compressors* must be at least 1.25 times the largest net capacity increment between combinations of compressors. The compressed air *system* shall include primary storage of at least 3 gal per actual cubic feet per minute (acfm) of the largest *trim compressor*.
b. The total effective trim capacity of a compressor *system* is the size of the continuous operational range where the specific power of the compressor(s) (*kW*/100 acfm) is within 15% of the specific power at their most efficient operating point. The total effective trim capacity of the *system* is the sum of the effective trim capacity of the *trim compressors*.

   Systems shall include primary storage of at least 4 gal/acfm of the largest *trim compressor* and meet (1) or (2) as follows:

   1. S*ystems* with more than one compressor, not including backup compressors, shall include a compressor or set of compressors with total effective trim capacity at least the size of the largest net capacity increment between combinations of compressors, or the size of the smallest compressor, whichever is larger.
   2. For s*ystems* with one compressor, not including backup compressors, the total effective trim capacity shall include the range from 70% to 100% of rated capacity.

Exceptions to 10.4.6.1:

1. *Alterations* where the total combined added or replaced compressor motor power is less than the average per-compressor power of all compressors in the *system*.
2. *Alterations* where all added or replaced compressors are VSD compressors and the compressed air *system* includes primary storage of at least 3 gal/acfm of the largest trim compressor.
3. Compressed air *systems* that have been approved by the *authority having jurisdiction* as having demonstrated that the *system* serves loads for which typical air demand fluctuates less than 10%.
4. *Alterations* of existing compressed air *systems* that include one or more centrifugal compressors.

10.4.6.2 Controls. Compressed air *systems* with three or more compressors, including backup compressors, with a combined input power of more than 150 hp shall operate with controls that are able to choose the most *energy*-efficient combination and loading of compressors in the *system* based on the current compressed air demand.

10.4.6.3 Monitoring. Compressed air *systems* having a combined input power rating equal to or greater than 150 hp shall have an *energy* and air demand monitoring *system* with the following minimum requirements:

a. Measurement of *system* pressure
b. Measurement or calculation of current or power of each compressor
c. Measurement or determination of total airflow from all compressors in acfm
d. Data logging of pressure, power in *kW*, airflow in acfm, and compressed air *system* specific power in *kW*/100 acfm at intervals of five minutes or less
e. The *equipment* shall be configured to record not less than six months of data and shall be capable of exporting the data.
f. Visual trending display of each recorded point, load, and specific power.

10.4.6.4 Leak Testing of Compressed Air Piping. Compressed air *system piping* shall be pressure tested after being isolated from the compressed air supply, storage tanks, and end uses. The *piping* shall be pressurized to the design operating pressure and the pressure allowed to stabilize. Test pressures shall be held for no less than 30 minutes, with no loss of pressure greater than 1.0%.

For *piping* less than or equal to 50 adjoining feet in length, connections shall optionally be tested with a noncorrosive leak-detecting fluid or other leak detecting methods at the discretion of the *authority having jurisdiction*.

10.4.6.5 Pipe Sizing. For new *systems* and *additions* to *systems* with operating pressures above 50 psig, compressed air *piping* greater than 50 adjoining feet in length shall be designed and installed to minimize frictional losses in the distribution network.

Service line *piping* that delivers compressed air from distribution *piping* to end uses shall have inner diameters greater than or equal to 1 in.

Added or replaced *piping* in *existing systems* shall meet the requirements of Section 10.4.6.5(a). New *systems* shall meet the requirements of either Section 10.4.6.5(a) or (b).

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a. Piping section average velocity: Compressor room interconnection and main header *piping* shall be sized so that at coincident peak flow conditions the average velocity in the segment of pipe is no greater than 20 ft/s. Compressor room interconnection and main header *piping* are the pipes that deliver compressed air from the compressor outlets to the inlet to the distribution *piping*. Each segment of distribution and service *piping* shall be sized so that at coincident peak flow conditions the average velocity in the segment of pipe is no greater than 30 ft/s. Distribution *piping* is pipes that deliver compressed air from the compressor room interconnection *piping* or main header *piping* to the service line *piping*.
b. Piping total pressure drop: *Piping* shall be designed such that *piping* frictional pressure loss at coincident peak loads are less than 5% of operating pressure between the compressor and connection at point of use, prior to any end-use regulators.

10.4.7 Whole-Building Energy Monitoring. Measurement devices shall be installed at the *building site* to monitor the *energy* use of each new *building*.

10.4.7.1 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

10.4.7.2 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 10.4.7.1 and 10.4.7.2:

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*.

10.4.8 Pumps. *Clean water pumps* meeting the following criteria shall comply with the requirements shown in Table 10.8-6:

a. A flow rate of 25 gal/min or greater at its *best efficiency point (BEP)* at full impeller diameter
b. Maximum head of 459 ft at its *BEP* at full impeller diameter and the number of stages required for testing
c. Design temperature range from 14°F to 248°F
d. Designed to operate with either
   1. a 2- or 4-pole induction motor or
   2. a noninduction motor with a speed of rotation operating range that includes speeds of rotation between 2880 and 4320 rpm and/or 1440 and 2160 rpm, and
   3. in either (1) or (2), the *driver* and impeller must rotate at the same speed
e. For *submersible turbine pumps*, a 6 in. or smaller bowl diameter
f. For *end-suction close-coupled pumps* and *end-suction frame-mounted/own bearings pumps*, specific speed less than or equal to 5000 rpm when calculated using U.S. customary units

Exceptions to 10.4.8: The standards in this section do not apply to the following *pumps*:

1. Fire *pumps*.
2. Self-priming *pump*.
3. Prime-assist *pumps*.
4. Magnet-driven *pumps*.
5. *Pumps* designed to be used in a nuclear facility subject to 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities."
6. *Pumps* meeting the design and construction requirements set forth in U.S. Military Specification MIL-P-17639F, "Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use" (as amended); MIL-P-17881D, "Pumps, Centrifugal, Boiler Feed, (Multi-Stage)" (as amended); MIL-P-17840C, "Pumps, Centrifugal, Close-Coupled, Navy Standard (For Surface Ship Application)" (as amended); MIL-P-18682D, "Pump, Centrifugal, Main Condenser Circulating, Naval Shipboard"

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(as amended); MIL-P-18472G, "Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, And Distilling Plant" (as amended).

Informative Note: Informative Appendix E contains additional information on *pump* nomenclature and definitions which are available from ANSI-HI 1.1-1.2-2014 and ANSI-HI 2.1-2.2-2014.

10.5 Prescriptive Compliance Path

10.5.1 Renewable Energy Resources. *Buildings* shall be served by *renewable energy resources* complying with Section 10.5.1.1.

10.5.1.1 On-Site Renewable Energy. The *building site* shall have *equipment* for *on-site renewable energy* with a rated capacity of not less than 0.50 W/ft^2 or 1.7 Btu/ft^2 multiplied by the sum of the *gross conditioned floor area* for all floors up to the three largest floors.

Exceptions to 10.5.1.1:

1. Any *building* located where an unshaded flat plate collector oriented toward the equator and tilted at an angle from horizontal equal to the latitude receives an annual daily average incident solar radiation less than 1.1 kBtu/ft^2·day.
2. Any *building* where more than 80% of the *roof* area is covered by any combination of *equipment* other than for *on-site renewable energy systems*, planters, vegetated *space*, *skylights*, or occupied *roof* deck.
3. Any *building* where more than 50% of *roof* area is shaded from direct-beam sunlight by natural objects or by *structures* that are not part of the *building* for more than 2500 annual hours between 8:00 a.m. and 4:00 p.m.
4. New *construction* or *additions* in which the sum of the *gross conditioned floor area* of the three largest *floors* of the new construction or *addition* is less than 10,000 ft^2.
5. *Alterations*.

10.6 Alternative Compliance Path (Not Used)

10.7 Submittals

10.7.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

10.7.2 Permit Application Documentation (Not Used)

10.7.3 Completion Requirements

10.7.3.1 Record Documents. *Construction documents* shall require that within 90 days after the date of *system* acceptance, *record documents* shall be provided to the *building* owner.

10.7.3.2 Manuals (Not Used)

10.8 Product Information

10.9 Verification, Testing, Commissioning, and Documentation

10.9.1 Verification and Testing. Other applicable *equipment* shall be verified and tested in accordance with this section and Section 4.2.5.1. Testing shall verify that *control* elements and monitoring *systems* are configured and operating in accordance with Section 10.4.2, 10.4.3.3, 10.4.5, and 4.2.5.2. *FPT* documentation shall comply with applicable requirements of

a. service water pressure-booster *system* controls (Section 10.4.2),
b. elevator standby mode (Section 10.4.3.3),
c. air curtains (Section 10.4.5),
d. whole-*building energy* monitoring (Section 10.4.7), and
e. *pumps* (Section 10.4.8).

Verification and *FPT* documentation shall comply with Section 4.2.5.1.2.

10.9.2 Commissioning. The *energy* performance of the other *equipment systems* shall be *commissioned* in accordance with Section 4.2.5.2 and reporting shall comply with Section 4.2.5.2.2.

Informative Note: See Informative Appendix E and Informative Appendix H for *commissioning* resources.

10.9.3 Documentation. Design documents shall list the following for new elevators:

a. The usage category as defined in ISO 25745-2 between 1 and 6. The usage category shall be in accordance with Annex B.
b. The *energy efficiency* class per ISO 25745-2, Table 7.

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Table 10.8-1 Minimum Nominal Full-Load Efficiency for NEMA Design A, NEMA Design B, and IEC Design N Motors (Excluding Fire Pump Electric Motors) at 60 Hz[a,b]

Motor Horsepower, hp	Nominal Full-Load Efficiency, %							
	2-Pole		4-Pole		6-Pole		8-Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1
250	95.8	95.0	96.2	95.8	95.8	95.8	95.0	95.0
300	95.8	95.4	96.2	95.8	95.8	95.8	NR	NR
350	95.8	95.4	96.2	95.8	95.8	95.8	NR	NR
400	95.8	95.8	96.2	95.8	NR	NR	NR	NR
450	95.8	96.2	96.2	96.2	NR	NR	NR	NR
500	95.8	96.2	96.2	96.2	NR	NR	NR	NR

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.

b. For purposes of determining the required minimum nominal full-load *efficiency* of an electric motor that has a horsepower or *kilowatt* rating between two horsepower or two *kilowatt* ratings listed in this table, each such motor shall be deemed to have a listed horsepower or *kilowatt* rating, determined as follows:

1. A horsepower at or above the midpoint between the two consecutive horsepowers shall be rounded up to the higher of the two horsepowers.
2. A horsepower below the midpoint between the two consecutive horsepowers shall be rounded down to the lower of the two horsepowers.
3. A *kilowatt* rating shall be directly converted from *kilowatts* to horsepower using the formula 1 *kilowatt* = (1/0.746) horsepower. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with paragraph (1) or (2), whichever applies.

c. NR = no requirement.

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Table 10.8-2 Minimum Nominal Full-Load Efficiency for NEMA Design C and IEC Design H Motors at 60 Hz [a,b]

	Nominal Full-Load Efficiency, %					
	4-Pole		6-Pole		8-Pole	
Motor Horsepower, hp	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	85.5	85.5	82.5	82.5	75.5	75.5
1.5	86.5	86.5	87.5	86.5	78.5	77.0
2	86.5	86.5	88.5	87.5	84.0	86.5
3	89.5	89.5	89.5	88.5	85.5	87.5
5	89.5	89.5	89.5	89.5	86.5	88.5
7.5	91.7	91.0	91.0	90.2	86.5	89.5
10	91.7	91.7	91.0	91.7	89.5	90.2
15	92.4	93.0	91.7	91.7	89.5	90.2
20	93.0	93.0	91.7	92.4	90.2	91.0
25	93.6	93.6	93.0	93.0	90.2	91.0
30	93.6	94.1	93.0	93.6	91.7	91.7
40	94.1	94.1	94.1	94.1	91.7	91.7
50	94.5	94.5	94.1	94.1	92.4	92.4
60	95.0	95.0	94.5	94.5	92.4	93.0
75	95.4	95.0	94.5	94.5	93.6	94.1
100	95.4	95.4	95.0	95.0	93.6	94.1
125	95.4	95.4	95.0	95.0	94.1	94.1
150	95.8	95.8	95.8	95.4	94.1	94.1
200	96.2	95.8	95.8	95.4	94.5	94.1

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.

b. For purposes of determining the required minimum nominal full-load *efficiency* of an electric motor that has a horsepower or *kilowatt* rating between two horsepower or two *kilowatt* ratings listed in this table, each such motor shall be deemed to have a listed horsepower or *kilowatt* rating, determined as follows:

1. A horsepower at or above the midpoint between the two consecutive horsepowers shall be rounded up to the higher of the two horsepowers.
2. A horsepower below the midpoint between the two consecutive horsepowers shall be rounded down to the lower of the two horsepowers.
3. A *kilowatt* rating shall be directly converted from *kilowatts* to horsepower using the formula 1 *kilowatt* = (1/0.746) horsepower. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with paragraph (1) or (2), whichever applies.

Table 10.8-3 Minimum Average Full-Load Efficiency for Polyphase Small Electric Motors [a]

	Full-Load Efficiency, %		
	Open Motors		
Number of Poles ⇒	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200
Motor Size, hp			
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.

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Table 10.8-4 Minimum Average Full-Load Efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run Small Electric Motors[a]

	Full-Load Efficiency, %		
	Open Motors		
Number of Poles ⇒	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200
Motor Size, hp			
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 10.8-5 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 Size, hp								
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

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Table 10.8-5 Minimum Nominal Full-Load Efficiency for Fire Pump Electric Motors[a] *(Continued)*

	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 Size, hp								
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.
b. For purposes of determining the required minimum nominal full-load *efficiency* of an electric motor that has a horsepower or *kilowatt* rating between two horsepower or two *kilowatt* ratings listed in this table, each such motor shall be deemed to have a listed horsepower or *kilowatt* rating, determined as follows:
1.A horsepower at or above the midpoint between the two consecutive horsepowers shall be rounded up to the higher of the two horsepowers.
2.A horsepower below the midpoint between the two consecutive horsepowers shall be rounded down to the lower of the two horsepowers.
3.A *kilowatt* rating shall be directly converted from *kilowatts* to horsepower using the formula 1 *kilowatt* = (1/0.746) horsepower. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with paragraph (1) or (2), whichever applies.
NR—No requirement

Table 10.8-6 Maximum Pump Energy Index (PEI)

Maximum PEI for Pumps Manufactured on or after January 27, 2020					
Pump Type	Nominal Speed of Rotation (RPM)	Operating Mode	Maximum PEI[a]	C-Value[b]	Test Procedure
End suction, close coupled	1800	Constant load	1.00	128.47	10 CFR Part 431
End suction, close coupled	3600	Constant load	1.00	130.42	10 CFR Part 431
End suction, close coupled	1800	Variable load	1.00	128.47	10 CFR Part 431
End suction, close coupled	3600	Variable load	1.00	130.42	10 CFR Part 431
End suction, frame mounted	1800	Constant load	1.00	128.85	10 CFR Part 431
End suction, frame mounted	3600	Constant load	1.00	130.99	10 CFR Part 431
End Suction, frame mounted	1800	Variable load	1.00	128.85	10 CFR Part 431
End suction, frame mounted	3600	Variable load	1.00	130.99	10 CFR Part 431
In-line	1800	Constant load	1.00	129.30	10 CFR Part 431
In-line	3600	Constant load	1.00	133.84	10 CFR Part 431
In-line	1800	Variable load	1.00	129.30	10 CFR Part 431
In-line	3600	Variable load	1.00	133.84	10 CFR Part 431
Radially split, vertical	1800	Constant load	1.00	129.63	10 CFR Part 431
Radially split, vertical	3600	Constant load	1.00	133.20	10 CFR Part 431
Radially split, vertical	1800	Variable load	1.00	129.63	10 CFR Part 431
Radially split, vertical	3600	Variable load	1.00	133.20	10 CFR Part 431
Submersible turbine	1800	Constant load	1.00	138.78	10 CFR Part 431
Submersible turbine	3600	Constant load	1.00	134.85	10 CFR Part 431
Submersible turbine	1800	Variable load	1.00	138.78	10 CFR Part 431
Submersible turbine	3600	Variable load	1.00	134.85	10 CFR Part 431

a. For *pumps* with the constant load operating mode, the relevant PEI is PEI_{CL}. For *pumps* with the variable load operating mode, the relevant PEI is PEI_{VL}.
b. The C-values shown in this table shall be used in the equation for PEI_{STD} when calculating PEI_{CL} or PEI_{VL}.

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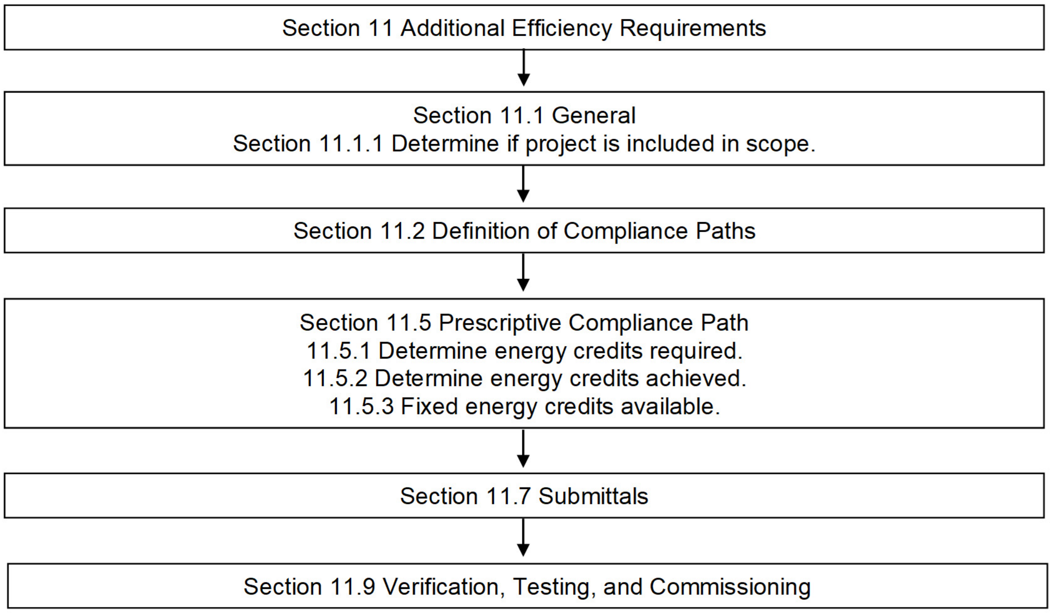

11. ADDITIONAL EFFICIENCY REQUIREMENTS

11.1 General

11.1.1 Scope. This section applies only to the *building envelope*, *equipment*, and *systems* installed in projects that include new *buildings*, *additions*, and *alterations* as described in Sections 11.1.2 through 11.1.4.

11.1.2 New Buildings. The *building envelope*, *equipment*, and *systems* in new *buildings* exceeding 2000 ft^2 of *gross floor area* shall comply with the requirements of Section 11.2.

11.1.3 Additions to Existing Buildings. The *building envelope*, *equipment*, and *systems* in *additions* to *existing buildings* exceeding 2000 ft^2 of *gross conditioned floor area* shall comply with the requirements of Section 11.2.

11.1.4 Alterations to Existing Buildings

11.1.4.1 Substantial Alterations to Existing Buildings. The *building envelope*, *equipment*, and *systems* in *alterations* of an *existing building*, other than *additions*, exceeding 5000 ft^2 of *gross conditioned floor area* shall comply with the requirements of Section 11.2 where the *alteration* includes replacement of two or more of the following:

a. *HVAC systems* that account for more than 50% of the capacity serving either the heating or cooling loads of the *alteration* area. This includes HVAC unitary *systems*, HVAC *terminal* units, or components of HVAC central heating or cooling *equipment*, not including *ductwork* or *piping*. HVAC *terminal* units, for the purposes of this section, can include *VAV* boxes, fan-coil units, *VRF* room units, or water-loop heat pumps.
b. Fifty percent (50%) or more of the *luminaires* in the *alteration* area
c. Twenty-five percent (25%) or more of the *building envelope* area of the *alteration* portion of the *building*, including new exterior cladding, *fenestration*, or insulation

Informative Note: Substantial *alterations* are intended to include a major renovation of part or all of an *existing building* that extends the life of the *building* and includes major replacement of at least two major *building systems*.

11.1.4.2 Initial Build-Out Construction. The *building envelope*, *equipment*, and *systems* in initial build-out *construction* exceeding 1000 ft^2 of *gross floor area* in *buildings* where the *alteration* did not have final lighting or *HVAC systems* installed under a prior *building* permit shall comply with the requirements of Section 11.2.

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11.1.5 Climate. Climate zones shall be determined in accordance with Section 5.1.5.

11.2 Compliance Paths. New *buildings*, *additions*, substantial *alterations* as described in Section 11.1.4.1, and initial build-out *construction* as described in Section 11.1.4.2, shall comply with Section 11.2.1 and 11.2.2.

11.2.1 Requirements for All Compliance Paths. The project shall comply with Section 11.1, "General"; Section 11.5, "Prescriptive Compliance Path"; Section 11.7, "Submittals"; and Section 11.9, "Verification, Testing, and Commissioning."

11.2.2 Additional Requirements to Comply with Section 11 (Not used)

11.3 Simplified Building Compliance Path (Not used)

11.4 Mandatory Provisions (Not used)

11.5 Prescriptive Compliance Path. Projects described in Section 11.1.1 shall achieve the total *energy* credits required in Section 11.5.1. Energy credits achieved by measures included in the *building* are determined in Section 11.5.2.

Informative Note: The *energy* credit values in Table 11.5.1-1 and Tables 11.5.3-1 through 11.5.3-9 represent about 0.1% total *building* annual *energy* cost savings per point.

11.5.1 Energy Credits Required. Projects shall achieve the total of credits required in Table 11.5.1-1 based on the *building* use type and climate zone. Projects with multiple *building* use types, *unconditioned* or *semiheated buildings*, parking garages, projects using *on-site renewable energy*, *alterations*, and *buildings* with separate shell-and-core and initial build-out *construction* permits shall comply as follows:

a. Where a project contains multiple *building* use types or situations covered in items (b), (c), and (d) below, credits in Table 11.5.1-1 from each *building* use type shall be weighted by the *gross floor area* of each *building* use type or situation to determine the weighted-average project *energy* credits that are required. Achieved credits from Section 11.5.2 shall be similarly weighted.
b. Where separate permits are used for *building* core/shell and initial build-out *construction*, the following shall apply:
   1. The *building* core and shell project shall achieve at least 50% of the *energy* credits required in Table 11.5.1-1 where the core and shell project includes a central *HVAC system* or *service water heating system* that includes chillers, *boilers*, *service water heating equipment*, or loop pumping *systems* with heat rejection. Otherwise, the *building* core and shell project shall achieve at least 33% of the *energy* credits required in Table 11.5.1-1. The *building* core and shell permit shall not be eligible for credits from measures involving nonpermanent services in future build-out areas, such as freeze protection and limited lighting.
   2. Initial build-out *construction*, as described in Section 11.1.4.2, shall be deemed to comply with this section where one of the following applies:
      i. Where the initial build-out project includes HVAC heating and cooling generation *equipment*, the *energy* credits achieved under the initial build-out project are not less than 50% of the credits required in Table 11.5.1-1.
      ii. Where the initial build-out project receives heating and cooling services from the core and shell *building*—excluding condenser loop water—the *energy* credits achieved under the initial build-out project are not less than 25% of the credits required in Table 11.5.1-1.
      iii. The *energy* credits achieved under the initial build-out project, plus the *energy* credits achieved under a prior core and shell permit—not including core and shell credits from measures L02, L03, L04, L05, L06, G01, or G02—total at least the credits required in Table 11.5.1-1.
c. Substantial *alterations*, as described in Section 11.1.4.1, that are not initial build-out *construction* shall achieve 50% of the credits required for the *building* use type in the substantial *alteration* portion of the *building*.
d. *Unconditioned spaces*, *semiheated spaces*, and parking garages shall achieve 50% of the credits required for the "Other" *building* use type in Table 11.5.1-1.
e. Where *roof space* or insolation available for *on-site renewable energy* is limited according to the definition of RA_{net} in Equation 11.5.1, the *energy* credit requirement in Table 11.5.1-1 shall be adjusted and EC_{adj} used in place of EC_{req}, where EC_{adj} is determined using one of the following:
   1. Where the project meets any exception to Section 10.5.1.1, the PV_{adj} credits shall be subtracted from the credits required for the climate zone to find EC_{adj}.
   2. Otherwise, *energy* credits adjusted for *renewable energy resource* availability shall be determined as follows:

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Table 11.5.1-1 Energy Credit Requirements by Building Use Type

Building Use Type [a]	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily [b]	50	50	50	50	50	50	46	50	50	48	50	46	50	50	49	50	50	50	50
Health care [c]	50	46	47	46	47	45	49	47	50	46	46	50	50	50	50	50	50	50	50
Hotel/motel	50	45	47	46	49	48	46	47	50	48	50	50	47	46	47	49	46	50	50
Office [d]	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Restaurant [e]	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Retail	50	50	50	50	50	50	50	50	50	50	50	50	49	50	47	48	45	42	46
Education [f]	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	46
Warehouse [g]	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Other [h]	39	36	37	37	35	34	30	32	33	28	32	30	29	31	30	29	30	29	29

a. All *building* use types include supporting functions such as corridors, break rooms, lobbies, restrooms, mechanical rooms, storage rooms, conference rooms, individual *equipment* and *computer rooms* with loads ≤10 *kW*, minor snack and beverage service without a commercial kitchen, and up to 10% of *gross floor area* of other *building* use types such as an office area less than 2000 ft^2 in a nonoffice *building* use type.
b. "Multifamily" includes apartments, condominiums, dormitories, retirement living facilities, nontransient lodging, and *residential* portions of institutional care facilities, excluding prisons.
c. "Health Care" includes *buildings* within the scope of ASHRAE Standard 170 *ventilation* requirements that are dedicated to patient care, including related support areas of health care facilities, hospitals, nursing facilities, outpatient facilities, and surgery centers.
d. Office includes offices or clinics where medical, dental, psychotherapy, physical therapy or other services are provided that are not within the scope of ASHRAE Standard 170 *ventilation* requirements.
e. Restaurants with commercial kitchens and dining areas that are separate *buildings* or constructed under separate permits shall meet restaurant building use type requirements. Where restaurants are part of a larger building and are not seeking credit for either measure W01, W02, W03, or Q02, their area is permitted to be included with the larger *building* use type.
f. Education includes schools, lecture halls, gymnasiums, and libraries.
g. Warehouse that are *conditioned spaces,* including storage and distribution *building*s, refrigerated warehouses, and storage rental facilities.
h. All other *buildings*, including any *building* use not covered in the eight listed *building* use types above and data centers using Standard 90.4, shall use the energy credits required and available for the "Other" category.

Table 11.5.1-2 Renewable Adjustment Credits

Building Use Type	PV_{adj} by Climate Zone																			PV_{incl}, W/ft^2
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	
Multifamily	6	7	8	7	8	18	16	19	20	13	13	14	6	9	13	6	7	6	5	0.1
Health care	3	3	3	3	3	4	3	4	7	5	7	3	2	3	3	3	3	2	2	0.1
Hotel/motel	4	8	9	9	9	12	10	13	8	9	10	8	8	12	9	9	10	8	5	0.1
Office	6	6	7	7	12	8	8	9	10	7	9	7	6	8	7	6	7	6	5	0.1
Restaurant	1	1	1	1	1	2	1	2	2	1	2	1	1	1	1	1	1	1	1	0.1
Retail	5	5	6	6	7	8	14	17	16	7	14	12	10	14	12	10	12	10	7	0.1
Education	5	6	7	6	7	9	16	14	12	11	11	9	11	11	9	12	10	12	10	0.1
Warehouse	20	20	20	20	20	20	20	20	20	19	20	20	14	20	20	12	17	12	10	0.1
Other	6	6	7	7	7	8	7	9	9	7	9	7	5	8	7	6	7	5	4	0.1

$$EC_{adj} = EC_{req} - PV_{adj} \times \left(1 - \frac{RA_{net}}{G_{floor} \times PV_{incl} \times 0.20}\right) \quad (11.5.1)$$

where

EC_{adj} = adjusted *energy* credit requirement used instead of the *energy* credit requirement from Table 11.5.1-1

EC_{req} = *energy* credit requirement from Table 11.5.1-1

PV_{adj} = PV_{adj} for *building* type from Table 11.5.1-2

RA_{net} = horizontal projection of *roof* area available for *renewable energy resources* not covered by any

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combination of *equipment* other than for *on-site renewable energy systems*, planters, vegetated *space*, *skylights*, or occupied *roof* deck after meeting requirements of Section 10.5.1

G_{floor} = *gross floor area* of *building*, ft^2

PV_{incl} = PV_{incl} for *building* type from Table 11.5.1-2, W/ft^2

Exceptions to 11.5.1:

1. Portions of *buildings* devoted to manufacturing or industrial use not including office areas.
2. Where the core/shell complies in accordance with Normative Appendix G or Section 12, the initial build-out *alterations* do not need to achieve any *energy* credits.

Informative Notes:

1. Under Section 11.5.1(a), a *building* may be split into multiple *building* use types unless there is a small area less than 10% of the *gross floor area* of a different use type. Examples: A small managers office in a multifamily *building*, retail, or hotel would be included with the main multifamily or other use type, while a large administrative wing of a hospital (>10% of gross *building* area or greater than 2000 ft^2) would be a separate *building* use type. A coffee bar in the lobby of an office *building* or bookstore would be included with the office or retail use type, while a restaurant with a commercial kitchen in a hotel seeking hot water or kitchen *equipment* measures would be a separate *building* use type, regardless of relative size.

   Where office areas 2000 ft^2 or more are associated with a larger *building* of a different type, such as a data center, warehouse, or hospital, the office area should be separated for *energy* credit treatment in the office *building* category, even if the special use was less than 10% of the total project *building* area.
2. The *energy* credit requirements in Table 11.5.1-1 are based on a cost-effectiveness analysis of a selection of credits that would typically be applied to each *building* use type. In all cases, photovoltaic renewable credits are included. The renewable credit adjustment in item (e) (based on Table 11.5.1-2) is included so that, where *on-site renewable energy* is not feasible, the required credits are appropriately reduced to match a typical cost-effective package of measures.

11.5.2 Energy Credits Achieved. Energy credits achieved for the project shall be the sum of measure *energy* credits for individual measures included in the project. Where a project contains multiple *building* use types, credits achieved for each *building* use type shall be weighted by the *gross floor area* of each *building* use type group to determine the weighted-average project *energy* credits achieved. The combined renewable (R01) and load management (G01 through G07) *energy* credits achieved through Section 11.5.2.6 and 11.5.2.8 shall be limited to meeting 60% of required *energy* credits. Credits are available for the measures listed in Section 11.5.2.1 through 11.5.2.8. Base *energy* credits are shown in Tables 11.5.3-1 through 11.5.3-9 for *building* use types in each climate zone. Measure *energy* credits achieved shall be determined in one of three ways, depending on the measure:

a. The measure *energy* credit shall be the base *energy* credit for the measure, where no adjustment factor or formula is shown in the measure description (e.g., EC_{H02_base}).
b. The measure *energy* credit shall be the base *energy* credit for the measure, adjusted by a factor or formula as stated in the measure description in this section. Where adjustments are applied, each measure *energy* credit shall be rounded to the nearest whole number (e.g., EC_{H02_adj}).
c. The measure *energy* credit shall be by direct formula as stated in the measure description in this section, where each measure credit shall be rounded to the nearest whole number (e.g., EC_{H02_calc}).

Informative Note: The number of *energy* credits achieved for each individual measure is determined in one of three ways:

1. The base *energy* credit for the measure shown in Tables 11.5.3-1 through 11.5.3-9 for the *building* use type and climate zone where no adjustment factor or formula is shown in the measure description. This applies to the following measures:
   - H04: 11.5.2.2.4, “Residential Space HVAC Control”
   - H07: 11.5.2.2.7, “Improved HVAC Sequence of Operations”
   - W01: 11.5.2.3.1(a), “Heat Recovery for Service Hot-Water Preheating”
   - W05: 11.5.2.3.3(a), “Point-of-Use Water Heater”
   - W06: 11.5.2.3.3(b), “Thermostatic Balancing Valves”
   - W07: 11.5.2.3.4, “Dwelling-Unit Service Hot-Water Submeters”
   - W08: 11.5.2.3.5, “Right Sizing the Hot-Water Distribution System”
   - P01: 11.5.2.4, “Energy Monitoring”

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- L03: 11.5.2.5.3, "Occupancy Sensor Control Areas"
- Q02: 11.5.2.7.2, "Efficient Kitchen Equipment"
- Q03: 11.5.2.7.3, "Fault Detection and Diagnostics System"
- G02: 11.5.2.8.2, "HVAC Load Management"
- G03: 11.5.2.8.3, "Automated Shading Load Management"
- G07: 11.5.2.8.7, "Building Thermal Mass"

2. The base credit for the measure shown in Tables 11.5.3-1 through 11.5.3-9 for the *building* use type and climate zone adjusted by proration factor or formula as stated in the measure description in this section. This applies to the following measures:
   - H02: 11.5.2.2.2, "HVAC Heating Performance Improvement"
   - H03: 11.5.2.2.3, "HVAC Cooling Performance Improvement"
   - H05: 11.5.2.2.5, "Ground-Source Heat-Pump System"
   - H06: 11.5.2.2.6, "Dedicated Outdoor Air System with Zone Fan Control"
   - W02: 11.5.2.3.1(b), "Heat-Pump Water Heater"
   - W03: 11.5.2.3.1(c), "Efficient Gas Water Heater"
   - W04: 11.5.2.3.2, "Service Hot-Water Piping Insulation Increase"
   - W09: 11.5.2.3.6, "Shower Drain Heat Recovery"
   - L02: 11.5.2.5.2, "Continuous Dimming and High-End Trim"
   - L04: 11.5.2.5.4, "Increased Daylighting Control Area"
   - L05: 11.5.2.5.5, "Lighting Control for Multifamily Buildings"
   - L06: 11.5.2.5.6, "Reduce Interior Lighting Power"
   - R01: 11.5.2.6, "On-Site Renewable Energy"
   - Q01: 11.5.2.7.1, "Efficient Elevator Equipment"
   - G01: 11.5.2.8.1, "Lighting Load Management"
   - G04: 11.5.2.8.4, "Electric Energy Storage"
   - G05: 11.5.2.8.5, "HVAC Cooling Energy Storage"
   - G06: 11.5.2.8.6, "Service Hot-Water Thermal Storage"
3. By direct formula, as stated in the measure description in this section. This applies to the following measure:
   - E01: 11.5.2.1, "Improved Envelope Performance"

11.5.2.1 E01: Improved Envelope Performance. To achieve this credit, *building envelope* measures shall be installed to improve the *energy* performance of the project. Measure *energy* credits for improvement of the *building envelope energy* performance shall be determined based on the following:

$$EC_{E01\_calc} = 1000 \times \frac{EPF_{E01\_base} - EPF_{prop}}{EPF_{E01\_base}}$$

where

EC_{E01_calc} = *energy* credits achieved for improved envelope performance

EPF_{E01_base} = *base envelope performance factor* calculated in accordance with Normative Appendix C

EPF_{prop} = *proposed envelope performance factor* calculated in accordance with Normative Appendix C

11.5.2.2 Improved HVAC Performance. To achieve these credits, *equipment* shall provide HVAC performance improvement in accordance with Section 11.5.2.2.2, 11.5.2.2.3, 11.5.2.2.4, 11.5.2.2.5, or 11.5.2.2.6. *Equipment* shall also meet applicable requirements of Sections 6.4 and 6.5. Credits shall be as shown in Section 11.5.3 or as specified in each subsection for *building* use types where base credits are included in Section 11.5.3 tables. Use of multiple credits from this section shall be allowed.

11.5.2.2.1 H01: HVAC System Performance Improvement (Reserved)

11.5.2.2.2 H02: HVAC Heating Performance Improvement. To achieve this credit, *space* heating *equipment* shall exceed the minimum heating *efficiency* requirements by 5% or more than listed in the tables in Section 6.8.1. The measure *energy* credit for heating *efficiency* improvement (EC_{HE}) shall be determined as follows:

$$EC_{H02\_adj} = EC_{H02\_base} \times \frac{EI_{heat}}{0.05}$$

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where

EC_{H02_adj} = *energy* credits achieved for heating *efficiency* improvement

EC_{H02_base} = H02 base *energy* credit from Section 11.5.3

EI_{heat} = lesser of the percentage improvement (as a fraction) above minimum heating *efficiency* requirements or 20% (0.20). Where heating *equipment* with different minimum efficiencies are included in the *building*, a heating capacity weighted-average improvement shall be used. Where *electric resistance* primary heating or *reheat* is included in the *building*, it shall be included in the weighted-average improvement with an EI_{heat} of 0. Supplemental gas and electric heat for heat-pump *systems* shall be excluded from the weighted EI_{heat}. For heat pumps rated at multiple ambient temperatures, use the *efficiency* at 47°F. Gas-fired *boiler systems* that are required to meet provisions of Section 6.5.4.8 shall use the minimum *system efficiency* as defined in Section 6.5.4.8.1. Gas-fired *boiler systems* that are required to meet provisions of Section 6.5.4.8 shall use the minimum *system efficiency* as defined in Section 6.5.4.8.1.

For metrics that increase as *efficiency* increases, EI_{heat} shall be calculated as follows:

$$EI_{heat} = \frac{HM_{des}}{HM_{min}} - 1$$

where

HM_{des} = design heating *efficiency* metric, part-load or annualized where available

HM_{min} = minimum required heating *efficiency* metric, part-load or annualized where available from Section 6.8.1 or Informative Appendix F

Informative Note: An example of an annualized or part-load heating efficiency is AFUE rather than E_t or E_c. Where only one efficiency rating is provided for equipment in Section 6.8.1 or Informative Appendix F, use that metric.

11.5.2.2.3 H03: HVAC Cooling Performance Improvement. To achieve this credit, *space* cooling *equipment* shall exceed the minimum cooling *efficiency* requirements by 5% or more than listed in the tables in Section 6.8.1 or Informative Appendix F. For water-cooled chiller plants, heat rejection *efficiency* shall also exceed the minimum *efficiency* listed in Table 6.8.1-7 by at least the percentage improvement in the chiller *efficiency*. The measure *energy* credit (EC_{CE}) for cooling *efficiency* improvement shall be determined as follows:

$$EC_{H03\_adj} = EC_{H03\_base} \times \frac{EI_{cool}}{0.05}$$

where

EC_{H03_adj} = *energy* credits achieved for cooling *efficiency* improvement

EC_{H03_base} = H03 base *energy* credits from Section 11.5.3

EI_{cool} = lesser of the percentage improvement (as a fraction) above minimum cooling *efficiency* requirements or 20% (0.20). Where cooling *equipment* with different minimum efficiencies are included in the *building*, a cooling capacity weighted-average improvement shall be used. Where multiple cooling performance requirements are provided, the *equipment* shall exceed the annualized *energy* or part-load requirement. Meeting both part-load and full-load *efficiencies* is not required.

For metrics that increase as *efficiency* increases, EI_{cool} shall be calculated as follows:

$$EI_{cool} = \frac{CM_{des}}{CM_{min}} - 1$$

For metrics that decrease as *efficiency* increases, EI_{cool} shall be calculated as follows:

$$EI_{cool} = \frac{CM_{min}}{CM_{des}} - 1$$

where

CM_{min} = minimum required cooling *efficiency* metric, part-load or annualized where available from Section 6.8 or Informative Appendix F

CM_{des} = design cooling *efficiency* metric, part-load or annualized where available

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Table 11.5.2.2.5 GSHP Heat Rejection Adjustments

	HR_{adj} by Field Source Capacity		
Climate Zones	**Full-Sized Bore Field with no Heat Rejection**	**90% Hours Source Size; Dry-Cooler Heat Rejection**	**90% Hours Source Size; Evaporative Heat Rejection**
0A, 1B, 2B, 3A, 3B, 4A, 4B	3.3		2.6
0B, 1A, 2A, 3C	7.6		5.3
4C, 5A, 5B, 5C	2.3		1.5
6A, 6B, 7, 8	1.4		1.1
All climate zones		1.0	

For data centers using Standard 90.4, EI_{cool} shall be calculated as follows:

$$EI_{cool} = \frac{AMLC_{max}}{AMLC_{des}} - 1$$

where

$AMLC_{max}$ = maximum annualized mechanical load component from Standard 90.4, Table 6.5

$AMLC_{des}$ = as-designed annualized mechanical load component calculated in accordance with Standard 90.4, Section 6.5

Informative Note: An example of an annualized or part-load cooling *efficiency* is *IEER* rather than *EER*, or *IPLV kW*/ton rather than FL *kW*/ton. Where only one *efficiency* rating is provided for *equipment* in Section 6.8.1 or Informative Appendix F, use that metric.

11.5.2.2.4 H04: Residential Space HVAC Control. To achieve this credit, in *buildings* with *nontransient residential spaces*, *HVAC system*s serving *dwelling units* shall be *controlled* to *automatically* activate the *setback* condition with one of the following:

a. A main control by each *dwelling-unit* main entrance that initiates *setback* and non-*ventilation* mode for all HVAC units serving the *dwelling* unit and that is clearly identified as "Heating/Cooling Master Setback."
b. *Occupancy sensors* in each room of the *dwelling unit* combined with a *door* switch to initiate *setback* and non-*ventilation* mode for all HVAC units in the dwelling within 20 minutes of a *door* switch operation followed by all *spaces* being vacant. Where separate room HVAC units are used, individual *occupancy sensors* shall meet this requirement.
c. An advanced learning *thermostat* or controller that recognizes occupant presence and *automatically* creates a schedule for occupancy and provides a dynamic *setback* schedule based on when the *spaces* are generally unoccupied. Where *ventilation* is provided by a separate *system*, it shall also have *occupancy sensor control*.

11.5.2.2.5 H05: Ground-Source Heat-Pump System. To achieve this credit, a ground-source heat-pump *system* shall provide cooling and heating for at least 25% of the *gross conditioned building area*. The ground-source heat-pump *systems* shall include *building* ground-loop *HVAC systems* coupled with a closed-bore ground-heat exchanger, submerged heat exchanger using water-based fluid as a heat transfer medium, groundwater (well), or fluid infrastructure (such as effluent and wastewater), and shall comply with the following:

a. Loop *pump(s)* shall have controls and/or devices that will result in *pump* motor *demand* of no more than 30% of design wattage at 50% of design water flow and allow turndown to 15% flow. Alternatively, a separate field-loop *pump* shall be provided, with either a variable-speed *building pump* or individual *pumps* for each ground-source heat pump.
b. The geothermal-source exchanger shall be sized based on the heating and cooling loads served by the ground-source heat-pump *system* and shall comply with one of the following:
   1. A closed bore field shall have at least 400 lineal ft of bore *piping* per 12,000 Btu/h of *system* cooling or heating capacity, whichever is greater. The *system* shall not include additional heat rejection or addition devices.
   2. The ground source shall be sized such that the loop heat pumps provide 100% of the heating and cooling loads for at least 90% of both the cooling and heating *system* annual operating hours without requiring any supplemental heating or heat rejection from nonground sources, as demonstrated by an

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Table 11.5.2.2.6 DOAS Energy Recovery Adjustments

ERE_{adj} Based on Lower of Actual Heating or Cooling Energy Recovery Effectiveness where Required		
Cooling ERR Is ≥	**Heating Enthalpy Recovery Ratio (ERR) or Sensible Energy Recovery Ratio Is ≥**	**Energy Recovery Effectiveness Adjustment (ERE_{adj})**
65%	65%	1.00
60%	60%	0.67
55%	55% [a]	0.33
50%	50% [a]	0.25

a. In climate zones where heating recovery is required for this measure, for multifamily buildings heating energy recovery effectiveness below 60% is not allowed.

analysis approved by the *authority having jurisdiction*. Heat rejection shall include a two-speed or variable-speed fan.

The allowed credits are based on serving 25% of *gross conditioned building area* and including dry-cooler partial heat rejection. Adjust the base credits as follows:

$$EC_{H05\_adj} = EC_{H05\_base} \times \frac{Floor_{GSHP}}{0.25} \times HR_{adj}$$

where

EC_{H05_adj} = *energy* credits achieved for ground-source heat-pump *system*

EC_{H05_base} = H05 base *energy* credit from Section 11.5.3

$Floor_{GSHP}$ = fraction of whole-project *gross conditioned floor area* with heating and cooling provided by the ground-source heat pump.

HR_{adj} = heat-rejection adjustment factor by climate zone from Table 11.5.2.2.5

11.5.2.2.6 H06: Dedicated Outdoor Air System with Zone Fan Control. Credits for this measure are only allowed where single-zone HVAC units are not required to have multispeed or variable-speed fans in accordance with Section 6.5.3.2.1. HVAC controls and *ventilation systems* shall include all of the following:

a. Zone controls shall cycle the heating/cooling-unit fans off when not providing required heating and cooling or shall limit fan power to 0.12 W/cfm of air delivered to the zone by the unit.
b. *Outdoor air* shall be supplied by an independent *ventilation system* designed to provide no more than 110% of the minimum *outdoor air* to each individual occupied *space* as specified by Standard 62.1
c. The *ventilation system* shall have *energy* recovery with an *enthalpy recovery ratio* (*ERR*) of 65% or more at heating *design conditions* in Climate Zones 3 through 8 and an *ERR* of 65% or more at cooling *design conditions* in Climate Zones 0, 1, 2, 3A, 3B, 4A, 4B, 5A, and 6A. In "A" climate zones, *energy* recovery shall include latent recovery. Where no humidification is provided, heating *energy* recovery effectiveness is permitted to be based on *sensible energy recovery ratio*. Where *energy* recovery effectiveness is less than the 65% required for full credit, adjust the credits from Section 11.5.3 by the factors in Table 11.5.2.2.6.
d. Where the *ventilation system* serves multiple zones, partial economizer cooling through an *outdoor air* bypass shall *automatic*ally *reset* the *energy* recovery leaving air temperature at 55°F or 100% *outdoor air* bypass when a majority of zones require cooling and *outdoor air* temperature is below 70°F. Recovery-wheel speed control or other means are permitted to allow partial economizer cooling. Partial economizer cooling is not required in a latent recovery *outdoor air* dehumidification mode.
e. *Ventilation systems* providing mechanical dehumidification shall use recovered *energy* for *reheat* within the limits of item (d). This shall not limit the use of latent *energy* recovery for dehumidification.

Where only a portion of the *building* is served by constant-air-volume (CAV) units or the *ERR* or *sensible energy recovery ratio* is less than 65%, the base *energy* credit shown in Section 11.5.3 shall be prorated as follows:

$$EC_{H06\_adj} = EC_{H06\_base} \times Floor_{CAV} \times ERE_{adj}$$

where

EC_{H06_adj} = *energy* credits achieved for dedicated *outdoor air system* with zone fan control

EC_{H06_base} = H06 base *energy* credit from Section 11.5.3

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$Floor_{CAV}$ = fraction of whole-project *gross conditioned floor area* where constant-air-volume single-speed fans are allowed and meet measure requirements

ERE_{adj} = *energy* recovery adjustment from Table 11.5.2.2.6 based on the lower of actual cooling or heating ERR or *sensible energy recovery ratio* where required for the climate zone

11.5.2.2.7 H07: Improved HVAC Sequence of Operations. To achieve this credit, all applicable control sequences shall be based on ASHRAE Guideline 36. Credits for this measure are only allowed where the *HVAC system* includes at least one of the following: a *VAV* air handler serving at least five (5) zone *terminals*, a chilled-water plant with at least two chillers, or a hot-water plant with at least two *boilers* or heat pumps.

11.5.2.3 Reduced Energy Use in Service Water Heating. Energy credits described in Section 11.5.2.3.1 through 11.5.2.3.6 are available in any combination described in those sections for *building* use types where base credits are included in Section 11.5.3 tables.

11.5.2.3.1 Improved Service Water Heating Effectiveness. *Service water heating* effectiveness *energy* credits are permitted to be achieved in *building* use types where credits are available in Section 11.5.3 for one of the following:

a. **W01: Heat Recovery for Service Hot-Water Preheating.** To achieve this credit, the *service water heating system* shall have waste heat recovery from service hot water, heat recovery chillers, *building equipment*, or process *equipment* that is sized to provide not less than 30% of the annual hot-water requirements or sized to provide not less than 70% of the annual hot-water requirements if the *building* is required to comply with Section 7.5.3.

b. **W02: Heat-Pump Water Heater.** To achieve this credit, air source heat-pump *water heaters* shall be installed according to the *manufacturer*'s instructions, and at least 30% of design end-use *service water heating* requirements shall be met using only heat-pump heating at an ambient condition of 67.5°F db without supplemental *electric resistance* or *fossil fuel* heating. For a hybrid heat-pump *water heater*, the heat-pump-only capacity shall be deemed at 40% of first hour draw. Where the heat-pump-only capacity exceeds 50% of the design end-use load, excluding *recirculating system* losses, the credits from the Section 11.5.3 tables shall be prorated as follows:

$$EC_{W02\_calc} = EC_{W02\_base} \times \frac{Cap_{HPWH}}{EndLoad \times 0.5} \qquad \text{(not greater than 2)}$$

where

EC_{W02_calc} = *energy* credits achieved for heat-pump *water heater*

EC_{W02_base} = W02 base *energy* credit from Section 11.5.3

Cap_{HPWH} = heat-pump-only capacity at 50°F entering air and 70°F without supplemental *electric resistance* or *fossil fuel* heat, Btu/h

EndLoad = end-use peak hot-water load, excluding load for *heat trace* or recirculation, Btu/h

The heat-pump *service water heating system* shall comply with the following requirements:

1. For central *systems* with an installed total output capacity of more than 100,000 Btu/h at an ambient condition of 67.5°F db, a preheat storage tank with ≥0.75 gal per 1000 Btu/h of design end-use *service water heating* requirements shall be heated only with heat-pump heating when the ambient temperature is >45°F.
2. For *systems* with *piping* temperature maintenance, either a *heat trace system* or a separate *water heater* in series for *recirculating system* and final heating shall be installed.
3. Heat-pump *water heater efficiency* shall meet or exceed one of the following:
   i. Output-capacity-weighted-average uniform *energy factor* (UEF) of 3.0 with a medium draw pattern in accordance with 10 CFR 430 Appendix E.
   ii. Output-capacity-weighted-average COP of not less than 4.0 tested at 50°F entering air and 70°F entering water in accordance with AHRI Standard 1300.

   Informative Note: *Service water heating system* control settings and operating temperatures should be determined in accordance with the ASHRAE Standard 188 *building* water *systems* water management program for the *building* or with *generally accepted engineering standards* and guidance (e.g., ASHRAE Guideline 12).

c. **W03: Efficient Gas Water Heater.** To achieve this credit, the combined input-capacity-weighted-average *equipment* rating of all gas water heating *equipment* in the *building* shall be not less than 95% E_t or 0.93 UEF. *Buildings* required to comply with Section 7.5.3 shall receive 29.6% of the Section 11.5.3 W03

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credit. *Buildings* where the installed *service water heating* capacity is less than 200,000 Btu/h and weighted UEF is not less than 0.82 shall achieve 25% of the base table W03 credit.

d. Combination *service water heating systems* shall achieve credits as follows:
   1. (W01 + W02) Where *service water heating* employs both *energy* recovery and heat-pump water heating, W01 is permitted to be combined with W02 and receive the sum of both credits.
   2. (W01 + W03) Where *service water heating* employs both *energy* recovery and efficient gas water heating, W01 is permitted to be combined with W03 and receive the sum of the W01 credit and the portion of the W03 credit based on item (4).
   3. (W02 + W03) Where *service water heating* employs both heat-pump water heating and efficient gas water heating, W02 is permitted to be combined with W03 and receive the sum of the W02 credit and the portion of the W03 credit based on item (4).
   4. For items (2) and (3), the portion of W03 credit shall be the Section 11.5.3 W03 credit multiplied by the share of total water heating installed capacity served by gas water heating with not less than 95% E_t or 0.93 UEF. In no case shall it exceed 60% of the W03 credit in Section 11.5.3. In *buildings* that have a *service water heating* design generating capacity greater than 900,000 Btu/h, that proportioned W03 credit shall be further multiplied by 29.6%.

11.5.2.3.2 W04: Service Hot-Water Piping Insulation Increase. To achieve this credit, where service hot water is provided by a central water heating *system*, the hot-water pipe insulation thickness shall be at least 1.5 times the thickness required in Table 6.8.3-1. All service hot-water *piping* shall be insulated from the hot-water source to the fixture shutoff. Where no more than 50% of hot-water *piping* does not have increased insulation due to installation in partitions, the credit shall be prorated as a percentage of lineal feet of *piping* with increased insulation.

11.5.2.3.3 Improved Service Hot-Water Temperature Maintenance. To achieve this credit, hot-water distribution temperature maintenance shall comply with one of the following:

a. **W05: Point-of-Use Water Heater.** Credits are available for office or school *buildings* larger than 10,000 ft^2. Fixtures requiring hot water shall be supplied from a localized source of hot water with no *recirculating system* or *heat trace piping*. Supply *piping* from the *water heater* to the termination of the fixture supply pipe shall be insulated to the levels shown in Table 6.8.3-1 without exception. The volume from the *water heater* to the termination of the fixture supply pipe shall be limited as follows:
   1. *Nonresidential* lavatories: not more than 2 oz
   2. All other plumbing fixtures or appliances: not more than 0.25 gal

   Exception to 11.5.2.3.3(a): Where all remotely located hot-water uses meet the requirements for measure W05, separate *water heater*s serving commercial kitchens or showers in locker rooms shall be permitted to have a local *recirculating system* or *heat trace piping*.

b. **W06: Thermostatic Balancing Valves.** Credits are available where *service water heating* is provided centrally and distributed throughout the *building*. Each *recirculating system* branch return connection to the main service hot-water supply *piping* shall have an *automatic* thermostatic balancing valve set to a minimal return water flow when the branch return temperature is greater than 125°F.

11.5.2.3.4 W07: Dwelling-Unit Service Hot-Water Submeters. To achieve this credit, each individual *dwelling unit* in a multifamily *building* served by a central *service water heating system* shall be provided with a service hot-water meter connected to a reporting *system* that provides individual *dwelling unit* reporting of actual domestic hot-water use. Recording of preheated water serving the cold water inlet to showers need not be metered.

11.5.2.3.5 W08: Right Sizing the Service Hot-Water Distribution System. To achieve this credit, where multifamily, dormitory, retirement, or hotel/motel *buildings* are served by a central service hot-water *system*, the *distribution system* serving *dwelling units* and guest rooms shall be sized using IAPMO/ANSI WE•Stand, Appendix C. Plumbing fixtures in *residential spaces* that are connected to the *service water heating system* shall have a flow or consumption rating less than or equal to the values shown in Table 11.5.2.3.5.

Informative Note: Where low water supply pressures are anticipated, user satisfaction may be enhanced if flow restrictors are specified to provide ≥80% of the rated flow at 20 psi. Where the distribution sizing protocol is applied to other than multifamily *residential buildings*, a variance to the plumbing code may be needed.

11.5.2.3.6 W09: Shower Drain Heat Recovery. To achieve this credit, cold water serving *building* showers shall be preheated by shower drain heat recovery units that comply with CSA B55.2. Potable water-side pressure loss shall be less than 10 psi at maximum design flow. The *efficiency* of drain heat recovery units shall be 54% or greater measured in accordance with CSA B55.1. Full credits are applicable to the fol-

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Table 11.5.2.3.5 Maximum Flow Rating for Residential Plumbing Fixtures with Heated Water

Plumbing Fixture	Maximum Flow Rate
Faucet for private lavatory [a], hand sinks, or bar sinks	1.50 gpm at 60 psi
Faucet for *residential* kitchen sink [a, b, c]	1.8 gpm at 60 psi
Shower head (including hand-held shower spray) [a, b, d]	2.0 gpm at 80 psi

a. Shower heads, lavatory faucets, and kitchen faucets are subject to U.S. federal requirements listed in 10 CFR 430.32(o) through (p).
b. Maximum flow allowed is less than required by flow rates listed in U.S. 10 CFR 430.32(o) through (p) for shower heads and kitchen faucets.
c. A *residential* kitchen faucet is permitted to temporarily increase the flow above the maximum rate but not above 2.2 gal/min at 60 psi and must default to the maximum flow rate listed.
d. When a shower is served by multiple shower heads, the combined flow rate of all shower heads controlled by a single valve shall not exceed the maximum flow rate listed, or the shower shall be designed to allow only one shower head to operate at a time.

lowing *building* use types: health clinic, hospital, hotel, motel, multifamily, retirement facility, dormitory, and schools with more than eight showers. Partial credits are applicable to *buildings* where all but ground-floor showers are served, where the base *energy* credit is adjusted by the following factor:

$$EC_{W09\_adj} = EC_{W09\_base} \times \frac{\text{Showers with drain heat recovery}}{\text{Total showers in building}}$$

11.5.2.4 P01: Energy Monitoring. To achieve this credit, projects not required to have electrical *energy* monitoring *systems* installed in accordance with Section 8.4.3 shall be equipped to measure, monitor, record, and report *energy* consumption data in compliance with Section 8.4.3.

11.5.2.5 Lighting Efficiency Measures. To achieve these credits, interior lighting in the project shall meet measure requirements in accordance with Sections 11.5.2.5.2, 11.5.2.5.3, 11.5.2.5.4, 11.5.2.5.5, or 11.5.2.5.6. Credits shall be as shown in Section 11.5.3 or as specified in each subsection. Use of multiple credits from this section shall be allowed. Functional testing of lighting controls shall comply with Section 9.9.

Informative Note: Where lighting *efficiency* measures include reductions in lighting power, the lighting design should achieve ANSI/IES recommended practice for illuminance levels as referenced at www.ies.org/standards/lighting-library/the-interactive-illuminance-selector or in relevant IES recommended practice (RP) standards.

11.5.2.5.1 L01: Lighting System Performance Improvement (Reserved)

11.5.2.5.2 L02: Continuous Dimming and High-End Trim. To achieve this credit, *general lighting* in 75% or more of *gross lighted floor area* shall have *luminaires* configured for *continuous dimming* with the following:

a. *High-end trim* shall be implemented, and *construction documents* shall state that maximum light output or power of controlled lighting shall be initially reduced by at least 15% from full output. The average maximum light output or power of the controlled lighting shall be documented without *high-end trim* and with *high-end trim* in accordance with Section 9.9.1 to verify reduction of light output or power by at least 15% when tuned.
b. Where *lumen maintenance control* without lighting sensors is used, controls shall be configured to limit the initial maximum lumen output or maximum lighting power to 85% or less of full light output or full power draw.
c. *High-end trim* and *lumen maintenance* controls shall be accessible only to authorized personnel.
d. Where this credit is taken, the additional *interior lighting power allowance* in Section 9.5.2.3 related to dimming control is not permitted to be used. For hotel and multifamily *building* use types, the *gross lighted floor area* is for common areas not including *dwelling units* or guest rooms. Where *general lighting* in less than 75% but at least 50% of the *gross lighted floor area* receives *high-end trim*, the base credits from the tables in Section 11.5.3 shall be prorated as follows:

$$\frac{\%\ \text{Tuned area of } \textit{gross lighted floor area}}{75\%} \times \text{Base energy credits for L02}$$

11.5.2.5.3 L03: Occupancy Sensor Control Areas. To achieve this credit, either *buildings* shall use Section 9.3, "Simplified Building Method Compliance Path," or in all *spaces* where *automatic* partial OFF (See Section 9.4.1.1[g]) or *automatic* full OFF (See Section 9.4.1.1[h]) is not required, it shall be installed as follows:

a. *Automatic* shutoff or light reduction shall occur within 15 minutes of all occupants leaving each control zone.

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Table 11.5.2.5.4 Added Daylighting Parameters

Building Use Type	DLA_{typ}	DLA_{max}
Small office ≤5000 ft^2	10%	20%
Office >5000 ft^2	21%	31%
Single-floor retail ≤3000 ft^2 or retail with ≤1000 ft^2 *roof* area	0%	20%
Retail >3000 ft^2 of single-floor area	60%	80%
School	42%	52%
Warehouse and semiheated	50%	70%
Medical, hotel, multifamily, dormitory, and other	NA	NA

b. For *spaces* with multiple control zones or *automatic* partial OFF control, *automatic* full shutoff shall occur within 15 minutes of all occupants leaving the *space*.
c. For *spaces* with one control zone, *automatic* full OFF control shall be used.
d. All areas of the project with *automatic* partial OFF or *automatic full* OFF control shall have one *control device* for every 600 ft^2 of *gross lighted area*.

Where this credit is taken, additional *interior lighting power allowance* in Section 9.5.2.3 related to *occupancy sensor control* shall not be used.

Exception to 11.5.2.5.3: Exception to *automatic* full OFF control requirement: stairwells.

11.5.2.5.4 L04: Increased Daylighting Control Area. To achieve this credit, the total *daylight area* of the project (DLA_{bldg}) with *continuous daylight dimming* meeting the requirements of Section 9.4.1.1(e) or 9.4.1.1(f) shall be at least 5% greater than the typical daylit area (DLA_{typ}). Where the actual *daylight area* includes additional daylit areas beyond the *primary sidelighted areas*, *secondary sidelighted areas*, *daylight area under skylights*, or *daylight area under roof monitor*, both of the following shall apply:

a. An analysis based on IES LM83 shall be submitted demonstrating that the spatial daylight autonomy is at least 200, 60% for the additional actual *daylight area*.
b. Additional daylit areas shall be separately controlled by *automatic* daylighting controls.

Credits shall be determined based on the following:

$$EC_{L04\_adj} = EC_{L04\_base} \times 20 \times \left(\frac{DLA_{bldg}}{GLFA} - DLA_{typ}\right)$$

where

EC_{L04_adj}	=	*energy* credits achieved for increased daylighting control area
EC_{L04_base}	=	L04 base *energy* credit from Section 11.5.3
DLA_{bldg}	=	lesser of actual *daylight area* of the project with *continuous daylight dimming*, ft^2, and (GLFA × DLA_{max}); see Table 11.5.2.5.4
GLFA	=	project *gross lighted floor area*, ft^2
DLA_{typ}	=	typical % of *building* area with daylight control (as a fraction) from Table 11.5.2.5.4 or 0 where nonretail *buildings* use Section 9.3

Informative Note: In IES LM83, “spatial daylight autonomy” (sDA) means the amount of daylight received in a *space* over a portion of operating hours each year. It is written as sDA###,YY% where the ### indicates the desired lux provided by the daylight. YY% indicates the portion of operating hours per year to receive that daylight. It also includes an area requirement or statement. For example, “sDA200,60% for 30% of regularly occupied spaces” means that 30% of regularly occupied *spaces* receive at least 200 lux for at least 60% of the operating hours each year.

11.5.2.5.5 L05: Lighting Control for Multifamily Buildings

a. Common-area restrooms, laundry rooms, storage rooms, utility rooms, and garages shall have *automatic* full OFF control in accordance with Section 9.4.1.1(h).
b. Stairwells, lobbies, and corridors shall have *automatic* partial OFF in accordance with Section 9.4.1.1(g) controls that shall reduce *general lighting* power in the *space* by at least 66% of full lighting power within 15 minutes of all occupants leaving the *space*.

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c. Each *dwelling unit* shall have a main control by the main entrance that turns off all the lights and all switched receptacles in the *dwelling unit*. Not less than two switched receptacles shall be provided in living and sleeping rooms or areas and clearly identified. All switched receptacles shall be located within 12 in. of an unswitched receptacle. The main control shall be permitted to have two controls, one for permanently wired lighting and one for switched receptacles. The main controls should be clearly identified as "lights master off" and "switched outlets master off". Alternatively, where all permanently wired lighting is controlled by *occupancy sensors*, only the switched outlets are required to be master switched.

Alternatively, stairwells are permitted to be excluded from item (b) and measure credits shall be one less than L05 base credits from Section 11.5.3.

11.5.2.5.6 L06: Reduce Interior Lighting Power. To achieve this credit, the *installed interior lighting power*, less any additional lighting allowed from Section 9.5.2.2, shall be 95% or less than the *interior lighting power allowance,* less any additional lighting allowed in Section 9.5.2.2. In multifamily, dormitory, hotel, and motel *buildings*, the credit is calculated for common areas other than *dwelling units* and guest rooms. Energy credits shall not be greater than two times the L06 base credit from Section 11.5.3 and shall be determined as follows:

$$EC_{L06\_adj} = EC_{sim} + EC_{L06\_base} \times 20 \times \frac{LPA_{net} - LP_{net}}{LPA_{net}}$$

where

EC_{L06_adj}	=	*energy* credits achieved for lighting power reduction
EC_{sim}	=	EC_{L06_base} where *buildings* use Section 9.3, otherwise $EC_{sim} = 0$
EC_{L06_base}	=	L06 base *energy* credit from Section 11.5.3
LPA_{net}	=	net *interior lighting power allowance* calculated in accordance with the method used to meet the requirements of Section 9.2.2.1, W, excluding any additional interior lighting allowances in Section 9.5.2.2
LP_{net}	=	net *installed interior lighting power* calculated in accordance with Sections 9.1.3 and 9.1.4, W, excluding any additional interior lighting allowances in Section 9.5.2.2

11.5.2.6 R01: On-Site Renewable Energy. To achieve this credit, the total minimum ratings of *on-site renewable energy systems* in addition to the requirements of Section 10.5.1.1 shall be not less than 0.1 W/ft^2 of *gross floor area*. Additional *energy* credits shall be determined as follows:

$$EC_{R01\_adj} = EC_{R01\_base} \times \frac{RR_{total} - RR_{req}}{0.1 \times PGFA}$$

where

EC_{R01_adj}	=	*energy* credits achieved for *on-site renewable energy*
EC_{R01_base}	=	R01 base *energy* credit from Section 11.5.3
RR_{total}	=	actual total minimum rating of *on-site renewable energy systems*, W
RR_{req}	=	minimum rating of *on-site renewable energy systems* required by Section 10.5.1.1 without exception, W
PGFA	=	project *gross floor area*

Informative Note: *On-site renewable energy* may include thermal *service water heating* or *pool* water heating in which case ratings in Btu/h can be converted to W, where W = Btu/h/3.413.

11.5.2.7 Equipment Efficiency Measures. Energy credits for *equipment efficiency* shall be determined in accordance with Sections 11.5.2.7.1, 11.5.2.7.2, and 11.5.2.7.3. Use of multiple credits from this section shall be allowed.

11.5.2.7.1 Q01: Efficient Elevator Equipment. To achieve this credit, qualifying elevators in the project shall be *energy efficiency* Class A per ISO 25745-2, Table 7. Elevators with regeneration capability shall have the means to absorb the regenerated electricity by other *building* loads or be able to export the *energy* to the utility grid. The electrical *system* shall not absorb regenerated electricity with *electric resistance* load banks. Base credits shall be adjusted based on qualified elevators in the *building* as follows:

$$EC_{Q01\_adj} = EC_{Q01\_base} \times \frac{F_A}{F_B}$$

where

EC_{Q01_adj}	=	*energy* credits achieved for efficient elevator *equipment*

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Table 11.5.2.7.2-1 Minimum Efficiency Requirements: Commercial Fryers

	Heavy-Load Cooking Energy Efficiency	Idle Energy Rate	Test Procedure
Standard open deep-fat gas fryers	≥50%	≤9000 Btu/h	ASTM Standard F1361-07
Standard open deep-fat electric fryers	≥83%	≤800 W	
Large-vat open deep-fat gas fryers	≥50%	≤12,000 Btu/h	ASTM Standard F2144-17
Large-vat open deep-fat electric fryers	≥80%	≤1100 W	

Table 11.5.2.7.2-2 Minimum Efficiency Requirements: Commercial Steam Cookers

Fuel Type	Pan Capacity	Cooking Energy Efficiency[a]	Idle Rate	Test Procedure
Electric steam	3-pan	≥50%	≤400 W	ASTM Standard F1484-18
	4-pan	≥50%	≤530 W	
	5-pan	≥50%	≤670 W	
	6-pan and larger	≥50%	≤800 W	
Gas steam	3-pan	≥38%	≤6250 Btu/h	
	4-pan	≥38%	≤8350 Btu/h	
	5-pan	≥38%	≤10,400 Btu/h	
	6-pan and larger	≥38%	≤12,500 Btu/h	

a. Cooking *energy efficiency* is based on heavy load (potato) cooking capacity.

EC_{Q01_base} = Q01 base *energy* credit from Section 11.5.3

F_A = sum of floors served by each Class A elevator

F_B = sum of floors served by all *building* elevators and escalators

Informative Note: For example, sum of floors is 10 where Elevator 1 serves five (5) floors, Elevator 2 serves three (3) floors, and an escalator serves two (2) floors: 5 + 3 + 2 = 10.

11.5.2.7.2 Q02: Efficient Kitchen Equipment. To achieve this credit, in projects or facilities that include a commercial kitchen with at least one gas or electric fryer, all fryers, dishwashers, steam cookers, and ovens shall comply with all of the following:

a. Achieve performance levels in accordance with the *equipment* specifications listed in Tables 11.5.2.7.2-1 through 11.5.2.7.2-4 when rated in accordance with the applicable test procedure.
b. Be installed prior to the issuance of the certificate of occupancy.
c. Have associated performance levels listed on the *construction documents* submitted for permitting.

Energy credits for efficient kitchen *equipment* shall be as stated in Section 11.5.3.

Informative Note: Where a commercial kitchen is included in a *building* where credits for efficient kitchen *equipment* are excluded, such as a cafeteria in an office *building*, treat the kitchen and dining area as a restaurant *building* use type following the weighted-average method in Section 11.5.1(a).

11.5.2.7.3 Q03: Fault Detection and Diagnostics System. To achieve this credit, where not otherwise required in Sections 6 through 10, a fault detection and diagnostics (FDD) *system* shall be installed to monitor the *HVAC system*'s performance and *automatically* identify faults. This installation is in addition to and more comprehensive than existing requirements in Section 6.4.3.12. The FDD *system* shall include all of the following:

a. Utilize sensors or devices to directly or indirectly monitor the *HVAC system*'s central plant *equipment*, zone *terminal equipment*, and associated mechanical components, including (but not limited to) motors, actuators, valves, and dampers. Control device positions or air and fluid flows shall be permitted to be estimated based on related sensed inputs.
b. Sample the sensors and devices at least once per 15 minutes.

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Table 11.5.2.7.2-3 Minimum Efficiency Requirements: Commercial Dishwashers

Machine Type	High-Temp Efficiency Requirements: Idle Energy Rate [a]	High-Temp Efficiency Requirements: Water Consumption [b]	Low-Temp Efficiency Requirements: Idle Energy Rate [a]	Low-Temp Efficiency Requirements: Water Consumption [b]	Test Procedure
Under counter	≤0.50 *kW*	≤0.86 GPR	≤0.50 *kW*	≤1.19 GPR	ASTM Standard F1696-18 ASTM Standard F1920-15
Stationary single-tank door	≤0.70 *kW*	≤0.89 GPR	≤0.60 *kW*	≤1.18 GPR	
Pot, pan, and utensil	≤1.20 *kW*	≤0.58 GPR	≤1.00 *kW*	≤0.58 GPSF	
Single-tank conveyor	≤1.50 *kW*	≤0.70 GPR	≤1.50 *kW*	≤0.79 GPR	
Multiple-tank conveyor	≤2.25 *kW*	≤0.54 GPR	≤2.00 *kW*	≤0.54 GPR	
Single-tank flight type	Reported	GPH ≤ 2.975*x* + 55.00	Reported	GPH ≤ 2.975*x* + 55.00	
Multiple-tank flight type	Reported	GPH ≤ 4.96*x* + 17.00	Reported	GPH ≤ 4.96*x* + 17.00	

a. Idle results should be measured with the door closed and represent the total idle *energy* consumed by the machine including all tank heater(s) and controls. Internal or external booster heater *energy* consumption shall not be part of this measurement unless it cannot be separately monitored.

b. GPR = gallons per rack; GPSF = gallons per square foot of rack; GPH = gallons per hour; x = square feet of conveyor belt (i.e., width × length)/min (max conveyor speed).

Table 11.5.2.7.2-4 Minimum Efficiency Requirements: Commercial Ovens

Fuel Type	Classification	Idle Rate	Cooking Energy Efficiency,%	Test Procedure
Convection Ovens				
Gas	Full size	≤12,000 Btu/h	≥46	ASTM F1496-13
Electric	Half size	≤1.0 *kW*	≥71	
	Full size	≤1.60 *kW*		
Combination Ovens [a]				
Gas	Steam mode	≤200P + 6511 Btu/h	≥41	ASTM F2861-17
	Convection mode	≤150P + 5425 Btu/h	≥56	
Electric	Steam mode	≤0.133P + 0.6400 *kW*	≥55	
	Convection mode	≤0.080P + 0.4989 *kW*	≥76	
Rack Ovens				
Gas	Single	≤25,000 Btu/h	≥48	ASTM F2093-18
	Double	≤30,000 Btu/h	≥52	

a. P = pan capacity, the number of steam table pans the combination oven is able to accommodate as per ASTM F1495-14a.

c. *Automatically* identify *HVAC system* faults using algorithmic-based analysis that performs rule-based, time-series trend-based, statistically based, or model-based diagnostics, including (where applicable) identification of, at a minimum, the following faults that affect *energy* performance:

1. Simultaneous heating and cooling above an expected threshold or short-term cycling between heating and cooling
2. *System* operation outside of scheduled hours above an expected threshold
3. Air or fluid flows not modulating when designed to be variable
4. Significant changes in *energy* use as a function of ambient or other conditions

d. *Automatically* provide authorized personnel with prioritized recommendations for fault *repair* of identified faults based on estimated excess *energy* consumption or cost of non-*repair.*

e. Be capable of transmitting the prioritized fault *repair* recommendations to remotely located authorized personnel.

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The FDD *system* requirements of items (a) through (e) shall be allowed to be incorporated into a *building* management *system* (BMS) or *building* automation *system* (BAS). Where credit is also taken for H07, all of the applicable *automatic* fault detection and diagnostics (AFDD) specified in Guideline 36 shall be included in FDD reporting and all necessary AFDD sensors recommended by Guideline 36 for applicable *HVAC systems* shall be installed.

Informative Note: FDD is in addition to standard BAS/BMS monitoring and alarming functionality. Faults identified may also include failing or failed *system* components, poor air or fluid flow, inoperable valves and dampers, sensors and devices out of calibration, undermaintained *equipment* and filters, failing or failed bearings, or unresponsive actuators and devices.

11.5.2.8 Load Management Systems. Energy credits for load management measures in Sections 11.5.2.8.1 through 11.5.2.8.7 are available in any combination to projects in *buildings* that have at least one of the following:

a. A serving electric utility that has any of these programs available:
   1. A *demand* response program
   2. Real-time or next-day pricing
   3. A time-of-use price schedule applicable to the *building*
b. Local *building*-level electrical *demand* monitoring and control integrated into the *building* control *system*
c. *Buildings* or *additions* that have ≤25,000 ft^2 of *gross floor area* with a central group time control schedule for lighting or HVAC *set points*

Where credits are taken for measures in Section 11.5.2.8, the following additional requirements shall apply:

a. Where the serving utility has an interface requirement for participation in items (a)(1) through (a)(3) above, an interface compliant with serving utility requirements shall be installed.
b. The *building* shall have a *building* automation control *system* configured with *automatic* load management controls that are activated by either a utility *demand* response signal, real-time or next-day peak-price-period notifications, or local *building* peak electrical *demand* monitoring. *Buildings* or *additions* that have ≤25,000 ft^2 of *gross floor area* shall be permitted to use a centralized group time control schedule for load management control.
c. Load management control sequences shall be implemented so that they are activated in response to either an automated serving utility signal; local *building* peak electrical *demand* monitoring; or, where *buildings* or *additions* have ≤25,000 ft^2 of *gross floor area*, on a schedule where peak-price-period dates and times shall be adjustable without reprogramming.

11.5.2.8.1 G01: Lighting Load Management. To achieve this credit, *luminaires* shall have dimming capability, and load management controls shall gradually, over a period of not more than 15 minutes, reduce *general lighting* power with *continuous dimming* in 75% of the project area by at least 20% during peak-price periods coincident with high *building* load. It shall be permitted to substitute decorative and display-lighting equivalent power reductions for *general lighting* reductions. Where less than 75% but at least 50% of the project *general lighting* is controlled, the base credits from the tables in Section 11.5.3 shall be prorated as follows:

$$\frac{\text{Portion of project with lighting load management, \%}}{75\%} \times \text{G01 table credits}$$

Exception to 11.5.2.8.1: Warehouse, semiheated, or retail storage areas with load management controls shall be permitted to switch off at least 25% of lighting power in 75% of the project area without dimming.

11.5.2.8.2 G02: HVAC Load Management. To achieve this credit, load management controls shall be configured to

a. gradually increase cooling *set point* by at least 3°F or reduce effective cooling capacity to 60% of installed capacity during the period of coincident high *building* load and summer peak prices;
b. where electric heating is used, gradually reduce heating *set point* by at least 3°F or reduce effective heating capacity to 60% of installed capacity during the period of coincident high *building* load and winter peak prices; and
c. provide excess *outdoor air* preceding the peak summer price period and reduce *outdoor air* by at least 30% during the period of coincident high *building* load and summer peak prices, in accordance with ASHRAE Standard 62.1, Section 6.2.5.2.

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11.5.2.8.3 G03: Automated Shading Load Management. To achieve this credit, movable exterior shading devices shall be installed to reduce solar gain through *south-oriented* and *west-oriented fenestration* by at least 50% with load management controls that operate during peak summer electrical price periods.

Informative Note: This credit can be met by exterior roller, movable blind, or movable shutter shading devices; however, base overhang, screen or shutter, shading will not meet the requirement. Roller shades that reject solar gain but still allow a view are allowed as long as they provide an effective 50% reduction in net solar gain—e.g., have a *shading coefficient* of less than 0.5 for the shading material itself. Interior shading devices will not meet the requirement.

11.5.2.8.4 G04: Electric Energy Storage. To achieve this credit, electric storage devices such as batteries or flywheel devices shall be charged by load management controls to store electricity during off-peak periods and use stored *energy* during on-peak periods to reduce *building* peak period *demand*. Electric storage devices shall have a capacity between 0.5 Wh/ft^2 and 15 Wh/ft^2 based on project *gross floor area*. For capacity other than 1.0 Wh/ft^2, credits can be prorated as follows:

$$\frac{\text{Installed electric storage capacity, Wh/ft}^2}{1.0} \times \text{G04 table credits}$$

11.5.2.8.5 G05: HVAC Cooling Energy Storage. To achieve this credit, ice or chilled-water storage *equipment* shall be installed and load management controls configured to reduce electric cooling peak *demand*. Storage tank(s) shall be demonstrated through analysis to have less than 2% loss of stored capacity over a 24-hour period for the cooling design day.

Base *energy* credits in Section 11.5.3 are for storage capacity of 1.0 ton-hours storage per ton of design-day cooling load with a 1.15 sizing factor. Prorate *energy* credits for other installed storage *systems* sized between 0.5 and 4.0 ton-hours storage per ton of design-day cooling load. Larger storage shall be permitted; however, credits are limited to 4.0 ton-hours storage per ton of design-day cooling load. Energy credits shall be determined as follows:

$$EC_{G05\_adj} = EC_{G05\_base} \times \frac{(1.44 \times SR + 0.71)}{2.15}$$

where

EC_{G05_adj}	=	*energy* credits achieved for HVAC cooling *energy* storage
EC_{G05_base}	=	G05 base *energy* credit for *building* use type and climate zone based on ton-hours storage per ton of design-day cooling load
SR	=	storage ratio in ton-hours storage per ton of design-day cooling load, where $0.5 \leq SR \leq 4.0$

11.5.2.8.6 G06: Service Hot-Water Thermal Storage. To achieve this credit, where service hot water is heated by electricity, *automatic* controls activated by utility *demand* response signal, peak price period time control, or local *building demand* monitoring shall preheat stored service hot water before the peak-price period and suspend electric water heating during the period of peak prices coincident with peak *building* load. Storage capacity shall be provided by either of the following:

a. Preheating water above 140°F delivery temperature with at least 1.2 kWh of *energy* storage per *kW* of water heating capacity. Tempering valves shall be provided at the *water heater* delivery location. This option is not available where heat-pump water heating is used.
b. Providing additional heated water tank storage capacity above peak service hot-water demand with equivalent peak storage capacity to item (a).

11.5.2.8.7 G07: Building Thermal Mass. To achieve this credit, the project shall have both additional passive interior mass and a night flush control of the *HVAC system*. The credit is only available to projects that have at least 80% of *gross floor area* unoccupied between midnight and 6:00 a.m.

a. Interior to the *building envelope* insulation, provide 10 lb/ft^2 of project *conditioned floor area* of passive thermal mass in the *building* interior *wall*, the inside of the *exterior wall*, or interior *floor construction*. Mass *construction* shall have mass surfaces directly contacting the air in *conditioned spaces* with directly attached gypsum panels allowed. Mass with carpet or furred gypsum panels, or *exterior wall* mass that is on the exterior of the insulation layer (e.g., the portion of CMU block on the exterior of insulation filled cell cavities), shall not be included toward the *building* mass required.
b. HVAC units for 80% or more of the supply airflow in the project shall be equipped with *outdoor air* economizers and fans that have variable or low speed capable of operating at 66% or lower airflow and be included in the night flush control sequence.

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c. Night flush controls shall be configured with the following sequence, or another night flush strategy shall be permitted where it is demonstrated to be effective, avoids added morning heating, and is approved by the *authority having jurisdiction*.
   1. Summer mode shall be activated when *outdoor air* temperature exceeds 70°F and shall continue uninterrupted until deactivated when *outdoor air* temperature falls below 45°F. During summer mode, the occupied cooling *set point* shall be set 1°F higher than normal, and the occupied heating *set point* shall be *reset* 2°F lower than normal.
   2. Night flush shall be activated when all of the following conditions exist:
      i. Summer mode is active in accordance with item (c)(1).
      ii. *Outdoor air* temperature is 5°F or more below indoor average zone temperature.
      iii. Indoor average zone temperature is greater than morning occupied heating *set point*.
      iv. In climate zones 0A through 3A, outdoor dew point is below 50°F, or *outdoor air* enthalpy is less than indoor air enthalpy.
      v. Local time is between 10:00 pm and 6:00 am.
   3. When night flush is active, *automatic* night flush controls shall operate *outdoor air economizers* at low fan speed not exceeding 66% during the unoccupied period with *mechanical cooling* and heating locked out.

d. The project shall demonstrate a contractual obligation for postoccupancy *commissioning* and control tuning in the spring or fall season to tune the summer mode activation *set points* and occupied heating *set point*, or other algorithms to achieve minimal morning heating due to night flush activation, while maintaining comfort conditions. Commissioning shall include monitoring of time-series *space* temperature, heating, and cooling operation to demonstrate both night cooling and minimization of morning heating along with monitoring of post-tuning operation to verify tuned parameters. Operating manuals shall include recommendations for tuned parameters and narrative training for operating staff on night flush automated settings.

Informative Note: The simplified night flush sequence described will operate in summer mode below the 70°F *outdoor air* trigger temperature until *outdoor air* of 45°F is reached and summer mode is deactivated. Summer mode is reestablished when the *outdoor air* rises above 70°F again. These *set points* need to be tuned under actual occupancy conditions, as *building* load characteristics vary. Other strategies may be implemented that cool the *space* below the heating *set point* and adjust the morning heating *set point* to avoid morning reheating.

11.5.3 Base Energy Credits Available. Base *energy* credits are shown in Tables 11.5.3-1 through 11.5.3-9, where the table is selected for the *building* use type, and the base credit is selected for the climate zone of the *building*.

11.6 Alternative Compliance Path (Not used)

11.7 Submittals

11.7.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

11.7.2 Permit Application Documentation. *Construction documents* shall list which credits were used to meet the requirements of Section 11.5 for this project.

11.7.3 Completion Requirements. *Construction documents* shall require that *equipment*, controls, or *systems* installed to meet the requirements of Section 11.5 shall meet completion requirements as specified in Sections 5.7.3, 6.7.3, 7.7.3, 8.7.3, 9.7.3, and 10.7.3.

11.8 Product Information (Not used)

11.9 Verification, Testing, and Commissioning. *Building envelope components*, *equipment*, controls, or *systems* installed to meet the requirements of Section 11.5 shall meet verification, testing, and *commissioning* requirements as specified in Sections 5.9, 6.9, 7.9, 8.9, 9.9, and 10.9.

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Table 11.5.3-1 Energy Credits for Multifamily

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	1	×	×	4	×	2	5	2	1	6	4	6	9
H03	Cooling Efficiency	11.5.2.2.3	19	17	14	14	11	9	6	7	3	4	5	2	3	4	2	3	3	2	2
H04	Residential HVAC Controls	11.5.2.2.4	10	11	8	12	10	12	8	9	12	9	11	7	9	11	7	10	10	8	8
H05	Ground-Source Heat Pump	11.5.2.2.5	9	8	5	7	4	4	5	4	2	10	5	6	13	9	4	18	13	16	16
H06	DOAS/Fan Controls	11.5.2.2.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H07	Guideline 36 Sequences	11.5.2.2.7	3	3	3	3	2	2	2	2	1	2	2	1	2	2	1	2	2	2	2
W01	SHW Preheat Recovery	11.5.2.3.1(a)	10	11	13	13	15	16	19	18	23	21	21	24	22	22	25	21	23	23	23
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	16	17	20	20	24	25	30	29	36	33	33	39	36	36	41	35	37	37	38
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	12	13	16	15	18	19	23	22	27	25	25	29	26	27	30	26	27	27	27
W04	SWH Pipe Insulation	11.5.2.3.2	2	2	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	3	4	4	4	5	5	7	6	8	7	7	8	8	8	9	8	8	8	8
W08	SHW Distribution Sizing	11.5.2.3.5	10	11	13	13	16	16	20	19	24	22	22	25	23	23	27	23	24	24	24
W09	Shower Drain Heat Recovery	11.5.2.3.6	9	9	11	11	13	14	17	16	20	19	19	22	20	20	23	20	21	21	21
P01	Energy Monitoring	11.5.2.4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
L02	Lighting Dimming and Tuning	11.5.2.5.2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
L03	Increase Occupancy Sensor	11.5.2.5.3	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L04	Increase Daylight Area	11.5.2.5.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L05	Residential Light Controls	11.5.2.5.5	9	9	10	9	10	10	9	10	11	9	9	10	7	9	10	7	8	8	6
L06	Light Power Reduction	11.5.2.5.6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
R01	On-Site Renewable Energy	11.5.2.6	12	13	15	14	15	18	16	19	21	13	19	14	11	17	13	12	14	11	9
Q01	Efficient Elevator Equipment	11.5.2.7.1	4	4	5	5	5	5	5	5	6	5	5	6	5	5	6	5	5	5	5
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	3	3	3	3	2	2	2	2	1	2	2	1	2	2	1	2	2	2	2
G01	Lighting Load Management	11.5.2.8.1	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G02	HVAC Load Management	11.5.2.8.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G03	Shading Load Management	11.5.2.8.3	11	×	7	18	10	13	4	13	12	×	13	6	8	11	11	×	6	5	14
G04	Electric Energy Storage	11.5.2.8.4	7	8	9	8	10	9	10	11	14	13	10	13	11	10	13	11	10	11	12
G05	HVAC Cooling Energy Storage	11.5.2.8.5	22	5	27	12	19	18	19	33	10	11	20	9	7	14	8	6	15	1	3
G06	SHW Thermal Storage	11.5.2.8.6	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
G07	Building Mass/Night Flush	11.5.2.8.7	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

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Table 11.5.3-2 Energy Credits for Health Care Buildings

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	1	1	1	1	2	2	2	2	2	3	2	3	4	3	4	6	5	7	9
H03	Cooling Efficiency	11.5.2.2.3	18	16	15	15	14	10	9	8	8	7	6	5	5	5	3	5	4	4	2
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	3	14	×	14	14	11	9	10	12	11	10	11	11	10	15	14	14	16	15
H06	DOAS/Fan Controls	11.5.2.2.6	20	19	18	18	17	16	15	15	15	13	15	13	11	14	10	9	9	6	2
H07	Guideline 36 Sequences	11.5.2.2.7	4	3	3	3	3	3	3	3	2	3	3	2	3	3	2	3	3	3	3
W01	SHW Preheat Recovery	11.5.2.3.1(a)	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W04	SWH Pipe Insulation	11.5.2.3.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
P01	Energy Monitoring	11.5.2.4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
L02	Lighting Dimming and Tuning	11.5.2.5.2	6	6	6	6	6	6	6	6	7	6	7	7	6	7	7	6	6	5	5
L03	Increase Occupancy Sensor	11.5.2.5.3	1	1	1	1	1	2	2	1	2	2	1	2	2	1	2	1	1	1	1
L04	Increase Daylight Area	11.5.2.5.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	7	8	8	8	8	8	9	9	10	8	9	10	8	9	9	7	8	7	6
R01	On-Site Renewable Energy	11.5.2.6	5	5	5	5	5	7	6	7	7	5	7	5	4	6	5	5	5	4	3
Q01	Efficient Elevator Equipment	11.5.2.7.1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	4	3	3	3	3	3	3	3	2	3	3	2	3	3	2	3	3	3	3
G01	Lighting Load Management	11.5.2.8.1	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G02	HVAC Load Management	11.5.2.8.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G03	Shading Load Management	11.5.2.8.3	1	1	1	1	×	×	×	1	×	×	2	×	×	2	×	×	1	1	×
G04	Electric Energy Storage	11.5.2.8.4	9	10	10	10	10	11	10	11	11	10	11	12	10	11	11	10	10	9	9
G05	HVAC Cooling Energy Storage	11.5.2.8.5	9	2	12	5	9	7	10	14	10	6	8	7	5	7	5	4	8	1	1
G06	SHW Thermal Storage	11.5.2.8.6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G07	Building Mass/Night Flush	11.5.2.8.7	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

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Table 11.5.3-3 Energy Credits for Hotel/Motel

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	×	×	×	×	×	×	2	1	×	3	1	3	5
H03	Cooling Efficiency	11.5.2.2.3	24	22	19	19	15	12	10	10	7	7	7	3	5	5	3	5	4	4	2
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	13	10	7	10	7	6	4	5	9	6	4	4	8	6	4	13	9	14	15
H06	DOAS/Fan Controls	11.5.2.2.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H07	Guideline 36 Sequences	11.5.2.2.7	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
W01	SHW Preheat Recovery	11.5.2.3.1(a)	3	4	4	4	5	5	6	6	7	7	7	8	8	8	9	8	8	8	9
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	5	5	7	6	8	8	10	10	11	12	11	13	13	12	14	13	13	14	14
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	4	4	5	5	6	6	8	7	8	9	8	10	10	9	10	10	10	10	10
W04	SWH Pipe Insulation	11.5.2.3.2	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	3	4	4	4	5	6	7	6	7	8	7	9	8	8	9	9	9	9	9
W09	Shower Drain Heat Recovery	11.5.2.3.6	3	3	4	4	4	5	6	5	6	6	6	7	7	7	8	7	7	8	8
P01	Energy Monitoring	11.5.2.4	3	3	3	3	3	3	3	3	3	3	3	2	3	3	2	3	3	3	3
L02	Lighting Dimming and Tuning	11.5.2.5.2	1	1	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	2	2
L03	Increase Occupancy Sensor	11.5.2.5.3	3	4	4	4	4	5	5	4	5	4	4	5	4	4	5	4	4	4	3
L04	Increase Daylight Area	11.5.2.5.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	2	2	2	2	2	2	2	2	3	2	3	3	2	2	3	2	2	2	2
R01	On-Site Renewable Energy	11.5.2.6	7	8	9	9	9	12	10	13	13	9	13	10	8	12	9	9	10	8	7
Q01	Efficient Elevator Equipment	11.5.2.7.1	2	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
G01	Lighting Load Management	11.5.2.8.1	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G02	HVAC Load Management	11.5.2.8.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G03	Shading Load Management	11.5.2.8.3	2	2	2	3	1	2	3	2	4	3	2	1	×	1	3	1	2	×	×
G04	Electric Energy Storage	11.5.2.8.4	6	7	7	8	7	9	9	12	11	11	9	11	12	11	14	11	10	10	11
G05	HVAC Cooling Energy Storage	11.5.2.8.5	18	5	25	11	19	17	22	33	20	14	19	12	12	16	8	9	19	2	3
G06	SHW Thermal Storage	11.5.2.8.6	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
G07	Building Mass/Night Flush	11.5.2.8.7	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

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Table 11.5.3-4 Energy Credits for Office Buildings

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	1	×	×	2	1	2	5	3	2	7	5	7	10
H03	Cooling Efficiency	11.5.2.2.3	18	18	15	16	12	10	8	8	7	6	5	3	4	4	2	4	2	3	1
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	9	8	5	8	5	4	7	5	2	10	6	7	15	10	8	21	15	19	20
H06	DOAS/Fan Controls	11.5.2.2.6	19	19	17	18	16	16	11	14	12	9	13	8	5	10	7	3	6	3	×
H07	Guideline 36 Sequences	11.5.2.2.7	3	3	3	3	3	3	2	2	2	2	2	1	2	2	1	2	2	2	2
W01	SHW Preheat Recovery	11.5.2.3.1(a)	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3
W04	SWH Pipe Insulation	11.5.2.3.2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	4	4	4	4	4	4	3	3	3	2	3	2	1	2	1	1	1	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
P01	Energy Monitoring	11.5.2.4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
L02	Lighting Dimming and Tuning	11.5.2.5.2	5	5	6	6	6	6	6	7	7	6	7	7	6	6	7	5	6	5	5
L03	Increase Occupancy Sensor	11.5.2.5.3	5	6	6	6	7	6	6	6	8	6	6	7	6	6	7	6	6	5	5
L04	Increase Daylight Area	11.5.2.5.4	7	7	8	8	8	8	9	9	10	8	8	9	8	8	8	7	8	8	6
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	7	7	8	8	8	9	8	8	9	8	9	9	8	8	9	7	8	7	6
R01	On-Site Renewable Energy	11.5.2.6	11	11	14	13	14	16	15	18	19	13	18	14	11	16	13	12	14	12	9
Q01	Efficient Elevator Equipment	11.5.2.7.1	4	4	4	4	5	5	5	5	6	5	5	6	5	5	6	5	5	5	5
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	3	3	3	3	3	3	2	2	2	2	2	1	2	2	1	2	2	2	2
G01	Lighting Load Management	11.5.2.8.1	5	5	6	6	6	6	7	7	6	6	7	7	6	7	8	6	7	6	6
G02	HVAC Load Management	11.5.2.8.2	10	10	7	13	8	13	14	12	8	14	15	14	14	17	14	11	17	15	11
G03	Shading Load Management	11.5.2.8.3	8	13	15	15	14	17	14	15	16	10	16	16	13	15	16	13	15	14	21
G04	Electric Energy Storage	11.5.2.8.4	19	19	21	21	22	24	27	26	27	27	28	31	26	28	33	22	27	25	23
G05	HVAC Cooling Energy Storage	11.5.2.8.5	22	6	29	13	21	19	22	37	22	13	21	12	12	16	8	9	20	2	3
G06	SHW Thermal Storage	11.5.2.8.6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
G07	Building Mass/Night Flush	11.5.2.8.7	4	1	6	3	9	14	12	14	20	11	20	20	19	20	20	16	26	25	12

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Table 11.5.3-5 Energy Credits for Restaurant Buildings

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	1	3	2	1	5	3	4	8	5	5	10	8	13	17
H03	Cooling Efficiency	11.5.2.2.3	20	18	15	16	13	10	8	7	3	5	4	1	3	3	1	3	2	2	1
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	11	9	6	9	7	6	8	8	4	13	11	11	14	15	14	19	17	20	17
H06	DOAS/Fan Controls	11.5.2.2.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H07	Guideline 36 Sequences	11.5.2.2.7	4	3	3	3	3	2	2	2	1	2	2	1	2	2	1	2	2	3	3
W01	SHW Preheat Recovery	11.5.2.3.1(a)	5	5	7	6	7	8	9	9	11	10	11	12	11	11	12	11	11	11	10
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	2	3	3	3	4	5	6	6	7	8	7	9	9	9	10	9	10	10	10
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	6	7	8	8	9	10	11	11	14	13	13	14	13	13	15	13	13	13	12
W04	SWH Pipe Insulation	11.5.2.3.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
P01	Energy Monitoring	11.5.2.4	3	3	2	2	2	2	2	2	1	2	2	1	2	2	2	2	2	2	2
L02	Lighting Dimming and Tuning	11.5.2.5.2	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2	2	2	2	2
L03	Increase Occupancy Sensor	11.5.2.5.3	2	2	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	1
L04	Increase Daylight Area	11.5.2.5.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	4	4	4	4	4	4	4	4	4	4	4	3	3	4	3	3	3	3	2
R01	On-Site Renewable Energy	11.5.2.6	2	2	2	2	2	3	2	3	3	2	3	2	2	2	2	2	2	2	1
Q01	Efficient Elevator Equipment	11.5.2.7.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Q02	Efficient Kitchen Equipment	11.5.2.7.2	19	21	24	22	24	26	26	27	31	27	28	30	26	27	30	24	26	23	22
Q03	Fault Detection and Diagnostics	11.5.2.7.3	4	3	3	3	3	2	2	2	1	2	2	1	2	2	1	2	2	3	3
G01	Lighting Load Management	11.5.2.8.1	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G02	HVAC Load Management	11.5.2.8.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G03	Shading Load Management	11.5.2.8.3	2	2	2	2	2	3	2	2	1	1	2	1	1	1	×	1	1	1	×
G04	Electric Energy Storage	11.5.2.8.4	3	3	4	4	5	5	4	4	4	3	4	3	3	4	3	3	3	3	2
G05	HVAC Cooling Energy Storage	11.5.2.8.5	4	1	5	2	4	3	4	6	2	2	3	1	1	2	×	1	2	×	×
G06	SHW Thermal Storage	11.5.2.8.6	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
G07	Building Mass/Night Flush	11.5.2.8.7	2	×	3	1	4	6	4	5	11	3	7	7	4	9	5	3	6	4	1

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Table 11.5.3-6 Energy Credits for Retail Buildings

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	3	1	×	7	2	5	10	6	6	12	9	9	13
H03	Cooling Efficiency	11.5.2.2.3	26	24	21	22	18	15	11	11	5	7	7	2	4	5	1	4	3	3	1
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	16	13	9	13	8	7	10	8	2	18	11	16	19	18	19	23	20	18	15
H06	DOAS/Fan Controls	11.5.2.2.6	29	30	26	28	24	25	18	23	23	12	22	15	7	17	13	3	10	5	2
H07	Guideline 36 Sequences	11.5.2.2.7	5	5	4	4	4	3	3	3	2	3	3	2	3	3	2	3	3	3	4
W01	SHW Preheat Recovery	11.5.2.3.1(a)	4	4	5	4	6	6	7	7	8	7	7	8	7	7	8	6	7	7	6
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	1	1	1	1	2	2	2	2	3	2	2	3	2	2	3	2	2	2	2
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	2	2	3	2	3	3	4	4	4	4	4	4	4	4	4	3	4	4	3
W04	SWH Pipe Insulation	11.5.2.3.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
P01	Energy Monitoring	11.5.2.4	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
L02	Lighting Dimming and Tuning	11.5.2.5.2	6	6	6	6	6	6	5	6	6	4	5	5	3	4	4	3	3	2	2
L03	Increase Occupancy Sensor	11.5.2.5.3	6	6	6	6	6	6	5	6	6	4	5	5	3	4	4	3	4	2	2
L04	Increase Daylight Area	11.5.2.5.4	7	7	8	7	7	7	6	7	7	4	6	5	4	5	4	3	4	4	3
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	11	11	12	12	12	12	11	12	14	10	11	9	8	8	9	8	8	7	6
R01	On-Site Renewable Energy	11.5.2.6	9	9	11	11	13	16	14	18	19	12	17	13	10	15	12	10	12	10	7
Q01	Efficient Elevator Equipment	11.5.2.7.1	3	3	4	4	4	5	5	5	6	5	5	5	5	5	5	4	4	4	4
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	5	5	4	4	4	3	3	3	2	3	3	2	3	3	2	3	3	3	4
G01	Lighting Load Management	11.5.2.8.1	9	8	10	10	11	11	11	12	12	10	12	12	11	11	12	11	11	9	8
G02	HVAC Load Management	11.5.2.8.2	14	13	14	14	12	10	10	7	5	7	1	3	6	×	×	7	4	6	1
G03	Shading Load Management	11.5.2.8.3	2	4	6	3	6	4	2	×	8	×	1	2	2	×	×	×	×	3	1
G04	Electric Energy Storage	11.5.2.8.4	5	8	6	7	9	10	10	9	11	10	8	9	8	10	9	9	7	8	6
G05	HVAC Cooling Energy Storage	11.5.2.8.5	24	6	35	15	26	23	28	40	18	15	23	9	10	16	3	8	16	2	2
G06	SHW Thermal Storage	11.5.2.8.6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
G07	Building Mass/Night Flush	11.5.2.8.7	4	1	6	2	8	14	11	14	32	9	20	20	16	20	18	13	23	21	10

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Table 11.5.3-7 Energy Credits for Education Buildings

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	1	1	1	2	2	3	3	4	2	5	4	7	11
H03	Cooling Efficiency	11.5.2.2.3	24	23	19	21	18	15	12	12	10	9	9	5	6	7	3	6	5	5	2
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	13	12	8	12	8	7	6	8	5	6	9	11	7	13	6	12	9	12	12
H06	DOAS/Fan Controls	11.5.2.2.6	28	27	25	26	23	23	19	21	19	17	19	13	14	14	13	11	13	9	2
H07	Guideline 36 Sequences	11.5.2.2.7	5	4	4	4	4	3	3	3	2	3	3	2	3	3	2	3	3	3	3
W01	SHW Preheat Recovery	11.5.2.3.1(a)	1	1	2	1	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	1	1	2	2	2	2	3	3	3	3	3	4	4	4	4	3	4	4	4
W04	SWH Pipe Insulation	11.5.2.3.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	1	2	2	2	2	2	2	2	3	2	3	3	3	3	3	2	3	2	2
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
P01	Energy Monitoring	11.5.2.4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3
L02	Lighting Dimming and Tuning	11.5.2.5.2	5	5	6	6	6	7	6	7	8	7	7	8	7	7	7	6	6	6	5
L03	Increase Occupancy Sensor	11.5.2.5.3	4	4	5	5	6	6	6	7	7	7	7	6	6	6	7	5	6	5	4
L04	Increase Daylight Area	11.5.2.5.4	6	7	8	7	7	8	8	9	10	8	8	9	8	8	9	7	8	8	6
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	7	7	8	8	8	9	9	10	11	9	9	10	9	9	10	8	9	8	7
R01	On-Site Renewable Energy	11.5.2.6	10	11	13	12	14	18	16	20	21	15	21	16	13	19	15	14	16	13	10
Q01	Efficient Elevator Equipment	11.5.2.7.1	3	4	4	4	5	5	5	6	6	6	6	6	6	6	7	6	6	6	5
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	5	4	4	4	4	3	3	3	2	3	3	2	3	3	2	3	3	3	3
G01	Lighting Load Management	11.5.2.8.1	2	3	3	3	3	4	3	4	3	3	4	4	2	4	5	4	3	3	3
G02	HVAC Load Management	11.5.2.8.2	6	5	8	6	6	8	6	6	5	6	8	6	5	8	3	4	7	4	2
G03	Shading Load Management	11.5.2.8.3	9	13	16	12	18	17	16	18	13	11	17	16	10	15	14	12	10	15	15
G04	Electric Energy Storage	11.5.2.8.4	12	12	13	13	14	16	16	17	20	16	18	18	17	18	18	15	17	15	14
G05	HVAC Cooling Energy Storage	11.5.2.8.5	26	7	37	17	30	28	36	40	38	23	37	22	20	28	13	16	32	3	4
G06	SHW Thermal Storage	11.5.2.8.6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
G07	Building Mass/Night Flush	11.5.2.8.7	4	1	6	2	8	14	11	14	20	10	20	20	19	30	19	16	20	20	10

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Table 11.5.3-8 Energy Credits for Warehouses

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	5	1	×	14	6	8	21	13	7	24	18	23	24
H03	Cooling Efficiency	11.5.2.2.3	13	13	9	10	7	6	3	4	1	1	2	×	1	1	×	×	×	×	×
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H06	DOAS/Fan Controls	11.5.2.2.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H07	Guideline 36 Sequences	11.5.2.2.7	3	3	2	3	2	2	2	2	1	3	2	2	4	3	2	4	3	4	4
W01	SHW Preheat Recovery	11.5.2.3.1(a)	2	2	3	2	3	3	3	3	4	3	3	3	2	3	3	2	2	2	2
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	1	1	1	1	2	2	2	2	2	1	2	2	1	2	2	1	1	1	1
W04	SWH Pipe Insulation	11.5.2.3.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
P01	Energy Monitoring	11.5.2.4	5	5	6	6	6	6	6	6	6	5	6	6	5	6	6	6	6	6	6
L02	Lighting Dimming and Tuning	11.5.2.5.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L03	Increase Occupancy Sensor	11.5.2.5.3	6	6	7	6	7	7	7	7	9	6	7	7	5	6	8	5	6	5	4
L04	Increase Daylight Area	11.5.2.5.4	15	14	18	16	18	18	17	18	21	14	17	17	12	15	17	11	14	12	10
L05	Residential Light Controls	11.5.2.5.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
L06	Light Power Reduction	11.5.2.5.6	14	14	17	16	17	17	16	18	19	13	16	17	11	14	17	11	14	11	10
R01	On-Site Renewable Energy	11.5.2.6	44	41	54	49	56	62	52	67	72	38	64	45	28	49	42	24	33	24	19
Q01	Efficient Elevator Equipment	11.5.2.7.3	5	4	5	5	6	5	5	6	6	5	5	6	4	5	6	3	4	3	3
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	3	3	2	3	2	2	2	2	1	3	2	2	4	3	2	4	3	4	4
G01	Lighting Load Management	11.5.2.8.1	6	7	8	7	8	9	8	9	9	6	8	9	6	7	9	5	7	5	5
G02	HVAC Load Management	11.5.2.8.2	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G03	Shading Load Management	11.5.2.8.3	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
G04	Electric Energy Storage	11.5.2.8.4	33	34	40	35	41	39	40	43	49	34	40	42	29	34	42	22	28	23	24
G05	HVAC Cooling Energy Storage	11.5.2.8.5	40	15	40	32	40	40	32	40	17	12	26	4	5	12	1	3	7	×	×
G06	SHW Thermal Storage	11.5.2.8.6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
G07	Building Mass/Night Flush	11.5.2.8.7	4	1	6	3	9	15	12	14	20	9	20	20	14	20	19	10	20	15	6

× = credits excluded from this *building* use type and climate zone.

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Table 11.5.3-9 Energy Credits for Other Buildings

ID	Energy Credit Abbreviated Title	Section	Climate Zone																		
			0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01	Improved Envelope Performance	11.5.2.1	Determined in accordance with Section 11.5.2.1																		
H02	Heating Efficiency	11.5.2.2.2	×	×	×	×	×	×	2	×	×	5	3	4	7	5	4	9	7	9	12
H03	Cooling Efficiency	11.5.2.2.3	20	17	14	15	12	10	7	7	5	5	5	3	3	4	2	4	3	3	2
H04	Residential HVAC Controls	11.5.2.2.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H05	Ground-Source Heat Pump	11.5.2.2.5	11	11	7	10	8	6	7	7	5	11	8	10	13	12	10	18	15	17	17
H06	DOAS/Fan Controls	11.5.2.2.6	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
H07	Guideline 36 Sequences	11.5.2.2.7	4	4	3	3	3	3	2	2	2	3	2	2	3	3	2	3	3	3	3
W01	SHW Preheat Recovery	11.5.2.3.1(a)	3	4	5	4	5	6	6	6	8	7	7	8	7	7	8	7	7	7	7
W02	Heat-Pump Water Heater	11.5.2.3.1(b)	4	4	4	4	5	6	7	6	8	8	7	9	8	8	9	8	9	9	9
W03	Efficient Gas Water Heater	11.5.2.3.1(c)	4	4	5	5	5	6	7	7	8	7	7	8	8	8	9	8	8	8	8
W04	SWH Pipe Insulation	11.5.2.3.2	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
W05	Point-of-Use Water Heaters	11.5.2.3.3(a)	1	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2	2	2	2
W06	Thermostatic Balancing Valves	11.5.2.3.3(b)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
W07	SHW Submeters	11.5.2.3.4	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W08	SHW Distribution Sizing	11.5.2.3.5	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
W09	Shower Drain Heat Recovery	11.5.2.3.6	4	4	5	5	6	7	8	8	9	9	9	10	10	10	11	10	10	10	10
P01	Energy Monitoring	11.5.2.4	4	4	4	4	4	4	4	4	3	3	4	3	3	4	3	4	4	4	4
L02	Lighting Dimming and Tuning	11.5.2.5.2	4	4	4	4	4	4	4	5	5	4	5	5	4	4	4	4	4	3	3
L03	Increase Occupancy Sensor	11.5.2.5.3	4	4	5	4	5	5	5	5	6	4	5	5	4	4	5	4	4	3	3
L04	Increase Daylight Area	11.5.2.5.4	9	9	11	10	10	10	10	11	12	9	10	10	8	9	10	7	9	8	6
L05	Residential Light Controls	11.5.2.5.5	9	9	10	9	10	10	9	10	11	9	9	10	7	9	10	7	8	8	6
L06	Light Power Reduction	11.5.2.5.6	6	6	6	6	6	7	6	7	8	6	7	7	6	6	6	5	6	5	4
R01	On-Site Renewable Energy	11.5.2.6	13	13	15	14	16	19	16	21	22	13	20	15	11	17	14	11	13	11	8
Q01	Efficient Elevator Equipment	11.5.2.7.1	3	3	4	4	4	4	4	4	5	4	4	5	4	4	5	4	4	4	4
Q02	Efficient Kitchen Equipment	11.5.2.7.2	Commercial kitchens and dining areas are a restaurant *building* use type in accordance with Section 11.5.1(a).																		
Q03	Fault Detection and Diagnostics	11.5.2.7.3	4	4	3	3	3	3	2	2	2	3	2	2	3	3	2	3	3	3	3
G01	Lighting Load Management	11.5.2.8.1	6	6	7	7	7	8	7	8	8	6	8	8	6	7	9	7	7	6	6
G02	HVAC Load Management	11.5.2.8.2	10	9	10	11	9	10	10	8	6	9	8	8	8	13	9	7	9	8	5
G03	Shading Load Management	11.5.2.8.3	5	6	7	8	9	9	7	9	9	6	8	7	7	8	11	7	6	7	13
G04	Electric Energy Storage	11.5.2.8.4	12	13	14	13	15	15	16	17	18	16	16	17	15	16	18	13	14	13	13
G05	HVAC Cooling Energy Storage	11.5.2.8.5	21	6	26	13	21	19	22	30	17	12	20	10	9	14	7	7	15	2	3
G06	SHW Thermal Storage	11.5.2.8.6	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
G07	Building Mass/Night Flush	11.5.2.8.7	4	1	5	2	8	13	10	12	20	8	19	20	14	25	16	12	20	18	8

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Section 12 Energy Cost Budget Method

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Section 12.1 General

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Section 12.2 Compliance (including Sections 5.4., 6.4, 7.4, 8.4, 9.4, 10.4)

↓

Section 12.4 Simulation General Requirements

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Section 12.5 Calculation of Design Energy Cost and Energy Cost Budget

↓

Section 12.7 Submittals

12. ENERGY COST BUDGET METHOD

12.1 General

12.1.1 Energy Cost Budget Method Scope. The *building* Energy Cost Budget Method is an alternative to the prescriptive provisions of this standard. It may be employed for evaluating the compliance of all *proposed designs* except designs with no mechanical *system*.

Informative Note: To fully utilize the investment made of creating a *building energy* model during the design process, the methodology described in ASHRAE Standard 209 should be considered.

12.1.2 Trade-Offs Limited to Building Permit. When the *building* permit being sought applies to less than the whole *building*, only the calculation parameters related to the *systems* to which the permit applies shall be allowed to vary. Parameters relating to unmodified existing conditions or to future *building* components shall be identical for both the *energy cost budget* and the *design energy cost* calculations. Future *building* components shall meet the prescriptive requirements of Sections 5.5, 6.5, 7.5, and 9.5.

12.1.3 Envelope Limitation. For new *buildings* or *additions*, the *building* Energy Cost Budget Method results shall not be submitted for *building* permit approval to the *authority having jurisdiction* prior to submittal for approval of the *building envelope* design.

12.2 Compliance. The proposed *building* design shall comply with all of the following:

a. Sections 5.2.1, 6.2.1, 7.2.1, 8.2.1, 9.2.1, and 10.2.1.
b. The *design energy cost* shall comply with the following:

$$\textit{Design Energy Cost} \le \textit{Energy Cost Budget} \times \left(1 - \frac{\mathrm{EC}_{req}}{1000} \times A_{adj}\right)$$

where

EC_{req} = *energy* credits required for the *building* in accordance with Section 11.5.1

A_{adj} = where the project includes *additions* or *alterations* use an adjustment factor as follows; otherwise use 1.0:

$$A_{adj} = \frac{\textit{Addition Gross Floor Area} + \textit{Alteration Gross Floor Area}}{\text{Modeled } \textit{gross floor area}}$$

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Design energy cost = as calculated in Section 12.5

Energy cost budget = as calculated in Section 12.5

c. The *energy efficiency* level of installed components and *systems* that meets or exceeds the *efficiency* levels used to calculate the *design energy cost*.
d. For new *buildings*, one of the following is met:
    1. The *building envelope* complies with Section 5.5, "Prescriptive Building Envelope Compliance Path."
    2. Using Section 5.6, "Building Envelope Trade-Off Compliance Option," the *proposed envelope performance factor* shall not exceed the *base envelope performance factor* by more than 15% in multifamily *residential*, hotel/motel, and dormitory *building* area types. For all other *building* area types, the limit shall be 7%. For *buildings* with both *residential* and *nonresidential* occupancies, the limit shall be based on the area-weighted average of the *gross conditioned floor area*.
e. Verification, testing, and *commissioning* requirements of Section 4.2.5 shall be met.
f. Proposed *building systems*, controls, or *building envelope* documented in Table 12.7.2(d) that do not have criteria in Sections 5 through 10 shall have verification or testing to document proper installation and operation in accordance with Section 4.2.5.

Informative Note: The *energy cost budget* and the *design energy cost* calculations are applicable only for determining compliance with this standard. They are not predictions of actual *energy* consumption or costs of 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 standard, changes in *energy* rates between design of the *building* and occupancy, and precision of the calculation tool.

12.3 Simplified Option (Not Used)

12.4 Simulation General Requirements

12.4.1 Simulation Program. The *simulation program* shall be a computer-based program for the analysis of *energy* consumption in *buildings*. For components that cannot be modeled by the *simulation program*, the exceptional calculation methods requirements in Section 12.4.5 shall be used.

Exception to 12.4.1: When approved by the *adopting authority*, a separate computer-based program shall be permitted to be used to calculate *on-site renewable energy*.

Informative Note: ASHRAE Standing Standard Project Committee 90.1 recommends that the *simulation program* implement the rules of Section 12 that *control* simulation inputs and outputs be adopted for the purposes of easier use and simpler compliance.

12.4.1.1 The *simulation program* shall be approved by the *adopting 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*, humidity *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-side economizer* and *fluid economizer* with integrated control
h. The *budget building design* characteristics unless otherwise specified in Section 12.5

12.4.1.2 The *simulation program* shall have the ability to either

a. directly determine the *design energy cost* and *energy cost budget* or
b. produce hourly reports of *energy* use by *energy* source suitable for determining the *design energy cost* and *energy cost budget* using a separate calculation.

12.4.1.3 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 Section 6.4.2 for both the *proposed design* and the *budget building design*.

12.4.1.4 Simulation Program Testing Requirements

12.4.1.4.1 The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The required tests shall include *building* thermal envelope and fabric load tests (Sections 5.2.1, 5.2.2, and 5.2.3), ground coupled slab-on-*grade* analytical verification tests (Section 5.2.4),

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space-cooling *equipment* performance tests (Section 5.3), *space*-heating *equipment* performance tests (Section 5.4), and air-side HVAC *equipment* analytical verification tests (Section 5.5), along with the associated reporting (Section 6).

12.4.1.4.2 The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the *simulation program* and input files used for generating results along with the results of the other *simulation programs* included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7, shall be completed for results exceeding the maximum or falling below the minimum of the reference values and for omitted results.

12.4.1.4.3 The testing shall be performed for the version of the *simulation program* used to calculate the *design energy cost* and *energy cost budget*.

Informative Notes:

1. There are no pass/fail criteria established by this requirement.
2. Based on the Section 3.2 definition, *simulation program* includes the simulation engine and the corresponding user interface. The testing of a *simulation program* only meets the requirements of Section 12.4.1.4 for that *simulation program* and cannot be used as proxy for documenting compliance of another *simulation program* that uses the same simulation engine.

12.4.2 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 *site* in which the *proposed design* is to be located. For locations for which several climatic data sources are available or 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 *authority having jurisdiction*.

12.4.3 Renewable, Recovered, and Purchased Energy

12.4.3.1 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 *design energy cost*. *On-site renewable energy* shall be subtracted from the *proposed design energy* consumption prior to calculating the *design energy cost*, provided that the *building* owner

a. owns the *on-site renewable energy system*,
b. has signed a lease agreement for the *on-site renewable energy system* for at least 15 years, or
c. has signed a contractual agreement to purchase *energy* generated by the *on-site renewable energy system* for at least 15 years.

The reduction in *design energy cost* associated with *on-site renewable energy* that exceeds the *on-site renewable energy* required by Section 10.5.1.1 shall be no more than 5% of the calculated *energy cost budget*.

On-site renewable energy included in the *budget building design* shall be subtracted from the *budget building design energy* consumption prior to calculating the *energy cost budget.*

12.4.3.2 Annual Energy Costs. The *design energy cost* and *energy cost budget* shall be determined using rates for *purchased energy* (such as electricity, gas, oil, propane, steam, and chilled water) that are approved by the *adopting authority*. Where *on-site renewable energy* or *site-recovered energy* is in excess of what is required in the *budget building design* by Table 12.5.1, the *budget building design* shall be based on the *energy* source used as the backup *energy* source, or electricity if no backup *energy* source has been specified. Where the *proposed design* includes *on-site electricity generation systems* other than *on-site renewable energy systems*, the baseline design shall include the same generation *systems* excluding its *site-recovered energy*.

12.4.4 Compliance Calculations. The *design energy cost* and *energy cost budget* shall be calculated using

a. the same *simulation program*,
b. the same weather data, and
c. the same *purchased energy rates*.

12.4.5 Exceptional Calculation Methods. When the *simulation program* does not model a design, material, or device, an exceptional calculation method shall be used as approved by the *authority having jurisdiction* to demonstrate compliance with Section 12.

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. All applications for approval of an exceptional method shall include the following:

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a. Theoretical and empirical information verifying the method's accuracy, and 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 that are estimated 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 *energy cost budget* and *design energy cost* calculated with and without the exceptional calculation methods.

12.5 Calculation of Design Energy Cost and Energy Cost Budget

12.5.1 The simulation model for calculating the *design energy cost* and the *energy cost budget* shall be developed in accordance with the requirements in Table 12.5.1.

Exception to 12.5.1: Energy used to recharge or refuel vehicles that are used for off-*site* transportation purposes shall not be modeled for the *design energy cost* or the *energy cost budget*.

12.5.2 HVAC Systems. The *HVAC system* type and related performance parameters for the *budget building design* shall be determined from Figure 12.5.2, the *system* descriptions in Table 12.5.2-1 and accompanying notes, and the following rules:

a. **Budget Building Systems Not Listed.** Components and parameters not listed in Figure 12.5.2 and Table 12.5.2-1 or otherwise specifically addressed in this subsection shall be identical to those in the *proposed design*.

   Exception to 12.5.2(a): Where there are specific requirements in Sections 6.4 and 6.5, the component *efficiency* in the *budget building design* shall be adjusted to the lowest *efficiency* level allowed by the requirement for that component type.
b. **Minimum Equipment Efficiency.** All HVAC and *service water-heating equipment* in the *budget building design* shall be modeled at the minimum *efficiency* levels, both part load and full load, in accordance with Sections 6.4, 6.5.4.8, 7.4, and 7.5 based on the budget *system* type determined following Section 12.5.2(j) and capacity determined following Section 12.5.2(i). Chillers shall use Path A efficiencies as shown in Table 6.8.1-3 and be modeled using the performance curves specified in Table J-1 and included in Normative Appendix J. When using performance curves from Normative Appendix J, chiller minimum part-load ratio (ratio of load to available capacity at a given simulation time step) and minimum compressor unloading ratio (part-load ratio below which the chiller capacity cannot be reduced by unloading and chiller is false loaded) shall be equal to 0.25. *Simulation programs* that do not use performance curves are permitted to use an alternative simulation method that results in the same performance as the curves described in Normative Appendix J.
c. **Supply Fan Energy in Certain Package Equipment.** Where *efficiency* ratings include supply fan *energy*, the *efficiency* rating shall be adjusted to remove the supply fan *energy*. For budget *system* Types 3, 4, 6, 8, 9, 10, and 11, calculate the minimum $COP_{nfcooling}$ and $COP_{nfheating}$ using the equation for the applicable performance rating as indicated in Tables 6.8.1-1, 6.8.1-2, 6.8.1-4, and 6.8.1-15. Where a full- and part-load *efficiency* rating is provided in Tables 6.8.1-1, 6.8.1-2, 6.8.1-4, and 6.8.1-15, the full-load equation below shall be used:

$$COP_{nfcooling} = 7.84\text{E-}8 \times EER \times Q + 0.338 \times EER$$

$$COP_{nfcooling} = -0.0076 \times SEER^2 + 0.3796 \times SEER$$

(applies to cooling *efficiency* only)

$$COP_{nfheating} = 1.48\text{E-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$$

(applies to Systems 6 and 9 heating *efficiency* only)

$$COP_{nfheating} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$$

$$COP_{nfcooling} = 0.3322 \times EER - 0.2145$$

(applies to Systems 8 and 10 cooling *efficiency* only)

$$COP_{nfheating} = 1.1329 \times COP - 0.214$$

(applies to System 8 heating *efficiency* only)

where $COP_{nfcooling}$ and $COP_{nfheating}$ are the packaged HVAC *equipment* cooling and heating *energy efficiency*, respectively, to be used in the *budget building design*, which excludes supply fan power, and Q is the AHRI-rated cooling capacity in Btu/h. If Q is greater than 760,000 Btu/h, use 760,000 Btu/h in the calculation.

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EER, *SEER*, *COP*, and *HSPF* shall be at AHRI test conditions. Fan *energy* shall be modeled separately according to Section 12.5.2(h). Supply and return/relief *system* fans shall be modeled as operating at least whenever the *spaces* served are occupied, except as specifically noted in Table 12.5.2-1.

d. **Minimum Outdoor Air Ventilation Rate.** Minimum *outdoor air ventilation* rates shall be the same for both the *budget building design* and *proposed design*. Exhaust air *energy* recovery shall be modeled for the *budget building design* in accordance with Section 6.5.6.1.

Exceptions to 12.5.2(d):

1. When modeling *demand control ventilation* in the *proposed design* for *spaces* where *demand control ventilation* is not required per Section 6.4.3.8.
2. Where the minimum *outdoor air* intake flow in the *proposed design* is provided in excess of the amount required by Section 6.5.3.8, the *baseline building design* shall be modeled to reflect the minimum amount required by Section 6.5.3.8.

e. **Economizers.** All budget *building systems* as listed in Table 12.5.2-1 shall have *air economizers* in accordance with Section 6.5.1 and Section 12.5.2(i). The high-limit shutoff shall be in accordance with Table 12.5.2-4.

f. **Preheat Coils.** If the *proposed design system* has a preheat coil, the *budget building design*'s *system* shall be modeled with a preheat coil controlled in the same manner.

g. **Supply Airflow Rates.** *System* design supply air rates for the *budget 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 *budget building design* shall also be modeled with fans serving the same functions and sized for the budget *system* supply fan air quantity less the minimum *outdoor air*, or 90% of the supply fan air quantity, whichever is larger.

Exceptions to 12.5.2(g):

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 (lb) used to calculate the *proposed design* airflow shall be used to calculate design airflow rates for the *budget building design*.

h. **Fan System Efficiency.** Fan *system efficiency* (bhp per cfm of supply air, including the effect of belt losses but excluding motor and motor drive losses) shall be the same as the *proposed design* or up to the limit prescribed in Section 6.5.3.1, whichever is smaller. If this limit is reached, each fan shall be proportionally reduced in brake horsepower until the limit is met. Fan electrical power shall then be determined by adjusting the calculated fan hp by the minimum motor *efficiency* prescribed by Section 10.4.1 for the appropriate motor size for each fan.

Exception to 12.5.2(h): When a *proposed design* includes *energy* recovery but it is not required in the *budget building design* per Section 12.5.2(d), the fan power of those baseline *systems* shall be equal to either the *proposed design system* or the fan power limit in Section 6.5.3.1 calculated without fan power credit for *energy* recovery, whichever is less.

i. **Equipment Capacities.** The *equipment* capacities for the *budget building design* shall be sized proportionally to the capacities in the *proposed design* based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the *proposed design* and *budget building design*. Where multiple *HVAC zones* are combined into a single *thermal block* or modeled as identical *thermal blocks* to which multipliers are applied in accordance with Table 12.5.1, the *equipment* capacities for the *budget building design* shall be determined as follows:

1. For budget *system* Types 8 and 10, *equipment* capacity shall be 9000 Btu/h.
2. For budget *system* Types 5, 6, 7, 9, and 11, *equipment* capacity shall be based on the load of the *thermal block* divided by the number of combined *HVAC zones*.
3. For budget *system* Types 1, 2, 3, and 4, *equipment* capacity shall be based on the total load of all associated *thermal blocks*, including multipliers, divided by the total number of corresponding HVAC *systems* specified in the design documents.

Unmet load hours for the *proposed design* or *baseline building designs* shall not exceed 300 hours (of the 8760 hours simulated). The *unmet load hours* for the *proposed design* shall not exceed the *unmet*

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load hours for the *budget building design*. Alternatively, *unmet load hours* exceeding these limits may be approved by the *building official*, provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

j. **Determining the HVAC System.** Each *HVAC system* in a *proposed design* is mapped on a one-to-one correspondence with one of eleven *HVAC systems* in the *budget building design*. To determine the budget *building system*, do the following:

1. Enter Figure 12.5.2 at "Water/Ground" if the *proposed design system* condenser is water or evaporatively cooled; enter Figure 12.5.2 at "Air/None" if the condenser is air cooled. Closed-circuit dry coolers shall be considered air cooled. *Systems* utilizing district cooling shall be treated as if the condenser water type were "Water." If no *mechanical cooling* is specified or the *mechanical cooling system* in the *proposed design* does not require heat rejection, the *system* shall be treated as if the condenser water type were "Air." For *proposed designs* with ground-source or groundwater-source heat pumps, the budget *system* shall be water-source heat pump (*System* 6).
2. Select the path that corresponds to the *proposed design* heat source: *electric resistance*, heat pump (including air source and water source), or *fuel*-fired. *Systems* utilizing district heating (steam or hot water) shall be treated as if the heating *system* type were "Fossil Fuel." *Systems* with no heating capability shall be treated as if the heating *system* type were "Fossil Fuel." For *systems* with mixed *fuel* heating sources, the *system* or *systems* that use the secondary heating source type (the one with the smallest total installed output capacity for the *spaces* served by the *system*) shall be modeled identically in the *budget building design*, and the primary heating source type shall be used in Figure 12.5.2 to determine budget *system* type.
3. Select the *budget building design system* category. The *system* under "Single-Zone Residential System" shall be selected if the *HVAC system* in the *proposed design* is a *single-zone system* and serves a *residential space*. The *system* under "Single-Zone Nonresidential System" shall be selected if the *HVAC system* in the *proposed design* is a *single-zone system* and serves other than *residential spaces*. The *system* under "All Other" shall be selected for all other cases.

k. **Kitchen Exhaust.** For kitchens with a total exhaust hood airflow rate greater than 5000 cfm, use a *demand ventilation system* on 75% of the exhaust air. The *system* shall reduce exhaust and *replacement air system* airflow rates by 50% for one half of the kitchen occupied hours in the *baseline building design*. If the *proposed design* uses *demand ventilation*, the same airflow rate schedule shall be used. The maximum exhaust flow rate allowed for the hood or hood section shall meet the requirements of Section 6.5.7.2.2 for the numbers and types of hoods and appliances provided in the *proposed design*.

12.5.3 Modeling Building Envelope Air Leakage. The *air leakage* rate of the *building envelope* (I_{75Pa}) at a pressure differential of 75 Pa (0.30 in. of water) shall be converted to appropriate units for the *simulation program* using one of the following formulas:

a. For methods describing *air leakage* as a function of *floor* area,

$$I_{FLR} = 0.112 \times I_{75Pa} \times S/A_{FLR}$$

b. 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,

$$I_{AGW} = 0.112 \times I_{75Pa} \times S/A_{AGW}$$

c. When using the measured *air leakage* rate of the *building envelope* at a pressure differential of 75 Pa (0.30 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* in cfm/ft^2 at a fixed *building* pressure differential of 75 Pa (0.30 in. of water)

Q = volume of air in cfm flowing through the *building envelope* when subjected to a pressure differential of 75 Pa (0.30 in. of water), in accordance with ASTM E779, ASTM E1827, or ASTM E3158

S = total area of the *building envelope* in 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

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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

Exception to 12.5.3: 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 12.4.5.
2. The method for converting the *air leakage* rate of the *building envelope* at 75 Pa (0.30 in. of water) to the appropriate units for the *simulation program* is fully documented and submitted to the *rating authority* for approval.

12.6 Alternative Compliance Path (Not Used)

12.7 Submittals

12.7.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

12.7.2 Permit Application Documentation. Compliance shall be documented and submitted to the *building official*. The information submitted shall include the following:

a. The *energy cost budget* for the *budget building design* and the *design energy cost* for the *proposed design*.
b. The *simulation program* used and the version of the *simulation program*.
c. 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*.
d. A list of the *energy*-related features that are included in the design and on which compliance with the provisions of Section 12 is based. This list shall document all *energy* features that differ between the models used in the *energy cost budget* and the *design energy cost* calculations.
e. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).
f. *Building* elevations and *floor* plans.
g. A diagram showing the *thermal blocks* used in the computer simulation.
h. An explanation of any significant modeling assumptions.
i. 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 12.5.1(1)(a).
j. Reports from the *simulation program* showing
    1. a breakdown of *energy* usage 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*);
    2. the amount of time any loads are not met by the *HVAC system* for both the *proposed design* and *budget building design*; and
    3. a description of *energy*-related features of the *budget building design* and the *proposed design* to support requirements of Section 12.7.2(d).
k. *Purchased energy rates* used in the simulations.
l. An explanation of any error messages noted in the *simulation program* output.
m. 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.
n. The reduction in *design energy cost* associated with *on-site renewable energy*.
o. The version of the software and the link to the website that contains the ASHRAE Standard 140 results for the version used in accordance with Section 12.4.1.4.
p. Simulation input files for the *budget building design* and the *proposed design* shall be made available if requested by the *building official.*

12.7.3 Completion Requirements. Completion requirements shall be in compliance with Sections 5.7.3, 6.7.3, 7.7.3, 8.7.3, 9.7.3, and 10.7.3.

12.8 Product Information (Not Used)

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Table 12.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

Proposed Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
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* envelope types and area; interior lighting power and controls; *HVAC system* types, sizes, and controls; and *service water-heating systems* and controls. b. All *conditioned spaces* in the *proposed design* shall be simulated as being both heated and cooled, even if no cooling or heating *system* is being installed. 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*. c. When the *Energy Cost Budget* 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* so that they minimally comply with applicable mandatory and prescriptive requirements from Sections 5 through 10. Where the *space* classification for a *building* is not known, the *building* shall be categorized as an office *building*.	The *budget building design* shall be developed by modifying the *proposed design* as described in this table. Except as specifically instructed in this table, all *building systems* and *equipment* shall be modeled identically in the *budget building design* and *proposed design*.
2. Additions and Alterations	
It is acceptable to demonstrate compliance using *building* models that exclude parts of the *existing building*, provided all of the following conditions are met: a. Work to be performed under the current permit application 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 identical. 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.	Same as *proposed design*.
3. Space Use Classification	
The *building* area type or *space* type classifications shall be chosen in accordance with Section 9.5.1 or 9.5.2. The user or designer shall specify the *space* use classifications using either the *building* area type or *space* type categories but shall not combine the two types of categories within a single permit application. More than one *building* area type category may be used for a *building* if it is a mixed-use facility. **Exception:** Where *space* types neither exist nor are designated in design documents, use type shall be specified in accordance with Section 9.5.1.	Same as *proposed design*.
4. Schedules	
The schedule types listed in Section 12.4.1.1(b) shall be required input. The schedules shall be typical of the *proposed design* as determined by the designer and approved by the *authority having jurisdiction*. Required schedules shall be identical for the *proposed design* and *budget building design*. **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.	Same as *proposed design*.

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Table 12.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

Proposed Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
4. Schedules (continued)	
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. Dedicated *outdoor air* supply fans shall stay off during unoccupied hours. 4. HVAC fans shall remain on during occupied and unoccupied hours in *systems* primarily serving *computer rooms*.	Same as *proposed design*.
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*. All *opaque building envelope* components shall be modeled accounting for thermal mass effects. **Exception:** The following *building* elements are permitted to differ from architectural drawings. 1. Each *linear thermal bridge* and *point thermal bridge* as identified in Section 5.5.5 shall be modeled using either of the following techniques: a. A separate model of the assembly within the *energy* simulation model. b. Adjustment of the clear-field *U-factor* in accordance with Section A10.2. 2. Each uninsulated assembly not identified in Section 5.5.5 shall be modeled using either of the following techniques: a. A separate model of the assembly within the *energy* simulation model. b. The *U-factors* of uninsulated assemblies can be averaged with larger adjacent surfaces of the same *class of construction* using an area-weighted average method. This average *U-factor* is modeled within the *energy* simulation model. 3. Any other *building envelope* assembly, not subject to the requirements of Section 5.5.5, that covers less than 5% of the total area of that *class of construction* need not be separately described, provided that it is similar to an assembly being modeled. If not separately described, the *U-factors* of these assemblies shall be averaged with larger adjacent surfaces using an area-weighted average method. This average *U-factor* shall be modeled within the *energy* simulation model. 4. Exterior surfaces whose azimuth *orientation* and tilt differ by less than 45 degrees and are otherwise the same shall be described as either a single surface or by using multipliers. 5. The exterior *roof* surface shall be modeled using the aged solar reflectance and thermal *emittance* determined in accordance with Section 5.5.3.1.4(a). Where aged test data are unavailable, the *roof* surface shall be modeled with a solar reflectance of 0.30 and a thermal *emittance* of 0.90. The *above-grade wall* surfaces of *buildings* shall be modeled with an initial solar reflectance and thermal *emittance* determined in accordance with the test methods identified in Section 5.5.3.2.2(a). Where initial test data are unavailable, the *above-grade wall* surfaces shall be modeled with a solar reflectance of 0.25 and a thermal *emittance* of 0.90. 6. Manually operated *fenestration* shading devices, such as blinds or shades, shall not be modeled. Permanent shading devices, such as fins, overhangs, and lightshelves, shall be modeled. b. To simulate *air leakage*, infiltration shall be modeled using the same methodology and adjustments for weather and *building* operation in both the *proposed design* and the *budget 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* shall be in accordance with one of the following: 1. When whole-*building* pressurization testing is required or specified during design, and completed in accordance with Section 5.4.3.1.4, the measured *air leakage* rate of the *building envelope* (I_{75Pa}) at a fixed *building* pressure differential of 75 Pa (0.30 in. of water) shall be modeled for purposes of demonstrating compliance with this standard.	The *budget building design* shall have identical *conditioned floor area* and identical exterior dimensions and *orientations* as the *proposed design*, except as follows: a. *Opaque* assemblies, such as *roof*, *floors*, *doors*, and *walls*, shall be modeled as having the same *heat capacity* as the *proposed design* but with the minimum *U-factor* required in Section 5.5 for new *buildings* or additions and Section 5.1.4 for *alterations*. b. Where *linear thermal bridges* and *point thermal bridges,* as identified in Sections 5.5.5.1 through 5.5.5.5, are included in the *proposed design*, they shall be modeled by adjusting the *U-factor* of the parent assembly in accordance with the default values in Section A10. If the *proposed design* does not have *linear thermal bridges* and *point thermal bridges,* as identified in Sections 5.5.5.1 through 5.5.5.5, they shall not be modeled in the *budget building design*. If the balcony length in the *proposed design* exceeds the maximum allowed by Sections 5.5.5.2.2, the area shall be reduced proportionally for each balcony until the limit set in Sections 5.5.5.2.2 is met. c. The exterior *roof* surfaces shall be modeled with a solar reflectance and thermal *emittance* as required in Section 5.5.3.1.4(a). All other *roofs*, including *roofs* exempted from the requirements in Section 5.5.3.1.4, shall be modeled the same as the *proposed design*. The *above-grade wall* surfaces of *buildings* shall be modeled with a solar reflectance and thermal *emittance* as required in Section 5.5.3.2.2 and 5.5.3.2.2(a). All other *above-grade walls*, including those exempt from the requirements in Section 5.5.3.2.2, shall be modeled the same as the *proposed design*. d. No shading projections are to be modeled; *fenestration* shall be assumed to be flush with the *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 *vertical fenestration area* facing west or east of the *proposed design* exceeds the area limit set in Section 5.5.4.5 then the *energy cost budget* shall be generated by simulating the *budget building design* with its actual *orientation* and again after rotating the entire *budget building design* 90, 180, and 270 degrees and then averaging the results. *Fenestration U-factor* shall be equal to the criteria from Tables 5.5-0 through 5.5-8 for the appropriate climate, and the *SHGC* shall be equal to the criteria from Tables 5.5-0 through 5.5-8 for the appropriate climate. 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(d). The *VT* shall be equal to that determined in accordance with Section C3.6(d). The *fenestration* model for *building envelope alterations* shall reflect the limitations on area, *U-factor*, and *SHGC* as described in Section 5.1.4. e. *Skylights* shall be included in each *thermal block* when required by Section 5.5.4.2.3. **Exception:** When trade-offs are made between an *addition* and an *existing building*, as described in the exception to Section 4.2.1.2, the *building envelope* assumptions for the *existing building* in the *budget building design* shall reflect existing conditions prior to any revisions that are part of this permit.

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Table 12.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

<table>
<tr><th>Proposed Design (Column A)
Design Energy Cost (DEC)</th><th>Budget Building Design (Column B)
Energy Cost Budget (ECB)</th></tr>
<tr><td colspan="2">5. Building Envelope (continued)</td></tr>
<tr><td>2. For buildings providing verification in accordance with Section 5.9.1.2, the air leakage rate of the building envelope (I_{75Pa}) at a fixed building pressure differential of 75 Pa (0.30 in. of water) shall be 0.45 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 12.5.3.</td><td>f. The air leakage rate of the building envelope (I_{75Pa}) at a pressure differential of 75 Pa (0.30 of water) shall be 0.35 cfm/ft^2 of building envelope area and shall be converted to appropriate units for the simulation software using the same method as the proposed design.</td></tr>
<tr><td colspan="2">6. Lighting</td></tr>
<tr><td>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 complete lighting system has been designed, lighting power for each thermal block shall be determined in accordance with Sections 9.1.3 and 9.1.4.
c. Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building area type.
d. Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures). For dwelling units, hotel/motel guest rooms, and other spaces in which lighting systems consist of plug-in light fixtures that are not shown or provided for on design documents, assume identical lighting power for the proposed design and baseline building design in the simulations.
e. The lighting schedules in the proposed design shall reflect the mandatory automatic lighting control requirements in Section 9.4.1 (e.g., programmable controls or occupancy sensors).
f. Automatic daylighting controls included in the proposed design may be modeled directly in the building simulation or be modeled in the building simulation through schedule adjustments determined by a separate analysis approved by the authority having jurisdiction. Modeling and schedule adjustments shall separately account for primary sidelighted areas, secondary sidelighted areas, and toplighted areas.
g. Automatic lighting controls included in the proposed design but not required by Section 9.4.1 shall be modeled using the following methods for each luminaire under control:
1. Manual-ON or partial-auto-ON occupancy sensors shall be modeled by reducing the lighting schedule each hour by the occupancy sensor reduction factors in Table G3.7-1 and G3.7-2for the applicable space type multiplied by 0.25.
2. Automatic lighting controls listed in Table 9.5.2.3 shall be modeled using the sum of the applicable control factors (CF). Apply control factors to only the portion of wattage of the fixtures in the space controlled by said lighting control. Divide each hour of the lighting schedule by $(1 + \sum CF)$, where $\sum CF$ indicates the sum of all applicable control factors for that space per Section 9.5.2.3 and Table 9.5.2.3.</td><td>a. Where a complete lighting system exists, lighting power in the budget building design shall be the same as in the proposed design.
b. Where a lighting system has been designed, the interior lighting power allowance shall be determined using either the Building Area Method or Space-by-Space Method, and the space use classification shall be the same as the proposed design with lighting power set equal to the maximum allowed for the corresponding method and category in Section 9.2. Additional interior lighting power for nonmandatory controls allowed under Table 9.5.2.3 shall not be included in the budget building design. Lighting power density in dwelling units shall be 0.60 W/ft^2.
c. Where lighting neither exists nor is submitted with design documents, the lighting power in the budget building design shall be the same as in the proposed design.
d. Power for fixtures not included in the lighting power calculation shall be modeled identically in the proposed design and budget building design.
e. Mandatory automatic lighting controls required by Section 9.4.1 shall be modeled the same as the proposed design.</td></tr>
<tr><td colspan="2">7. Thermal Blocks—HVAC Zones Designed</td></tr>
<tr><td>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, or all of the zones have peak internal loads that differ by less than 10 Btu/h·ft^2 from the average.
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.
4. All of the zones have schedules that differ by 40 or less equivalent full-load hours per week.</td><td>Same as proposed design.</td></tr>
</table>

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Table 12.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

Proposed Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
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: a. Separate *thermal blocks* shall be assumed for interior and perimeter *spaces*. Interior *spaces* shall be those located more than 15 ft from an *exterior wall* or *semiexterior wall*. Perimeter *spaces* shall be those located closer than 15 ft from 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 *HVAC zone* per *dwelling unit* except for those units with the same *orientations*, which 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, such as *equipment* capacities and efficiencies, in the *proposed design* 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, 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 *budget building design*. The equations in Section 12.5.2 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. **Exception to (a) and (b):** Where part-load performance of chillers in the *proposed design* is not available, and design temperature across the condenser is 10°F, the performance curves in Normative Appendix J for the appropriate chiller type and capacity, as referenced in Table J-1 shall be modeled for the specified chiller. When using performance curves from Normative Appendix J, chiller minimum part-load ratio (ratio of load to available capacity at a given simulation time step) and minimum compressor unloading ratio (part-load ratio below which the chiller capacity cannot be reduced by unloading and chiller is false loaded) shall be equal to 0.25. *Simulation programs* that do not use performance curves are permitted to use an alternative simulation method that results in the same performance as the curves described in Normative Appendix J. c. Where no heating *system* exists or no heating *system* has been specified, the heating *system* shall be modeled as *fossil fuel*. The *system* characteristics shall be identical to the *system* modeled in the *budget building design*. d. Where no cooling *system* exists or no cooling *system* has been specified, the cooling *system* shall be modeled as an air-cooled *single-zone system*, one unit per *thermal block*. The *system* characteristics shall be identical to the *system* modeled in the *budget building design*.	The *HVAC system* type and related performance parameters for the *budget building design* shall be determined from Figure 12.5.2, the *system* descriptions in Table 12.5.2-1 and accompanying notes, and in accord with rules specified in Section 12.5.2(a) through 12.5.2(k).

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Table 12.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

Proposed Design (Column A) **Design Energy Cost (DEC)**	**Budget Building Design (Column B)** **Energy Cost Budget (ECB)**
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: a. Where a complete *service water-heating system* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. 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 submitted with the design documents, no *service water heating* shall be modeled. Piping losses shall not be modeled.	The *service water-heating system* type in the *budget building design* shall be identical to the *proposed design*. The *service water-heating system* performance of the *budget building design* shall meet the requirements of Sections 7.4 and 7.5. **Exceptions:** 1. If the *service water-heating system* type is not listed in Table 7.4-1, it shall be determined based on Table G3.1.1-2. 2. Where Section 7.5 applies, the *boiler* shall be split into a separate *space*-heating *boiler* and hot-*water heater* with *efficiency* requirements set to the least efficient allowed. 3. For 24-hour 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 6.5.6.2.2. 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 *budget building design*. *Service water-heating energy* consumption shall be calculated explicitly based on the volume of *service water heating* required, the entering makeup water, and the leaving *service water heating* temperatures. Entering water temperatures shall be estimated based on the location. Leaving temperatures shall be based on the end-use requirements. Service water loads and use shall be the same for both the *proposed design* and *baseline building design* and typical of the proposed *building* type. Piping losses shall not be modeled.
12. Miscellaneous Loads	
Receptacle, motor, and *process loads* shall be modeled and estimated based on the *building area type* or *space* type category and shall be assumed to be identical in the proposed and *budget building designs*. These loads shall be included in simulations of the *building* and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the *property* shall be modeled, unless specifically excluded by Table 12.5.1(14), including but not limited to exhaust fans, parking garage *ventilation* fans, exterior *property* lighting, swimming *pool* heaters and *pumps*, elevators and escalators, and cooking *equipment*. 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	Same as *proposed design*.
13. Refrigeration	
Where refrigeration *equipment* in the *proposed design* is rated in accordance with AHRI 1200, the rated *energy* use shall be modeled. Otherwise, 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 Table 6.8.1-11, the *budget building design* shall be modeled as specified in Table 6.8.1-11 using the actual *equipment* capacities. If the refrigeration *equipment* is not listed in Table 6.8.1-11, the *budget building design* shall be modeled the same as the *proposed design*.
14. Modeling Exceptions	
All elements of the *proposed design building envelope*, HVAC, *service water heating*, lighting, and electrical *systems* shall be modeled in the *proposed design* in accordance with the requirements of Table 12.5.1(1) through (13).	None.

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Table 12.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

Proposed Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
14. Modeling Exceptions (continued)	
Exception: Components and *systems* in the *proposed design* may be excluded from the simulation model provided that 1. component *energy* use does not affect the *energy* use of *systems* and components that are being considered for trade-off and 2. the applicable prescriptive requirements of Sections 5.5, 6.5, 7.5, and 9.5 applying to the excluded components are met.	
15. On-Site Renewable Energy	
On-site renewable energy in the *proposed design* shall be determined as follows: a. Where a complete *system* providing *on-site renewable energy* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where a *system* providing *on-site renewable energy* has been designed, the *system* model shall be consistent with design documents. c. Where no *system* exists or is specified to provide *on-site renewable energy*, no *system* shall be modeled.	*On-site renewable energy* shall be included in the *budget building design* when required by Section 10.5.1, and shall be determined as follows: a. Where a *system* providing *on-site renewable energy* has been modeled in the *proposed design*, the same *system* shall be modeled identically in the *budget building design*, except the rated capacity shall meet the requirements of Section 10.5.1.1. Where more than one type of *on-site renewable energy* system is modeled, the total capacities shall be allocated in the same proportion as in the *proposed design*. b. Where no *system* exists or is specified to provide *on-site renewable energy* in the *proposed design*, *on-site renewable energy* shall be modeled as an unshaded photovoltaic system with the following physical characteristics: • Size: Rated capacity per Section 10.5.1.1 • Module Type: Crystalline silicon panel with a glass cover, 19.1% nominal efficiency and temperature coefficient of –0.19%/°F; performance shall be based on a reference temperature of 77°F and irradiance of 317 Btu/ft^2·h. • Array Type: Rack-mounted array with installed nominal operating cell temperature (INOCT) of 103°F • Total system losses (DC output to AC output): 11.3% • Tilt: 0-degrees (mounted horizontally) • Azimuth:180 degrees If the *on-site renewable energy system* cannot be modeled in the *simulation program*, Section 12.4.5 shall be used.

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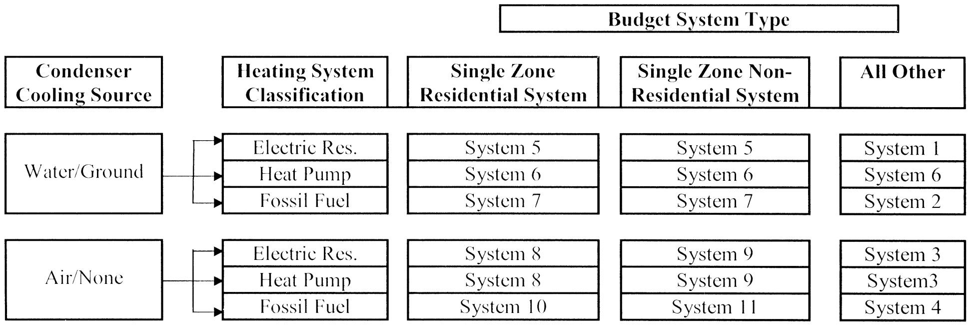

Figure 12.5.2 HVAC systems map.

Table 12.5.2-1 Budget System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1	*VAV* with parallel fan-powered boxes[a]	*VAV*[d]	Chilled water[e]	*Electric resistance*
2	*VAV* with reheat[b]	*VAV*[d]	Chilled water[e]	Hot-water *fossil fuel* boiler[f]
3	Packaged *VAV* with parallel fan-powered boxes[a]	*VAV*[d]	Direct expansion[c]	*Electric resistance*
4	Packaged *VAV* with reheat[b]	*VAV*[d]	Direct expansion[c]	Hot-water *fossil fuel* boiler[f]
5	Two-pipe fan coil	Single- or two-speed fan[i,j]	Chilled water[e]	*Electric resistance*
6	Water-source heat pump	Single- or two-speed fan[i,j]	Direct expansion[c]	Electric heat pump and boiler[g]
7	Four-pipe fan-coil	Single- or two-speed fan[i,j]	Chilled water[e]	Hot-water *fossil fuel* boiler[f]
8	*Packaged terminal heat pump*	Single-speed fan[i]	Direct expansion[c]	Electric heat pump[h]
9	Packaged rooftop heat pump	Single- or two-speed fan[i,j]	Direct expansion[c]	Electric heat pump[h]
10	*Packaged terminal air conditioner*	Single-speed fan[i]	Direct expansion	Hot-water *fossil fuel* boiler[f]
11	Packaged rooftop air conditioner	Single- or two-speed fan[i,j]	Direct expansion	*Fossil fuel* furnace

a. **VAV with Parallel Fan-Powered Boxes:** Fans in parallel *VAV* fan-powered boxes shall be sized for 50% of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume *set points* for fan-powered boxes shall be equal to the minimum rate for the *space* required for *ventilation* consistent with Section 6.5.2.1, Exception 1(b). Supply air temperature *set point* shall be constant at the *design condition* (see Section 12.5.2[g]).

b. **VAV with Reheat:** Minimum volume *set points* for *VAV reheat* boxes shall be the larger of the following: (1) the minimum primary outdoor airflow rate required to meet the Simplified Procedure *ventilation* requirements of ASHRAE Standard 62.1 for the zone or (2) the airflow rate required to comply with applicable codes or accreditation standards, including, but not limited to, pressure relationships or minimum air change rates. The supply air temperature for cooling shall be *reset* higher by 5°F under the minimum cooling load conditions.

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

d. **VAV:** The supply, return, or relief fan motor shall be modeled assuming a variable-speed drive and shall meet the *VAV* fan part-load performance requirements of Section G3.2.3.15. If the *proposed design*'s *system* has a *DDC system* at the zone level, static pressure *set-point reset* based on zone requirements in accordance with Section 6.5.3.2.3 shall be modeled.

e. **Chilled Water:** For *systems* using purchased chilled water, the chillers are not explicitly modeled, and chilled-water costs shall be based as determined in Section 12.4.3. Otherwise, the *budget building design*'s chiller plant shall be modeled with chillers having the number as indicated in Table 12.5.2-2 as a function of *budget building design* chiller plant load and type as indicated in Table 12.5.2-3 as a function of individual chiller load. Where chiller *fuel* source is mixed, the *system* in the *budget building design* shall have chillers with the same *fuel* types and with capacities having the same proportional capacity as the *proposed design*'s chillers for each *fuel* type. Chilled-water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. *Piping* losses shall not be modeled in either *building* model. Chilled-water supply water temperature shall be *reset* in accordance with Section 6.5.4.4. *Pump system power* for each pumping *system* shall be the same as for the *proposed design*; if the *proposed design* has no chilled-water *pumps*, the *budget building design pump* power shall be 22 W/gpm (equal to a *pump* operating against a 75 ft head, 65% combined impeller and motor *efficiency*). The chilled-water *system* shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled-water *pumps* shall be modeled as riding the *pump* curve or with variable-speed drives when required in Section 6.5.4.2. The heat-rejection device shall be an open-circuit axial-fan cooling tower with variable-speed fan control, if required in Section 6.5.5, and shall meet the performance requirements of 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 10°F:

$$\text{Approach}_{10°F\,Range} = 25.72 - (0.24 \times \text{WB})$$

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 cooling tower leaving water temperature, where weather permits, per Table 12.5.2-4, floating up to the design leaving water temperature for the cooling tower. *Pump system power* for each pumping *system* shall be the same as the *proposed design*; if the *proposed design* has no condenser water *pumps*, the *budget building design pump* power shall be 19 W/gpm (equal to a *pump* operating against a 60 ft head, 60% combined impeller and motor *efficiency*). Each chiller shall be modeled with separate condenser water and chilled-water *pumps* interlocked to operate with the associated chiller.

f. **Fossil Fuel Boiler:** For *systems* using purchased hot water or steam, the *boilers* are not explicitly modeled and hot-water or steam costs shall be based on actual utility rates. Otherwise, the *boiler* plant shall use the same *fuel* as the *proposed design* and shall be natural draft. The *budget building design boiler* plant shall be modeled with a single *boiler* if the *budget building design* plant load is 600,000 Btu/h or less and with two equally sized *boilers* for plant capacities exceeding 600,000 Btu/h. *Boilers* shall be staged as required by the load. For *boiler systems* meeting the requirements of Section 6.5.4.8, the hot-water supply temperature shall be modeled at 170°F design supply temperature and 120°F return temperature. For all other boiler systems, the hot-water supply temperature shall be modeled at 180°F design supply temperature and 130°F return temperature. *Piping* losses shall not be modeled in either *building* model. Hot-water supply water temperature shall be *reset* in accordance with Section 6.5.4.4. *Pump system power* for each pumping *system* shall be the same as for the *proposed design*; if the *proposed design* has no hot-water *pumps*, the *budget building design pump* power shall be 19 W/gpm (equal to a *pump* operating against a 60 ft head, 60% combined impeller and motor *efficiency*). The hot-water *system* shall be modeled as primary-only with continuous variable flow. Hot-water *pumps* shall be modeled as riding the *pump* curve or with variable-speed drives when required by Section 6.5.4.2.

g. **Electric Heat Pump and Boiler:** Water-source heat pumps shall be connected to a common heat-pump water loop controlled to maintain temperatures between 60°F and 90°F. Heat rejection from the loop shall be provided by a closed-circuit axial-fan evaporative fluid cooler with fan-speed control as required in Section 6.5.5.2. Heat addition to the loop shall be provided by a *boiler* that uses the same *fuel* as the *proposed design* and shall be natural draft. If no *boilers* exist in the *proposed design*, the budget *building boilers* shall be *fossil fuel*. The *budget building design boiler* plant shall be modeled with a single *boiler* if the *budget building design* plant load is 600,000 Btu/h or less and with two equally sized *boilers* for plant capacities exceeding 600,000 Btu/h. *Boilers* shall be staged as required by the load. *Piping* losses shall not be modeled in either *building* model. *Pump system power* shall be the same as for the *proposed design*; if the *proposed design* has no *pumps*, the *budget building design pump* power shall be 22 W/gpm, which is equal to a *pump* operating against a 75 ft head, with a 65% combined impeller and motor *efficiency*. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles OFF as required by Section 6.5.4.5 Loop *pumps* shall be modeled as riding the *pump* curve or with variable-speed drives when required by Section 6.5.4.2.

h. **Electric Heat Pump:** Electric air source heat pumps shall be modeled with electric auxiliary heat. The *system* shall be controlled with a multistage *space thermostat* and an *outdoor air thermostat* wired to energize auxiliary heat only on the last *thermostat* stage and when *outdoor air* temperature is less than 40°F.

i. **Fan System Operation:** Fans shall be controlled in the same manner as in the *proposed design*; i.e., fan operation whenever the *space* is occupied or fan operation cycled ON calls for heating and cooling.

j. **Fan Speed Control:** Fans shall operate as one or two speed as required by Section 6.5.3.2, regardless of the fan speed control used in the *proposed design*.

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Table 12.5.2-2 Number of Chillers

Total Chiller Plant Capacity	Number of Chillers
≤300 tons	One
>300 tons, <600 tons	Two sized equally
≥600 tons	Two minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

Table 12.5.2-3 Water Chiller Types

Individual Chiller Plant Capacity	Electric Chiller Type	Fossil Fuel Chiller Type
≤100 tons	Scroll	Single-effect absorption, direct fired
>100 tons, <600 tons	Screw	Double-effect absorption, direct fired
≥600 tons	Centrifugal	Double-effect absorption, direct fired

Table 12.5.2-4 Cooling Tower 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

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13. NORMATIVE REFERENCES

Reference		Section
Air Conditioning, Heating and Refrigeration Institute (AHRI) **2311 Wilson Blvd., Arlington, VA 22201**		
AHRI 210/240 (2017) with addendum 1	Unitary Air Conditioning and Air-Source Heat Pump Equipment (applicable before 1/1/2023)	Table 6.8.1-1, Table 6.8.1-2, Table F-1, Table G3.5.1, Table G3.5.2
AHRI 210/240-2023 (2020)	Unitary Air Conditioning and Air-Source Heat Pump Equipment (applicable on or after 1/1/2023)	Table 6.8.1-1, Table 6.8.1-8, Table 6.8.1-9, Table F-1
AHRI 310/380 (2017)	Packaged Terminal Air-Conditioners and Heat Pumps	Table 6.8.1-4, Table G3.5.4
AHRI 340/360 (I-P/2022)	Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment	Table 6.8.1-1, Table 6.8.1-2, Table G3.5.1, Table G3.5.2
ANSI/AHRI 365 (I-P/2009)	Commercial and Industrial Unitary Air-Conditioning Condensing Units	Table 6.8.1-1
AHRI 390 (I-P/2021)	Performance Rating of Single Packaged Vertical Air-Conditioners and Heat Pumps	Table 6.8.1-4
ANSI/AHRI 400 (I-P/2015)	Performance Rating of Liquid-to-Liquid Heat Exchangers	6.4.7
ANSI/AHRI 460 (2005)	Remote Mechanical Draft Air Cooled Refrigerant Condensers	Table 6.8.1-7
AHRI 550/590 (I-P/2020) (with Addendum 1)	Performance Rating of Water-Chilling and Heat-Pump Water-Heating Packages Using the Vapor Compression Cycle	6.4.1.2.1, 6.4.1.2.2.1, 6.4.1.2.2.2, 6.4.1.2.2.3, 6.4.1.2.2.4, Table 6.8.1-3, Table 6.8.1-16, Table G3.5.3
AHRI 560 (2000)	Absorption Water Chilling and Water Heating Packages	Table 6.8.1-3
ANSI/AHRI 910 (I-P/2014)	Performance Rating of Indoor Pool Dehumidifiers	Table 6.8.1-12
ANSI/AHRI 920 (I-P/2015)	Performance Rating of DX-Dedicated Outdoor Air System Units	3.2, Table 6.8.1-13, Table 6.8.1-14
ANSI/AHRI 1200 (I-P/2013)	Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets	Table 6.8.1-11, Table 12.5.1, Table G3.1, Table G3.10.1, Table G3.10.2
ANSI/AHRI 1230 (I-P/2014) (with Addendum 1)	Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment	Table 6.8.1-8, Table 6.8.1-9
ANSI/AHRI 1230 (I-P/2021)	Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment	Table 6.8.1-8, Table 6.8.1-9
AHRI Standard 1250 (I-P/2020)	Performance Rating of Walk-In Coolers and Freezers	Table 6.8.1-20
AHRI Standard 1300 (I-P/2013)	Performance Rating of Commercial Heat Pump Water Heaters	11.5.2.3.1
AHRI Standard 1360 (I-P/2017)	Performance Rating of Computer and Data Processing Room Air Conditioners	Table 6.8.1-10, Table 6.8.1-17

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Reference		Section
Air Movement and Control Association International (AMCA) **30 West University Drive, Arlington Heights, IL 60004-1806**		
ANSI/AMCA 208-18	Calculation of the Fan Energy Index	3.2, 6.5.3.1.3, Table 6.8.1-21
ANSI/AMCA 220-21	Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings	10.4.5
ANSI/AMCA Standard 230-15 with errata	Laboratory Methods of Testing Air Circulating Fans for Rating and Certification	Table 6.8.1-21
ANSI/AMCA Standard 500-D-18	Laboratory Methods of Testing Dampers for Rating	Table 6.4.3.4.3
American Architectural Manufacturers Association (AAMA) **Fenestration and Glazing Industry Alliance (FGIA)** **1900 E. Golf Rd, Suite 1250, Schaumburg, IL 60173-4268**		
Canadian Standards Association (CSA) **78 Rexdale Blvd., Toronto, On, Canada M9W 1R3**		
Window and Door Manufacturers Association (WDMA) **2025 M Street, NW, Suite 800, Washington, DC 20036**		
AAMA/WDMA/CSA 101/I.S.2/A440-17	NAFS-North American Fenestration Standard/Specification for Windows, Doors, and Skylights	Table 5.8.3.2
American Iron and Steel Institute (AISI) **25 Massachusetts Avenue, NW, Suite 800** **Washington, DC 20001**		
ANSI/AISI S250-2021	North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing	A2.5.3, A9.2
American National Standards Institute (ANSI) **1899 L Street, NW, 11th Floor, Washington, DC 20036**		
ANSI Z21.47-2021/CSA 2.3-2021	Gas-Fired Central Furnaces	Table G3.5.5, Table 6.8.1-5
ANSI Z83.8-2016/CSA 2.6-2016 (R2021)	Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters And Gas-Fired Duct Furnaces	Table G3.5.5, Table 6.8.1-5
American Society of Mechanical Engineers (ASME) **Two Park Avenue, New York, NY 10016-5990**		
ASME A17.1-2019/CSA B44-16	Safety Code for Elevators and Escalators	10.4.3.3, 10.4.4
ASHRAE **180 Technology Parkway, Peachtree Corners, GA 30092**		
ANSI/ASHRAE Standard 51-2016	Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating	Table 6.5.3.7
ANSI/ASHRAE Standard 55-2020	Thermal Environmental Conditions for Human Occupancy	Table G3.1
ANSI/ASHRAE Standard 62.1-2019	Ventilation for Acceptable Indoor Air Quality	6.4.3.3.2, 6.4.3.3.5.1, 6.4.3.8, Table 6.4.3.8, 6.5.1, 6.5.2.1, 6.5.2.3, 6.5.3.2.1, 6.5.3.3, 6.5.3.8, 6.5.3.9, 6.5.6.1.2, 6.5.7.1, 11.5.2.2.6, 11.5.2.8.2, Table 12.5.2-1, G3.2.2.4, G3.2.2.5, Table L2.2.3
ANSI/ASHRAE Standard 62.2-2019	Ventilation and Acceptable Indoor Air Quality in Residential Buildings	6.5.3.8
ANSI/ASHRAE/IESNA Standard 90.1-2007	Energy Standard for Buildings Except Low-Rise Residential Buildings	6.4.1.2.1

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Reference		Section
ANSI/ASHRAE/IESNA Standard 90.1-2010	Energy Standard for Buildings Except Low-Rise Residential Buildings	6.4.1.2.1
ANSI/ASHRAE/IESNA Standard 90.1-2013	Energy Standard for Buildings Except Low-Rise Residential Buildings	6.4.1.2.1
ANSI/ASHRAE/IES Standard 90.1-2016	Energy Standard for Buildings Except Low-Rise Residential Buildings	6.4.1.2.1
ANSI/ASHRAE/IES Standard 90.1-2019	Energy Standard for Buildings Except Low-Rise Residential Buildings	6.4.1.2.1
ANSI/ASHRAE/IES Standard 90.4-2019 (with addenda a, b, d, e, and f)	Energy Standard for Data Centers	6.6.1, 6.6.2.1, 8.6.1, Table 11.5.1-1, 11.5.2.2.3
ANSI/ASHRAE Standard 140-2020	Method of Test for Evaluating Building Performance Simulation Software	12.4.1.4.1, 12.4.1.4.2, 12.7.2, C2.8, C3.1.4.1, C3.1.4.2, G1.3.2, G2.2.4.1, G2.2.4.2, L3.2.4.1, L3.2.4.2, L3.4
ANSI/ASHRAE Standard 154-2016	Ventilation for Commercial Cooking Operations	6.5.7.2.2
ANSI/ASHRAE Standard 169-2013	Climatic Data for Building Design Standards	5.1.5.1, 5.1.5.2
ANSI/ASHRAE/ASHE Standard 170-2021	Ventilation of Health Care Facilities	6.4.3.8, 6.5.3.8, 6.5.6.1.2, Table 11.5.1-1
ANSI/ASHRAE/ACCA Standard 183-2007 (RA 2020)	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings	6.4.2.1
ASHRAE/IES Standard 202-2018	Commissioning Process for Buildings and Systems	4.2.5.2, 4.2.5.2.2
Association of Home Appliance Manufacturers (AHAM) 1111 19th Street NW, Suite 402, Washington, DC 20036		
ANSI/AHAM HRF-1-2016	Energy and Internal Volume of Refrigerating Appliances	Table G3.10.1
ANSI/AHAM RAC-1-2020	Room Air Conditioners	Table 6.8.1-4
ASTM International 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959		
ASTM C90-16A	Standard Specification for Loadbearing Concrete Masonry Units	5.5.3.2, A3.1.1, A9.4.4
ASTM C177-19	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance Properties by Means of the Guarded-Hot-Plate Apparatus	A9.3.1
ASTM C272/C272M-18	Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions	5.8.1.7.3
ASTM C518-21	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus	Table 6.8.2, A9.3.1
ASTM C835-06 (2013) e1	Standard Test Method for Total Hemispherical Emittance of Surfaces up to 1400°C	5.5.3.2.2
ASTM C1224 (2020)	Standard Specification for Reflective Insulation for Building Applications	A9.4.2, Table A9.4.2-2
ASTM C1363-19	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus	A3.3.3.2, A9.3.1, A9.3.2, A10.1
ASTM C1371-15	Standard Test Method for Determination of Emittance of Materials Near Room Temperature using Portable Emissometers.	5.5.3.2.2
ASTM C1549-16	Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer	5.5.3.2.2

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Reference		Section
ASTM D1003-21	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics	5.5.4.2.3, 5.5.4.4.2
ASTM E283/E283M-19	Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen	Table 5.8.3.1, 5.8.3.2
ASTM E408-13 (2019)	Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques	5.5.3.2.2
ASTM E3158-18	Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building	5.4.3.1.4, 12.5.3, G3.2.1.7
ASTM E779-19	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization	5.4.3.1.4, 12.5.3
ASTM E972-96 (2021)	Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight	5.8.2.6
ASTM E1677-19	Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls	Table 5.8.3.1
ASTM E1680-16	Standard Test Method for Rate of Air Leakage through Exterior Metal Roof Panel Systems	Table 5.8.3.1
ASTM E1827-11 (2017)	Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door	5.4.3.1.4, 12.5.3, G3.2.1.7
ASTM E1980-11 (2019)	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low Sloped Opaque Surfaces	5.4.3.1.4
ASTM E2178-21a	Standard Test Method for Air Permeance of Building Materials	Table 5.8.3.1
ASTM E2357-18	Standard Test Method for Determining Air Leakage of Air Barrier Assemblies	Table 5.8.3.1
ASTM F1361-17	Standard Test Method for Performance of Open Deep Fat Fryers	Table 11.5.2.7.2-1
ASTM F1484-18	Standard Test Method for Performance of Steam Cookers	Table 11.5.2.7.2-2
ASTM F1495-14a	Standard Specification for Combination Oven Electric or Gas Fired	Table 11.5.2.7.2-4
ASTM F1496-13	Standard Test Method for Performance of Convection Ovens	Table 11.5.2.7.2-4
ASTM F1696-18	Standard Test Method for Energy Performance of Stationary-Rack, Door-Type Commercial Dishwashing Machines	Table 11.5.2.7.2-3
ASTM F1920-15	Standard Test Method for Performance of Rack Conveyor Commercial Dishwashing Machines	Table 11.5.2.7.2-3
ASTM F2093-18	Standard Test Method for Performance of Rack Ovens	Table 11.5.2.7.2-4
ASTM F2144-17	Standard Test Method for Performance of Large Open Vat Fryers	Table 11.5.2.7.2-1
ASTM F2861-17	Standard Test Method for Enhanced Performance of Combination Oven in Various Modes	Table 11.5.2.7.2-4
Cool Roof Rating Council (CRRC) **2435 N. Lombard St., Portland, OR 97217, United States**		
ANSI/CRRC S100 (2021)	Standard Test Methods for Determining Radiative Properties of Materials	5.5.3.1.4
Cooling Technology Institute (CTI) **3845 Cypress Creek Parkway, Suite 420, Houston, TX 77068; P.O. Box 681807, Houston, TX 77268**		
CTI ATC-105 (19)	Acceptance Test Code for Water Cooling Towers	Table 6.8.1-7
CTI ATC-105DS (18)	Acceptance Test Code for Dry Fluid Coolers	Table 6.8.1-7

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Reference		Section
CTI ATC-105S (11)	Acceptance Test Code for Closed-Circuit Cooling Towers	Table 6.8.1-7
CTI ATC-106 (11)	Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers	Table 6.8.1-7
CTI STD-201 RS (21)	Performance Rating of Evaporative Heat Rejection Equipment	Table 6.8.1-7
Door and Access Systems Manufacturers Association (DASMA) **1300 Sumner Avenue, Cleveland, OH 44115-2851**		
ANSI/DASMA 105-2020	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors	5.8.3.2, Table 5.8.3.2
International Association of Plumbing and Mechanical Officials (IAPMO) **4755 E. Philadelphia Street, Ontario, CA 91761-2816**		
IAPMO/ANSI WE·Stand-2017	Water Efficiency and Sanitation Standard for the Built Environment	11.5.2.3.5
International Organization for Standardization (ISO) ISO Central Secretariat BIBC II **Chemin de Blandonnet 8, CP 401, 1214, Vernier, Geneva, Switzerland**		
ISO 9050 (2003)	Glass in Building—Determination of Light Transmittance, Solar Direct Transmittance, Total Solar Energy Transmittance, Ultraviolet Transmittance and Related Glazing Factors	5.5.3.2.2
ISO 10211 (2017)	Thermal bridges in building construction—Heat flows and surface temperatures—Detailed calculations	A10.1
ANSI/AHRI/ASHRAE/ISO 13256-1:1998 (2021)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps	Table 6.8.1-15
ANSI/AHRI/ASHRAE/ISO 13256-2:1998 (2021)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 2: Water-to-Water and Brine-to-Water Heat Pumps	Table 6.8.1-15
ISO 14683 (2017)	Thermal bridges in building construction—Linear thermal transmittance—Simplified methods and default values	A10.1
ISO 25745-2:2015	Energy Performance of Lifts, Escalators and Moving Walks—Part 2: Energy Calculation and Classification for Lifts (Elevators)	10.4.3.4, 10.9.3, 11.5.2.7.1
National Electrical Manufacturers Association (NEMA) **1300 N. 17th Street, Suite 900, Arlington, VA 22209**		
ANSI/NEMA MG 1-2016, with 2021 Revisions	Motors and Generators	3.2
National Fenestration Rating Council (NFRC) **6305 Ivy Lane, Suite 140, Greenbelt, MD 20770-6323**		
ANSI/NFRC 100-2020	Procedure for Determining Fenestration Product U-Factors	5.8.2.4
ANSI/NFRC 200-2020	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence	5.5.4.6, 5.8.2.5 5.8.2.6
ANSI/NFRC 203-2020	Procedure for Determining Visible Transmittance of Tubular Daylighting Devices	5.8.2.6
NFRC 300-2020	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems	5.8.2.6
NFRC 301-2020	Standard Test Method for Emittance of Glazing Products	5.5.4.6
ANSI/NFRC 400-2020	Procedure for Determining Fenestration Product Air Leakage	Table 5.8.3.2, 5.8.3.2
National Fire Protection Association (NFPA) **1 Battery March Park, Quincy, MA 02269-9101; P.O. Box 9101**		
NFPA 70-2020	National Electric Code	6.5.1, 8.4.3.1, 8.4.3.2
NFPA 96-2021	Ventilation Control and Fire Protection of Commercial Cooking Operations	G3.2.2.9

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Reference		Section
Telecommunications Industry Association (TIA) **1320 North Courthouse Road, Suite 200**		
ANSI/TIA-942-REV B, July 12, 2017	Telecommunication Infrastructure Standard for Data Centers	6.5.1
UL, LLC **333 Pfingsten Rd., Northbrook, IL 60062**		
UL 181A-2021	Closure Systems for Use with Rigid Air Ducts and Air Connectors	6.4.4.2.1
UL 181B-2021	Closure Systems for Use with Flexible Air Ducts and Air Connectors	6.4.4.2.1
UL 727-2018	UL Standard for Safety—Oil Fired Central Furnaces	Table 6.8.1-5
UL 731-2021	UL Standard for Safety—Oil-Fired Unit Heaters	Table 6.8.1-5
U.S. Department of Defense **3010 Defense Pentagon, Washington, DC 20301**		
MIL-P-17639F (1996)	Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use	10.4.8
MIL-P-17840C (1986)	Pumps, Centrifugal, Close-Coupled, Navy Standard (for Surface Ship Application)	10.4.8
MIL-P-17881D (1972)	Pumps, Centrifugal, Boiler Feed (Multi-Stage)	10.4.8
MIL-P-18472 (1989)	Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, and Distilling Plant	10.4.8
MIL-P-18682D	Pump, Centrifugal, Main Condenser Circulating, Naval Shipboard	10.4.8
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	Table 6.8.1-5, Table 6.8.1-6, Table F-4
10 CFR Part 430, App U	Uniform Test Method for Measuring the Energy Consumption of Ceiling Fans	6.5.3.7, Table 6.8.1-21, Table F-6
10 CFR Part 430 Subpart B App U	Uniform Test Method for Measuring the Energy Consumption of Ceiling Fans	F3
10 CFR Part 431.304	Uniform Test Method for the Measurement of Energy Consumption of Walk-In Coolers and Walk-In Freezers	
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	
10 CFR Part 431, Subpart Y	Pumps: Definitions, Energy Conservation Standards, and Uniform Test Method of the Measurement of Energy Consumption of Pumps	
42 USC 6831, et seq., Public Law 102-486	Energy Policy Act of 1992, EPACT 2005, and EISA 2007	6.4.1.1
U.S. Security and Exchange Commission (SEC) **100 F Street, NE, Washington, DC 20549**		
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	6.5.1

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(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX A
RATED R-VALUE OF INSULATION AND ASSEMBLY U-FACTOR, C-FACTOR, AND F-FACTOR DETERMINATIONS

A1. GENERAL

Where using Normative Appendix A to demonstrate compliance with Section 5.5, the thermal performance of *building envelopes* shall be determined in accordance with Section A1.1 or A1.2.

A1.1 Precalculated Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. Precalculated *U-factors*, *C-factors*, *F-factors*, and *heat capacities* for typical *building envelope* assemblies shall be used for assemblies consistent with the specifications in Sections A2 through A8. These precalculated values shall be permitted to be used to demonstrate compliance for a *building envelope* assembly with any type of exterior covering or interior finish.

Interpolation between values in a particular table in Normative Appendix A shall be permitted 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. Testing, calculation, and modeling procedures in Section A9 shall be used to determine *U-factors, C-factors, F-factors* or *heat capacities* for assemblies that are not addressed by or are different from the assembly specifications listed in Sections A2 through A8 and the associated precalculated values.

A1.3 Applicant-Determined Psi-Factors and Chi-Factors for Thermal Bridges. The applicant shall determine values for *point thermal bridges* and *linear thermal bridges* using the assumptions in Section A10.

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 to A2.2.2: 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.

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 ft on 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

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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 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 semiexterior 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 *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.

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*.

A2.5.3 *U-factors* for attic *roofs* constructed of cold-formed-steel conventional C-shape framing or cold-formed steel trusses, where the insulation is located at the ceiling joist or the bottom chord, and where the framing spacing does not exceed 24 in. on-center, shall be determined in accordance with AISI S250.

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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

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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
	R-19 + R-11	0.037									
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.

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Table A2.4.2 Single-Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d* (Actual)		
	d ≤ 8 in.	8 < d ≤ 10 in.	10 < d ≤ 12 in.
0 to 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

Cavity Insulation R-Value	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing)			
	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

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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

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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* with metal *wall* panels and a metal structure. Insulation is installed in accordance with this section. Insulation exposed to a *conditioned space* or *semiheated space* shall have a facing with seams overlapped or sealed.

A3.2.2 Rated R-Value of Insulation for Metal Building Walls

A3.2.2.1 Single-Layer Compressed. 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 of the girts, uncompressed and uninterrupted by the framing members.

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A3.2.2.3 Single-Layer in Cavity. The insulation is installed in the cavity between the girts, not compressed by the framing. A membrane or facing, installed separately or adhered to the insulation, is installed inside of the girts to form a continuous layer. A thermal spacer block or thermal break strip between the girts and metal *wall* panels is required when specified in Table A3.2.3.

A3.2.2.4 Double-Layer. The first *rated R-value of insulation* is for insulation installed in the cavity between the girts, not compressed by the framing. The second *rated R-value of insulation* is for insulation compressed between metal *wall* panels and the steel structure. A membrane or facing, installed separately or adhered to the insulation, is installed inside of the girts to form a continuous layer. A thermal spacer block or thermal break strip between the girts and metal *wall* panels is required when specified in Table A3.2.3.

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 cold-formed steel stud framing. The steel stud framing thickness is up to 54 mils (0.0538 in. minimum base steel thickness). 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.

A3.3.2 Rated R-Value of Insulation for Steel-Framed Walls

A3.3.2.1 Steel stud framing spaced 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 serve as the basis for the *R-value* compliance values in Tables 5.5-0 through 5.5-8.

A3.3.2.2 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.

A3.3.2.3 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.

A3.3.2.4 *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 determined from one of the following methods:

a. Table A3.3.3.1
b. Testing or calculation methods listed in Section A9.2(b)(3)

A3.3.3.2 Where *steel-framed wall* framing is spaced greater than 24 in. on center, the *U-factor* shall be permitted to be determined based on the 24 in. on-center spacing options from Section A3.3.3.1 or based on ASTM C1363 testing at the actual frame spacing used.

A3.3.3.3 Where *steel framed wall* assemblies contain no cavity insulation, and where the *building envelope* assembly uses *continuous insulation* to satisfy the minimum *R-value* for the relevant climate zone in Tables 5.5-0 through 5.5-8, the on-center framing spacing is permitted to be at any dimension.

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 A9.4.3 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.

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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.

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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 Where 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
	R-3.8	U-0.325	U-0.290	U-0.263
	R-5	U-0.314	U-0.281	U-0.255
	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
	R-10	U-0.219	U-0.202	U-0.188
	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
	R-15	U-0.168	U-0.158	U-0.149
	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
	R-13.0	U-0.161	U-0.152	U-0.144
	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
	R-22.5	U-0.124	U-0.119	U-0.114
	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
	R-25.0	U-0.115	U-0.110	U-0.106
	R-28.0	U-0.112	U-0.107	U-0.103
	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
	R-20.9	U-0.114	U-0.109	U-0.105
	R-21.0	U-0.113	U-0.109	U-0.105
	R-27.5	U-0.106	U-0.102	U-0.099
	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
	R-30.0	U-0.099	U-0.095	U-0.092
	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

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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 Where 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**
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
	R-5.0	U-0.184	U-0.172	U-0.162
	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
	R-7.5	U-0.138	U-0.131	U-0.125
	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
	R-10.0	U-0.110	U-0.106	U-0.102
	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
	R-12.5	U-0.092	U-0.089	U-0.086
	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
	R-15.0	U-0.078	U-0.076	U-0.074
	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
	R-17.5	U-0.069	U-0.067	U-0.065
	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
	R-20.0	U-0.061	U-0.060	U-0.058
	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

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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 Where Specified)
	R-0	**U-0.740**	**U-0.580**	**U-0.480**
No Framing	**Ungrouted Cores Filled with Loose-Fill Insulation**	**NA**	**NA**	**U-0.350**
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
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

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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/ft³ Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft³ Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft³ Concrete Block Walls: Partially Grouted (Cores Uninsulated Except Where 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-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
	R-3.8+R-19.0 *c.i.*	U-0.045	U-0.044	U-0.044
	R-5+R-19.0 *c.i.*	U-0.045	U-0.044	U-0.043
	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
	R-10+R-19.0 *c.i.*	U-0.042	U-0.041	U-0.041
	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
	R-15+R-19.0 *c.i.*	U-0.040	U-0.039	U-0.039
	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
	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
	R-25+R-19.0 *c.i.*	U-0.036	U-0.035	U-0.035
	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
	R-21.0+R-19.0 *c.i.*	U-0.035	U-0.035	U-0.035

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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

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.

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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
115	*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
	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
125	*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
	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
135	*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
	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
144	*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
	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.

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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
6 in. block	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
6 in. block	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
6 in. block	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
6 in. block	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
6 in. block	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
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
8 in. block	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

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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	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
8 in. block	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
8 in. block	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
8 in. block	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
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
10 in. block	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
10 in. block	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

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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	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
10 in. block	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
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
12 in. block	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
12 in. block	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
12 in. block	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
12 in. block	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
12 in. block	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

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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

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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
Continuous insulation only	R-0	1.180	0.136	0.094	0.072	0.060	0.050	0.044	0.039	0.030	0.026
Single compressed layer	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
Single layer in cavity	R-25[a]	0.059	0.044	0.039	0.035	0.032	0.029	0.027	0.025	0.021	0.019
	R-30[b]	0.052	0.042	0.037	0.033	0.031	0.028	0.026	0.024	0.021	0.019
Double layer	R-25 + R-10	0.047	0.038	0.034	0.031	0.028	0.026	0.024	0.023	0.020	0.018
	R-25 + R-16	0.042	0.036	0.032	0.029	0.027	0.025	0.023	0.022	0.019	0.018
	R-25 + R-10[c]	0.039	0.032	0.029	0.027	0.025	0.023	0.022	0.021	0.018	0.017
	R-30 + R-16	0.039	0.036	0.032	0.029	0.027	0.025	0.023	0.022	0.019	0.017

(Multiple *R-values* are listed in order from inside to outside.)

a. A minimum R-0.375 thermal spacer block or thermal break strip is required when installed without *continuous insulation*.

b. A minimum R-0.75 thermal spacer block or thermal break strip is required when installed without *continuous insulation*.

c. A minimum R-3 thermal spacer block is required.

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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 A9.2-2])	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

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Table A3.4.3.1 Assembly U-Factors for Wood-Frame Walls

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed [see Table A9.4.3])	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

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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 Table A3.1-3, A3.1-2, 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 A3.1-3 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.

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 semiexterior 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

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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 semiexterior 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 air space 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 semiexterior 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. The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between wood joists.

A5.4.2.1 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.

A6. SLAB-ON-GRADE FLOORS

A6.1 General. For the purpose of Section A1.2, the base assembly is a *slab-on-grade 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 five 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.
d. Under-Slab Insulation only: Insulation installed under the entire slab. The slab edge remains uninsulated.
e. Uninsulated: Slabs without insulation under the slab and at the slab edge.

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 to A6.2.1: 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 cli-

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mates, 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 A6.3.1-1 or Table A6.3.1-2.

A6.3.2 These *F-factors* are acceptable for all *slab-on-grade floors*.

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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

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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

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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

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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-Joist																						
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

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Table A6.3.1-1 Assembly F-Factors for Slab-on-Grade Floors

Insulation Description	Rated R-Value of Insulation												
	R-3.5	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													
Uninsulated: 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													
Uninsulated: 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
Underslab insulation only	1.06	1.01	0.95	0.90	0.82	0.76							

Table A6.3.1-2 Assembly F-Factors for Fully Insulated Heated Slab-on-Grade Floors

Insulation Description	Rated R-Value of Edge Insulation							
	R-3.5	R-5	R-7.5	R-10	R-15	R-20	R-25	R-30
Heated Slabs								
R-3.5 under slab	0.81	0.78	0.74	0.71	0.69	0.671	0.670	0.669
R-5 under slab	0.77	0.74	0.69	0.66	0.62	0.602	0.602	0.601
R-7.5 under slab	0.71	0.67	0.64	0.60	0.58	0.566	0.564	0.563
R-10 under slab	0.66	0.62	0.58	0.55	0.51	0.496	0.494	0.493
R-15 under slab	0.57	0.54	0.50	0.47	0.45	0.433	0.432	0.431
R-20 under slab	0.51	0.48	0.44	0.41	0.39	0.371	0.370	0.369

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A7. OPAQUE DOORS

All *opaque doors* with *U-factors* determined, certified, and *labeled* in accordance with NFRC 100 or ANSI/DASMA 105 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 *nonswinging doors*, including single-layer uninsulated *access hatches* and uninsulated smoke vents: U-1.45.
b. Insulated double-layer *metal coiling doors*: U-1.00.
c. Uninsulated double-layer metal *swinging doors* or *nonswinging doors*, including double-layer uninsulated *access hatches* and uninsulated smoke vents: U-0.70.
d. Insulated metal *swinging doors*, including fire-rated *doors*, insulated *access hatches*, insulated smoke vents, and other insulated metal *nonswinging doors*: U-0.50.
e. 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*: U-0.50.
f. Any other wood *door*: U-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.

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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. air space	1.31	1.11	1.05	0.84	0.82	0.70	0.66
5	1/2 in. air space	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. air space	1.27	1.08	1.01	0.81	0.78	0.67	0.63
9	1/2 in. air space	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. air space	1.25	1.05	0.99	0.78	0.76	0.64	0.60
13	1/2 in. air space	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. air space	1.20	1.00	0.94	0.74	0.71	0.60	0.56
17	1/2 in. air space	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. air space	1.18	0.99	0.92	0.72	0.70	0.58	0.54
21	1/2 in. air space	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. air space	1.17	0.97	0.91	0.70	0.68	0.57	0.52
25	1/2 in. air space	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

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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. air spaces	1.12	0.89	0.84	0.64	0.64	0.53	0.48
29	1/2 in. air spaces	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. air space	1.08	0.85	0.79	0.59	0.60	0.49	0.43
33	1/2 in. air space	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. air space	1.03	0.80	0.75	0.55	0.56	0.45	0.39
37	1/2 in. air space	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. air space	1.01	0.78	0.73	0.53	0.54	0.43	0.37
41	1/2 in. air space	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. air space	0.97	0.74	0.69	0.49	0.50	0.39	0.33
45	1/2 in. air space	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

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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

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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

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A9. DETERMINATION OF ALTERNATE ASSEMBLY U-FACTORS, C-FACTORS, F-FACTORS, OR HEAT CAPACITIES

A9.1 General. Alternative assembly *U-factors, C-factors, F-factors* or *heat capacities* for *opaque* assemblies shall be determined in accordance with Section A9. 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 A9.4.6.
   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 compressed, single-layer in cavity, double-layer systems, and *continuous insulation*, calculation method in Section A9.4.6.
   3. *Steel-framed walls*: Determined by testing, series path calculation method using the insulation/framing layer adjustment factors in Table A9.2-2, or in accordance with AISI S250 as modified herein:
      i. Where the *steel-framed wall* contains no cavity insulation and uses *continuous insulation* to satisfy the *U-factor* maximum, the *steel-framed wall* member spacing is permitted to be installed at any on-center spacing.
      ii. Where the *steel-framed wall* contains framing at 24 in. on center with a 23% framing factor or framing at 16 in. on-center with a 25% framing factor, the next lower framing member spacing input values shall be used when calculating using AISI S250.
      iii. Where the *steel-framed wall* contains less than 23% framing factors, AISI S250 shall be used without any modifications.
      iv. Where the *steel-framed wall* contains other than standard C-shape framing members, the AISI S250 calculation option for other than standard C-shape framing is permitted to be used.
   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
   1. 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:

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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, air spaces, insulation, and *building materials* shall be taken from Sections A9.4.1 through A9.4.4, respectively. In addition, applicable 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 semiexterior 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 Semiexterior 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*.

A9.4.2 Air Spaces. The *R-value* for air spaces shall be taken from Table A9.4.2-1 based on the effective *emittance* of the surfaces facing the air space from Table A9.4.2-2, provided the following criteria are satisfied:

a. The air space shall be an enclosed and unventilated cavity designed to minimize airflow into and out of the enclosed air space. Airflow shall be deemed minimized when the enclosed air space is located on the interior of the *continuous air barrier* and bounded on all sides by *building* components.
b. Reflective insulation as defined in ASTM C1224, where used, shall be fitted closely around all non-heat-producing components and taped or otherwise sealed to eliminate gaps or voids through which air, dust, or water vapor has the potential to pass.
c. Nonparallel spaces shall use the average distance to determine the thickness of the air space.
d. Air spaces less than 0.5 in. thickness shall have no *R-value*.
e. The *R-value* for 3.5 in. air spaces shall be used for air spaces of that thickness or greater, provided that air space does not exceed 12 in. between the surfaces at any point.

For material emissivity properties not listed in Table A9.4.2-2, Equation A9.4-1 shall be permitted to calculate the effective emissivity for the air space.

$$1/e_{eff} = 1/e_1 + 1/e_2 - 1 \qquad \text{(A9.4-1)}$$

where

e_{eff} = effective *emittance* for the air space
e_1 = surface 1 *emittance*
e_2 = surface 2 *emittance*

A9.4.3 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 A9.4.3.
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.

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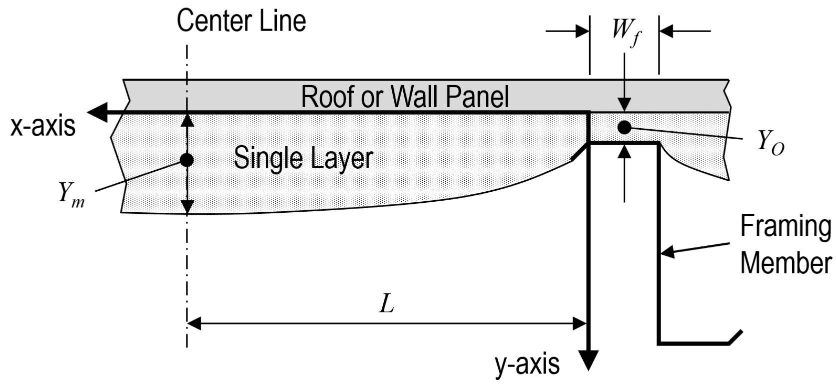

Figure A9.4.6.1 Geometry of single-layer fiberglass batt.

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

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.

A9.4.4 Building Material Thermal Properties. *R-values* for *building materials* shall be taken from Table A9.4.4-1. Concrete block *R-values* shall be calculated using the isothermal planes method or a two-dimensional calculation program, thermal conductivities from Table A9.4.2-2, and dimensions from ASTM C90. The parallel path calculation method is not acceptable.

Exception to A9.4.4: *R-values* for *building materials* or thermal conductivities determined from testing in accordance with Section A9.3.

A9.4.5 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.

A9.4.6 Metal Building U-Factor Equations. The calculation procedures in this section shall use a fixed purlin and girt spacing of 60 in., and the results shall be permitted to be used in accordance with Sections A2.3.3 and A3.2.3. For single-layer *metal building roof* and single-layer compressed *metal building wall* systems, the calculation procedure outlined in Section A9.4.6.1 shall be used to calculate the assembly *U-factor*. For double-layer *metal building roof* systems, the calculation procedure outlined in Section A9.4.6.2 shall be used to calculate the assembly *U-factor*. For single-layer in cavity and double-layer *metal building wall* systems, the calculation procedure outlined in Section A9.4.6.3 shall be used to calculate the assembly *U-factor*. Each of the above insulation methods and calculation procedures also shall be used where *continuous insulation* is applied to the assembly. The calculation procedures outlined in this section shall not be used for other *metal building roof* and *wall* systems.

A9.4.6.1 Single-Layer Roof and Single-Layer Compressed Wall. The *U-factor* of *metal building roofs* or *metal building walls* that are insulated with a single layer of fiberglass insulation (see Figure A9.4.6.1) 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.

Step 1: The thermal conductivity of the fiberglass batt insulation is represented by a thermal curve of the form in Equation A9.4-2:

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$$k = A + B\rho + \frac{C}{\rho} \tag{A9.4-2}$$

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 A9.4-3:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{L}\right)\left(2 - \frac{X}{L}\right) \tag{A9.4-3}$$

Determine the cavity *U-factor* (U_c) using Equation A9.4-4:

$$U_c = \frac{C}{\rho_o t_o} + \frac{B\rho_o t_o}{2Y_o Y_m} + \left[A + \frac{B\rho_o t_o}{2Y_m}\right]\frac{1}{2(Y_m - Y_o)}\sqrt{\frac{Y_m - Y_o}{Y_m}}\ln\left(\frac{1 + \sqrt{\frac{Y_m - Y_o}{Y_m}}}{1 - \sqrt{\frac{Y_m - Y_o}{Y_m}}}\right) \tag{A9.4-4}$$

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 A9.4.6.1.

Include the *thermal resistance*s of the interior (R_i) and exterior (R_e) air films to calculate the overall cavity *U-factor* (U_{co}) using Equation A9.4-5:

$$U_{co} = \frac{1}{\frac{1}{U_c} + R_i + R_e} \tag{A9.4-5}$$

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 A9.4-6:

$$\rho_c = \frac{\rho_o t_o}{t_c} \tag{A9.4-6}$$

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 A9.4-7:

$$R_c = \frac{t_c}{A + B\rho_c + C/\rho_c} \tag{A9.4-7}$$

Determine the overall framing *U-factor* (U_{fo}) at the structural framing member, including the air film resistances, using Equation A9.4-8:

$$U_{fo} = \frac{1}{R_{TB} + R_c + R_i + R_e} \tag{A9.4-8}$$

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

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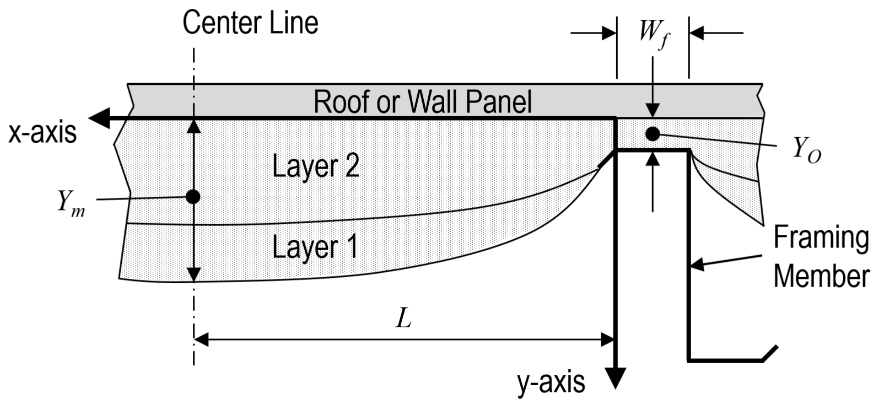

Figure A9.4.6.2-1 Geometry of double layers of fiberglass batts.

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

Step 4: Determine the overall area-weighted *U-factor* for the entire system using Equation A9.4-9:

$$U_{es} = \frac{L \times U_{co} + (w_f/2) \times U_{fo}}{L + (w_f/2)} \qquad \text{(A9.4-9)}$$

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 A9.4-10:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \qquad \text{(A9.4-10)}$$

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 A9.4-11:

$$U = \frac{1}{\frac{1}{U_{adj}} + R_{ci}} \qquad \text{(A9.4-11)}$$

A9.4.6.2 Double-Layer Roof. The *U-factor* of *metal building roofs* that are insulated with double layers of fiberglass insulation (see Figure A9.4.6.2-1) 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 A9.4-12:

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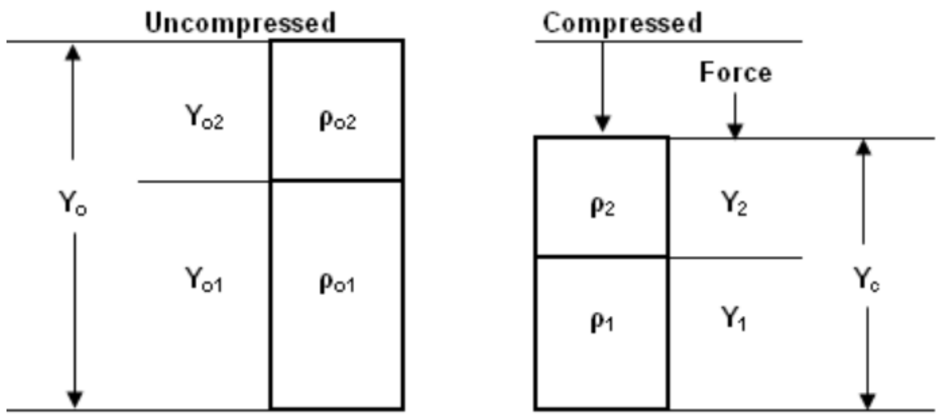

Figure A9.4.6.2-2 Compression of double layers of fiberglass insulation.

$$k = A + B\rho + \frac{C}{\rho} \tag{A9.4-12}$$

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 A9.4-13:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{L}\right)\left(2 - \frac{X}{L}\right) \tag{A9.4-13}$$

The presence of two layers of fiberglass adds complexity because each layer has distinct reference properties (see Table A9.4.6.1). 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 A9.4.6.2-2.

The thickness of the second layer (Y_2) is described by Equation A9.4-14:

$$\left(\frac{Y_2}{Y_c}\right)^2 + \left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c/12)} - 1\right]\left(\frac{Y_2}{Y_c}\right) - \frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)Y_c/12} = 0 \tag{A9.4-14}$$

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 A9.4-14 are Equations A9.4-15a and A9.4-15b:

$$\frac{Y_{2,a}}{Y_c} = \left|\frac{-b + \sqrt{b^2 - 4ac}}{2a}\right| \tag{A9.4-15a}$$

$$\frac{Y_{2,b}}{Y_c} = \left|\frac{-b - \sqrt{b^2 - 4ac}}{2a}\right| \tag{A9.4-15b}$$

where

a = 1

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$$b = \left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c / 12)} - 1\right]$$

$$c = \left[\frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2) Y_c / 12}\right]$$

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 A9.4-14 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 A9.4-16:

$$\rho_c = \frac{\rho_o t_o}{t_c} \qquad \text{(A9.4-16)}$$

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 A9.4-17:

$$R_c = \frac{t_c}{A + B\rho_c + C / \rho_c} \qquad \text{(A9.4-17)}$$

Determine the overall framing *U-factor* (U_{fo}) at the structural framing member, including the air film resistances, using Equation A9.4-18:

$$U_{fo} = \frac{1}{R_{TB} + R_c + R_i + R_e} \qquad \text{(A9.4-18)}$$

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 A9.4-19:

$$U_{es} = \frac{L \times U_{co} + (w_f / 2) \times U_{fo}}{L + (w_f / 2)} \qquad \text{(A9.4-19)}$$

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 A9.4-20:

$$U_{adj} = \frac{1}{0.8676 / U_{es} + 1.1423} \qquad \text{(A9.4-20)}$$

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 A9.4-21:

$$U_o = \frac{1}{\frac{1}{U_{adj}} + R_{ci}} \qquad \text{(A9.4-21)}$$

A9.4.6.3 Single-Layer in Cavity and Double-Layer Walls. The *U-factor* of *metal building walls* that are insulated with a single-layer in cavity or multiple layers of mineral fiber insulation (see Figure A9.4.6.3) shall be calculated using the procedure outlined in this section. For double-layer *walls*, the procedure assumes that the outer layer of insulation is compressed between the *wall* panel and girt. There may also be

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a thermal spacer block or *continuous insulation* present. Air spaces may also exist depending on the specific drape profiles.

There are nine steps in the calculation process:

- Step 1—Characterize the thermal conductivity of the mineral fiber insulation.
- Step 2—Define the parabolic profiles for each insulation layer.
- Step 3—Calculate the *R-values* for insulation and air spaces in cavity both outside and inside insulation layers, including air films.
- Step 4—Calculate the *R-value* inside the girt and adjacent to the web.
- Step 5—Calculate the *R-value* outside the girt.
- Step 6—Add the *R-values* inside and outside the girt, including air films.
- Step 7—Calculate the overall insulation assembly using the *R-values* in Steps 3 and 6.
- Step 8—Calculate the *U-factor* from the finite element analysis results.
- Step 9—Calculate the *U-factor* for any *continuous insulation* if present.

Step 1: The thermal conductivity of the mineral fiber insulation is represented by a thermal curve of the form in Equation A9.4-22:

$$k = A + B\frac{\rho_o\delta_o}{y} + C\frac{y}{\rho_o\delta_o} \qquad \text{(A9.4-22)}$$

where

k = thermal conductivity, Btu·ft/h·ft^2·°F

ρ_o = nominal density, lb/ft^3

δ_o = nominal thickness, ft

y = thickness of insulation, ft

A = 0.014917

B = 0.0004377

C = 0.0056897

Step 2: Assume that each layer of mineral fiber has a parabolic profile defined by Equation A9.4-23:

$$\frac{y - Y_o}{Y_m - Y_o} = \frac{x}{x_m}\left(2 - \frac{x}{x_m}\right) \qquad \text{(A9.4-23)}$$

where

x = distance from edge of girt, ft

y = distance from edge of *wall* panel, ft

Y_o = insulation thickness at $x = 0$, ft

Y_m = insulation thickness at $x = X_m$, ft

Step 3: Calculate *R-values* for the insulation and air spaces in the cavity both inside and outside insulation layers, including air films.

Because the configuration can possibly consist of both mineral fiber insulation and an air space, the composite is given by Equation A9.4-24:

$$R = \frac{1}{x_a}\int_0^{x_a}\left(\frac{y}{k_a} + \frac{Y_m - y}{k}\right)\mathrm{d}x + \frac{Y_m}{k(Y_m)} \qquad \text{(A9.4-24)}$$

where k_a is the thermal conductivity of air in Btu·ft/h·ft^2·°F.

The trapezoidal integration method is used to evaluate the integral and calculate R and is given by Equation A9.4-25:

$$\int_a^b f(x)\mathrm{d}x \approx \frac{1}{2}\sum_{k=1}^{N}(x_{k+1} - x_k)(y_k + y_{k+1}) \qquad \text{(A9.4-25)}$$

where

x_k = point to analyze along the x-axis, ft

x_{k+1} = point ahead of the point being analyzed, ft

y_k = thickness at point being analyzed, ft

y_{k+1} = thickness at point ahead of the point being analyzed, ft

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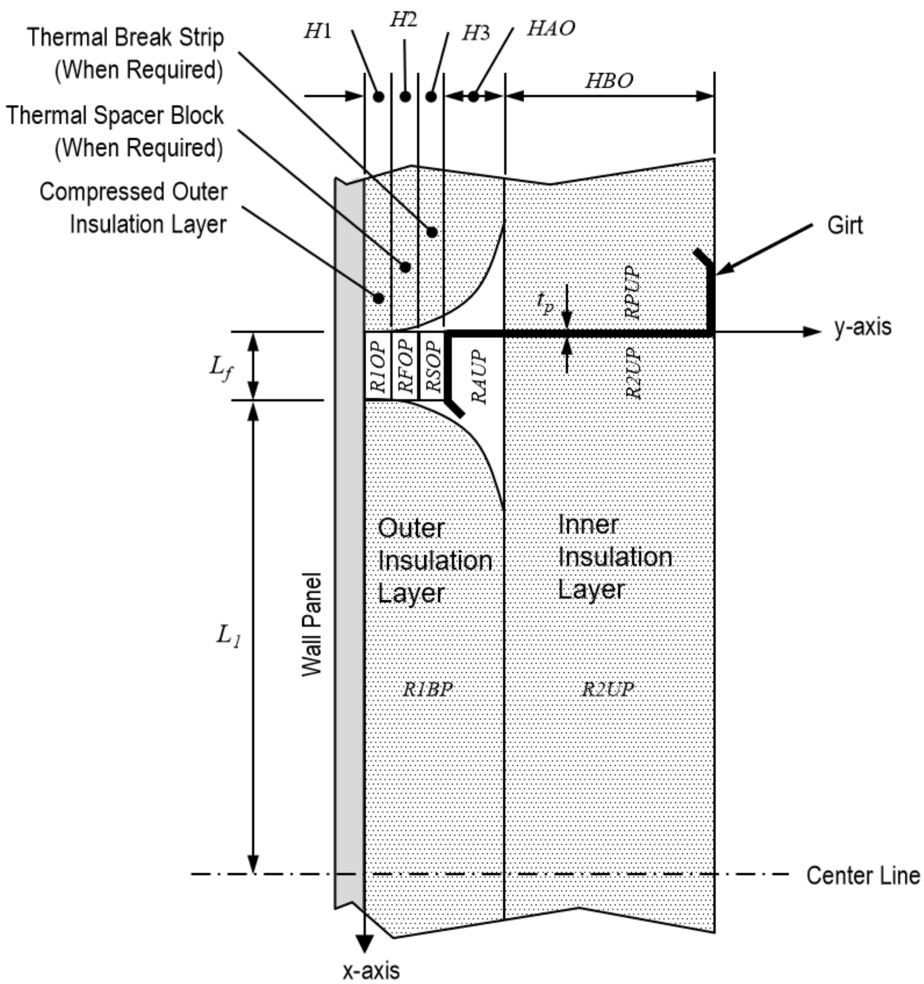

Figure A9.4.6.3 Geometry of single cavity layer or double-layer wall.

The integral represents the combined *R-value* of the air space and insulation over the region $0 < x < X_a$. Because the thermal conductivity of air is independent of the thickness, Equation A9.4-25 can be simplified using the air space mean thickness (Y_a) to produce Equation A9.4-26:

$$R = \frac{Y_a}{K_a} + \frac{1}{X_a}\int_0^{x_a}\left(\frac{Y_m - y}{K}\right)\mathrm{dx} + \frac{Y_m}{K(Y_m)} \qquad \text{(A9.4-26)}$$

However, if the air space is characterized by convection instead of conduction then the term Y_a/k_a can be replaced by the *R-value* for convection (R-0.92 h·ft^2·°F/Btu for *walls*). Adding the inside and outside layers is expressed in Equation A9.4-27:

$$R_{BP} = R1BP + R2BP \qquad \text{(A9.4-27)}$$

Add the air film resistances at the exterior (R_{AT}) and interior (R_{AB}), which are defined as Equation A9.4-28:

$$R_{AB} = \frac{1}{h_{AB}} \qquad \text{(A9.4-28)}$$

where h_{AB} is the air film heat transfer coefficient at the exterior in Btu/h·ft^2·°F.

$$R_{AT} = \frac{1}{h_{AT}} \qquad \text{(A9.4-29)}$$

where h_{AT} is the air film heat transfer coefficient at the interior in Btu/h·ft^2·°F.

The sum of the *R-values* for the insulation and air films beyond the girt are expressed in Equation A9.4-30.

$$R_{BP+air} = R_{BP} + R_{AB} + R_{AT} \qquad \text{(A9.4-30)}$$

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Step 4: Calculate the *R-values* inside the girt and adjacent to the web.

The *R-values* inside the girt are the air space (RAUP) added in series with the insulation (R2UP); their combined value is then added in parallel to RPUP. Depending on the thickness of the air space, it can be modeled as conduction as shown in Equation A9.4-31:

$$\text{RAUP} = \frac{H3}{k_a} \tag{A9.4-31}$$

where

$H3$ = thickness of the air space, ft

k_a = thermal conductivity of air, Btu·ft/h·ft^2·°F

When appropriate, the air space can be modeled as convection, which is a constant R-0.92 h·ft^2·°F/Btu for *walls*.

The *R-value* for R2UP is expressed in Equation A9.4-32. The insulation thickness is also not limited by the girt height and can extend beyond it.

$$\text{R2UP} = \frac{H4}{A + B\dfrac{\rho_o\delta_o}{H4} + C\dfrac{H4}{\rho_o\delta_o}} \tag{A9.4-32}$$

where $H4$ is the thickness of the mineral fiber at $x = 0$ in feet.

The *R-value* of the web (RPUP) is calculated using 26.2 h·ft^2·°F/Btu as the thermal conductivity of the girt in Equation A9.4-33:

$$\text{RPUP} = \frac{\text{Web Height}}{k_p} \tag{A9.4-33}$$

where

k_p = thermal conductivity of the girt, Btu·ft/h·ft^2·°F

Web Height = height of the girt, ft

The addition of the air space and insulation in series are combined to be in parallel with the girt, which is expressed as Equation A9.4-34:

$$\frac{L_f}{\text{RUP}} = \frac{L_f - t_p}{\text{RAUP} + \text{R2UP}} + \frac{t_p}{\text{RPUP}} \tag{A9.4-34}$$

Equation A9.4-34 can be rearranged and solved for RUP as presented in Equation A9.4-35:

$$\text{RUP} = \frac{(\text{RAUP} + \text{R2UP})\text{RPUP}}{(L_f - t_p)\text{RPUP} + t_p(\text{RAUP} + \text{R2UP})}L_f \tag{A9.4-35}$$

Because the thickness of the girt is significantly less than the flange width (L_f), Equation A9.4-35 can be simplified as Equation A9.4-36. However it is important to note that RUP will be close to 2 or lower (depending on how the air is modeled) because of the significant effects of the steel girt:

$$\text{RUP} = \frac{(\text{RAUP} + \text{R2UP})\text{RPUP}}{L_f\text{RPUP} + t_p(\text{RAUP} + \text{R2UP})}L_f \tag{A9.4-36}$$

Step 5: Calculate the *R-value* outside the girt.

Typical *construction* above the girt consists of a thermal spacer block and compressed mineral fiber insulation. These two insulations are in series, and the total *R-value* (R_{OPI}) is expressed as Equation A9.4-37. If there is thermal break tape present it is included as the third insulation in this series.

$$R_{OPI} = \frac{H1}{k_f} + \frac{H2}{k_I} \tag{A9.4-37}$$

where

$H1$ = thickness of thermal spacer block, ft

$H2$ = thickness of compressed mineral fiber insulation, ft

k_f = thermal conductivity of the thermal spacer block, Btu·ft/h·ft^2·°F

k_I = thermal conductivity of the compressed mineral fiber insulation, Btu·ft/h·ft^2·°F

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The impact of the thermal bridging associated with the outside of the girt and the insulation is to reduce the *thermal resistance* of the insulation. The reduction is calculated using Equation A9.4-38:

$$R_{OP} = R_{OPI}\frac{1}{\left[1+\frac{2(H1+H2)}{\pi L_f}\right]} \qquad \text{(A9.4-38)}$$

Step 6: Add the *R-values* inside and outside the girt including air films.

The total *thermal resistance* associated with the girt is the sum of the *R-values* inside and outside the girt as shown in Equation A9.4-39:

$$R_{TP} = R_{UP} + R_{OP} \qquad \text{(A9.4-39)}$$

The next calculation is to add the inside and *outdoor air* film coefficients using Equation A9.4-40:

$$R_{TP+air} = R_{TP} + R_{AB} + R_{AT} \qquad \text{(A9.4-40)}$$

Step 7: Calculate the overall insulation assembly using the *R-values* in Steps 3 and 6.

The overall insulation system *R-value* is determined using Equation A9.4-41:

$$R_{insul-sys} = \frac{(2L_1+L_f)R_{BP+air}R_{TP+air}}{2L_1R_{TP+air}+L_fR_{BP+air}} \qquad \text{(A9.4-41)}$$

Step 8: Calculate the *U-factor* from the finite element analysis results.

The overall *U-factor* for the insulation assembly is determined using Equation A9.4-42:

$$U_{adj} = \frac{1}{0.8627R_{insul-sys}+1.132} \qquad \text{(A9.4-42)}$$

where

U_{adj} = adjusted overall *U-factor* represented by the correlation with the finite element modeling in Btu/h·ft^2·°F.

Step 9: Calculate the overall *U-factor* for any *continuous insulation* if present.

If there is any *continuous insulation* present, first calculate the *R-value* adjacent to the flange using Equation A9.4-43:

$$R_{BFci} = R_{ci}\frac{1}{\left[1+\frac{2(h_{ci})}{\pi L_f}\right]} \qquad \text{(A9.4-43)}$$

where

R_{BFci} = *thermal resistance* of *continuous insulation* adjacent to the flange, h·ft^2·°F/Btu

R_{ci} = *thermal resistance* of the *continuous insulation*, h·ft^2·°F/Btu

h_{ci} = thickness of the *continuous insulation*, ft

Next, calculate the area-weighted *R-value* for the *continuous insulation* using Equation A9.4-44:

$$R_{oci} = \frac{(2L_1+L_f)R_{BPci}R_{ci}}{2L_1R_{BPci}+L_fR_{ci}} \qquad \text{(A9.4-44)}$$

where

R_{oci} = overall *thermal resistance* of *continuous insulation* in h·ft^2·°F/Btu

Finally, calculate the overall *U-factor* using Equation A9.4-45:

$$U_o = \frac{1}{\frac{1}{U_{adj}}+R_{oci}} \qquad \text{(A9.4-45)}$$

A9.4.7 Insulated Metal Panels. *U-factors* of *insulated metal panels* shall be determined by two- or three-dimensional finite difference or finite volume computer models or by testing in accordance with Section A9.3.2 and shall include panel side joints.

A10. THERMAL BRIDGING CHI FACTORS AND PSI FACTORS

A10.1 Determination of Psi-Factors and Chi-Factors. *Psi-factor* (ψ) and *chi-factor* (χ) values representative of an as-designed *thermal bridging* condition shall be determined in accordance with one of the following:

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a. From simulation models compliant with ISO 10211 using details representative of the actual construction and modeling assumptions consistent with generally accepted architectural and engineering practice.
b. From ISO 14683.
c. From testing of the assembly in accordance with ASTM C1363 with and without the presence of the *thermal bridge* condition to determine a linear transmittance value or point transmittance value for the *thermal bridge* condition.
d. From application of heat transfer theory in accordance with generally accepted engineering practice and where approved by the a*uthority having jurisdiction*.
e. As indicated in Table A10.1. The default column shall be used where the *thermal bridge* meets prescriptive requirements. The unmitigated column shall be used where the *thermal bridge* does not meet the prescriptive requirements.

(***Informative Note:*** In Table A10.1, the values for *thermal bridge* details prescribed in Section 5.5.5 are based on data from ASHRAE Research Project 1365 and the BC Hydro Thermal Bridging Guide listed in Informative Appendix E.)

A10.2 Assembly U-Factor Adjustment for Simulation of Thermal Bridges. For the purpose of incorporating the effects of *thermal bridges* in simulations as required by Section 12 and Normative Appendix G, where a *thermal bridge* is not modeled as a separate element, the clear-field *U-factors* of modeled assemblies shall be modified in accordance with Equation A10.2. This modification shall be achieved in the simulation model by altering the conductance value assigned to any one or more insulation layers within the modeled assembly without altering the properties of modeled *building material* layers.

$$U_{tot} = \{[(\sum\psi_i \times L_i) + (\sum\chi_j \times n_j)]/A_{total}) + U_o\} \quad \text{(A10.2)}$$

where

U_{tot}	=	overall *thermal transmittance*, including the effect of *linear thermal bridges* and *point thermal bridges* not included in the *construction* assembly U_o-factor, Btu/(h·ft^2·°F)
U_o	=	clear-field *thermal transmittance* of the *construction* assembly as determined in accordance with Section 5, Btu/(h·ft^2·°F)
A_{total}	=	total *opaque* projected surface area of the *construction* assembly, ft^2
ψ_i	=	*psi-factor*, *thermal transmittance* for each type of *linear thermal bridge*, Btu/(h·ft^2·°F)
L_i	=	length of a particular *linear thermal bridge* as measured on the outside surface of the *building envelope*, ft^2
χ_i	=	*chi-factor*, *thermal transmittance* for each detail type of *point thermal bridge*, Btu/(h·°F)
n_i	=	number of occurrences a particular type of *point thermal bridge*

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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 Air Space 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

Table A9.4.2-1 R-Values for Cavity Air Spaces [a]

Component	Air Space Thickness, in.	Climate Zone 1 Effective Emittance				Climate Zone 2 Effective Emittance				Climate Zone 3 Effective Emittance			
		0.05	0.20	0.50	0.82	0.05	0.20	0.50	0.82	0.05	0.20	0.50	0.82
Roof	0.50	2.5	1.9	1.2	0.9	2.4	1.8	1.2	0.9	2.2	1.7	1.1	0.9
	0.75	3.5	2.4	1.4	1.0	3.2	2.2	1.4	1.0	2.8	2.0	1.3	0.9
	1.50	5.6	3.1	1.7	1.1	4.9	2.9	1.6	1.1	4.2	2.5	1.5	1.0
	3.50	8.0	3.8	1.9	1.2	7.0	3.4	1.7	1.1	5.9	3.0	1.6	1.1
Wall	0.50	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9
	0.75	2.8	2.0	1.3	0.9	2.8	2.0	1.3	0.9	2.8	2.0	1.3	0.9
	1.50	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9
	3.50	2.6	1.9	1.3	0.9	2.6	1.9	1.3	0.9	2.6	1.9	1.3	0.9

a. Interpolation shall be permitted to be used for effective *emittance* values and air space thicknesses between those listed. Extrapolation below an effective *emittance* of 0.05 is not permitted.

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Table A9.4.2-1 R-Values for Cavity Air Spaces [a] *(Continued)*

Component	Air Space Thickness, in.	Climate Zone 1 Effective Emittance				Climate Zone 2 Effective Emittance				Climate Zone 3 Effective Emittance			
		0.05	**0.20**	**0.50**	**0.82**	**0.05**	**0.20**	**0.50**	**0.82**	**0.05**	**0.20**	**0.50**	**0.82**
Floor	0.50	1.6	1.3	1.0	0.8	1.8	1.4	1.0	0.8	1.9	1.5	1.1	0.8
	0.75	1.7	1.4	1.0	0.8	2.0	1.5	1.1	0.8	2.4	1.7	1.2	0.9
	1.50	1.9	1.5	1.1	0.8	2.5	1.8	1.2	0.9	3.2	2.1	1.3	0.9
	3.50	2.1	1.6	1.1	0.8	3.2	2.0	1.2	0.9	4.3	2.4	1.4	1.0
Component	Air Space Thickness, in.	**Climate Zone 4 Effective Emittance**				**Climate Zone 5 Effective Emittance**				**Climate Zone 6 Effective Emittance**			
		0.05	0.20	0.50	0.82	0.05	0.20	0.50	0.82	0.05	0.20	0.50	0.82
Roof	0.50	2.0	1.6	1.1	0.8	1.9	1.5	1.1	0.8	1.8	1.4	1.0	0.8
	0.75	2.5	1.8	1.2	0.9	2.3	1.7	1.1	0.9	2.1	1.6	1.1	0.8
	1.50	3.5	2.2	1.3	0.9	3.1	2.0	1.3	0.9	2.8	1.9	1.2	0.9
	3.50	4.7	2.6	1.4	1.0	4.1	2.4	1.4	1.0	3.6	2.2	1.3	0.9
Wall	0.50	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9
	0.75	2.8	2.0	1.3	0.9	2.8	2.0	1.3	0.9	2.8	2.0	1.3	0.9
	1.50	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9
	3.50	2.6	1.9	1.3	0.9	2.6	1.9	1.3	0.9	2.6	1.9	1.3	0.9
Floor	0.50	2.1	1.6	1.1	0.8	2.2	1.7	1.1	0.9	2.3	1.7	1.2	0.9
	0.75	2.7	1.9	1.2	0.9	2.9	2.0	1.3	0.9	3.1	2.1	1.3	1.0
	1.50	3.9	2.4	1.4	1.0	4.3	2.6	1.5	1.0	4.7	2.7	1.5	1.1
	3.50	5.5	2.9	1.5	1.1	6.0	3.1	1.6	1.1	6.6	3.3	1.7	1.1
Component	Air Space Thickness, in.	**Climate Zone 7 Effective Emittance**				**Climate Zone 8 Effective Emittance**							
		0.05	0.20	0.50	0.82	0.05	0.20	0.50	0.82				
Roof	0.50	1.8	1.4	1.0	0.8	1.6	1.3	1.0	0.8				
	0.75	2.0	1.6	1.1	0.8	1.8	1.4	1.0	0.8				
	1.50	2.6	1.8	1.2	0.9	2.1	1.6	1.1	0.8				
	3.50	3.2	2.0	1.3	0.9	2.4	1.7	1.2	0.9				
Wall	0.50	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9				
	0.75	2.8	2.0	1.3	0.9	2.8	2.0	1.3	0.9				
	1.50	2.5	1.8	1.2	0.9	2.5	1.8	1.2	0.9				
	3.50	2.6	1.9	1.3	0.9	2.6	1.9	1.3	0.9				
Floor	0.50	2.3	1.8	1.2	0.9	2.5	1.8	1.2	0.9				
	0.75	3.2	2.2	1.4	1.0	3.4	2.3	1.4	1.0				
	1.50	4.9	2.8	1.6	1.1	5.4	3.1	1.7	1.1				
	3.50	6.9	3.4	1.7	1.1	7.7	3.7	1.8	1.2				

a. Interpolation shall be permitted to be used for effective *emittance* values and air space thicknesses between those listed. Extrapolation below an effective *emittance* of 0.05 is not permitted.

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Table A9.4.2-2 Emittance Values of Various Surfaces and Effective Emittances of Air Spaces

Surface	Average Emissivity *e*	Effective Emissivity of Air Space	
		One Surface *e*; Other, 0.9	Both Surfaces Emissivity *e*
Aluminum foil, bright	0.05	0.05	0.03[a]
Metalized film, tested[b]	0.05	0.05	0.03[a]
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	0.14
Aluminum paint	0.50	0.47	0.32
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

a. When referencing Table A9.4.2-1, use an effective *emittance* of 0.05.
b. Tested *emittance* in accordance with ASTM C1224 at 0.05 or less.

Table A9.4.3 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

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Table A9.4.4-1 R-Values for Building Materials

Material	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
Gypsum board	0.5	0.45
	0.625	0.56
Metal Deck		0
Roofing, built-up	0.375	0.33
Soil at R-0.104/in.	12	1.25
Steel, Mild	1	0.0031807
Stucco	0.75	0.08
Wood panels, 7/16 in.	0.438	0.62
Wood subfloor	0.75	0.94
Wood, 2 × 4 at R-1.25/in.	3.5	4.38
Wood, 2 × 6 at R-1.25/in.	5.5	6.88
Wood, 2 × 8 at R-1.25/in.	7.25	9.06
Wood, 2 × 10 at R-1.25/in.	9.25	11.56
Wood, 2 × 12 at R-1.25/in.	11.25	14.06
Wood, 2 × 14 at R-1.25/in.	13.25	16.56

Table A9.4.4-2 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

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Table A9.4.6.1 Fiberglass Reference Properties

R-Value, $h \cdot ft^2 \cdot °F/Btu$	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

Table A10.1 Thermal Bridging Psi-Factors and Chi-Factors for Thermal Bridges

			Unmitigated		Default	
Class of Construction—Wall, above Grade	**Thermal Bridge Type**	**Section**	**Psi-Factor, Btu/(h·ft·°F)**	**Chi-Factor, Btu/(h·°F)**	**Psi-Factor, Btu/(h·ft·°F)**	**Chi-Factor, Btu/(h·°F)**
Steel framed and *metal buildings*	*Roof* edge	5.5.5.1.1	0.450	N/A	0.140	N/A
	Parapet	5.5.5.1.2	0.289		0.151	
	Intermediate floor to *wall* intersection	5.5.5.2.1	0.487		0.177	
	Intermediate floor balcony or overhang to opaque *wall* intersection	5.5.5.2.2	0.487		0.177	
	Intermediate floor balcony in contact with *vertical fenestration*	5.5.5.2.2	0.974		0.177	
	Cladding support	5.5.5.3	0.314		0.217	
	Wall to *vertical fenestration* intersection	5.5.5.4	0.262		0.112	
	Other element and assembly intersections	5.5.5.5	N/A	1.73	N/A	0.91
Mass (exterior or integral)	*Roof* edge	5.5.5.1.1	0.500	N/A	0.100	N/A
	Parapet	5.5.5.1.2	0.238		0.125	
	Intermediate floor to *wall* intersection	5.5.5.2	0.476		0.179	
	Intermediate floor balcony or overhang to opaque *wall* intersection	5.5.5.2.2	0.476		0.179	
	Intermediate floor balcony in contact with *vertical fenestration*	5.5.5.2	0.974		0.177	
	Cladding support	5.5.5.3	0.270		0.186	
	Wall to *vertical fenestration* intersection	5.5.5.4	0.188		0.131	
	Other element and assembly intersections	5.5.5.5	N/A	0.91	N/A	0.19

N/A = not applicable

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Table A10.1 Thermal Bridging Psi-Factors and Chi-Factors for Thermal Bridges *(Continued)*

			Unmitigated		Default	
Class of Construction—Wall, above Grade	**Thermal Bridge Type**	**Section**	**Psi-Factor, Btu/(h·ft·°F)**	**Chi-Factor, Btu/(h·°F)**	**Psi-Factor, Btu/(h·ft·°F)**	**Chi-Factor, Btu/(h·°F)**
Mass (interior)	*Roof* edge	5.5.5.1.1	0.500	N/A	0.100	N/A
	Parapet	5.5.5.1.2	0.511		0.227	
	Intermediate floor to *wall* intersection	5.5.5.2	0.476		0.286	
	Intermediate floor balcony or overhang to opaque *wall* intersection	5.5.5.2.2	0.476		0.286	
	Intermediate floor balcony in contact with *vertical fenestration*	5.5.5.2	0.974		0.177	
	Cladding support	5.5.5.3	Same as *mass* (exterior)			
	Wall to *vertical fenestration* intersection	5.5.5.4	0.313	N/A	0.083	N/A
	Other element and assembly intersections	5.5.5.5	Same as *mass* (exterior)			
Wood-framed and other	*Roof* edge	5.5.5.1.1	0.450	N/A	0.140	N/A
	Parapet	5.5.5.1.2	0.032		0.032	
	Intermediate floor to *wall* intersection	5.5.5.2.1	0.336		0.049	
	Cladding support	5.5.5.3	0.186		0.043	
	Wall to *vertical fenestration* intersection	5.5.5.4	0.150		0.099	
	Other element and assembly intersections	5.5.5.5	N/A	0.33	N/A	0.07

N/A = not applicable

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INFORMATIVE APPENDIX B
(RETAINED FOR FUTURE USE)

Climatic data are no longer contained in this appendix. See Section 5.1.4 for requirements. Annex 1 of this standard contains

a. an extraction of ASHRAE Standard 169, Table B-1, “U.S. Climate Zones by State and County” (which is normative for Standard 90.1),
b. an extraction of ASHRAE Standard 169, Figure B-1, “Climate Zone for United States Counties” (which is informative for Standard 90.1),
c. an extraction of ASHRAE Standard 169, Table A-5, “Canada Stations and Climate Zones” (which is normative for Standard 90.1),
d. an extraction of ASHRAE Standard 169, Table A-6, “International Stations and Climate Zones” (which is normative for Standard 90.1),
e. an extraction of ASHRAE Standard 169, Section A3, “Climate Zone Definitions” (which is normative for Standard 90.1),
f. an extraction of ASHRAE Standard 169, Table A-3, “Thermal Climate Zone Definitions” (which is normative for Standard 90.1),
g. an extraction of ASHRAE Standard 169, Figure A-1, “Thermal Climate Zones as a Function of Heating and Cooling Degree Days” (which is informative for Standard 90.1), and
h. an extraction of ASHRAE Standard 169, Figure C-2, “World Climate Zones Map” (which is informative for Standard 90.1).

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(This is a normative appendix and is part of this standard.)

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 Semiexterior 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 semiexterior. A semiexterior surface separating a *conditioned space* from a *semiheated space* shall be specified with two associated *space conditioning categories*. A semiexterior 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* slabs, concrete *floor* beams over parking garages, *roof* parapet) shall be separately modeled.

C1.2.7 For Thermal Bridges Identified in Section 5.5.5. *Thermal bridge* inputs and specifications shall be individually identified for the *thermal bridges* indicated in Section 5.5.5 according to one of the following:

a. Where the *thermal bridge* complies with one of the requirements of Sections 5.5.5.1 through 5.5.5.5, no additional inputs shall be required.
b. Where the *thermal bridge* does not comply with one or more of the requirements of Sections 5.5.5.1 through 5.5.5.5, the *linear thermal bridge* type or *point thermal bridge* type, length or count, the assembly interrupted by this *thermal bridge*, and the *psi-factor* or *chi-factor* shall be specified. The input shall be a user-defined value or one of the unmitigated values from Table A10.1.
c. Where Section 5.5.5 and Sections 5.5.5.1 through 5.5.5.5, including exceptions, are not applicable to the *thermal bridge,* no additional inputs shall be required.

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 described in Section C1.2 and shall have the *orientation* of that surface.

C1.4 For Fenestration. The *class of construction*, area, assembly *U-factor*, assembly *SHGC*, *VT*, and *PF* shall be specified for *fenestration*. Each *fenestration* element shall be associated with a surface as defined in Section C1.2 and shall have the *orientation* of that surface.

C1.5 For Continuous Air Barriers. The method of compliance used for *continuous air barriers*, either whole-*building* pressurization testing or verification, shall be specified.

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.

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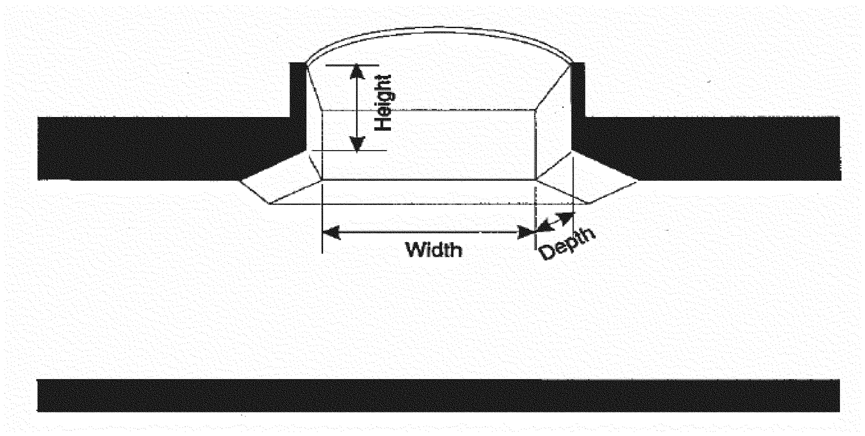

Figure C1.4 Skylight well dimensions.

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 Peak heating and cooling loads for *building classes of constructions*.

C2.8 The version of the software and the link to the website that contains the ASHRAE Standard 140 results for the version used in accordance with Section C3.1.4.

C2.9 For *thermal bridges*,

a. confirmation that the *proposed design* complies with the each of the requirements of Sections 5.5.5.1 through 5.5.5.5 including exceptions or
b. where the *proposed design* does not comply with each of the individual requirements of Sections 5.5.5.1 through 5.5.5.5, list the *thermal bridges*, the proposed *psi-factors*, proposed *chi-factors*, and source information.

C3. SIMULATION GENERAL REQUIREMENTS

C3.1 Simulation Program. The *simulation program* shall be a computer-based software program for the analysis of *energy* consumption in *buildings*. The *simulation program* shall include calculation methodologies for the *building* components being modeled.

Informative Note: Examples of *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 set points*, 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 design* or nine thermal zones, whichever is greater.
f. *Air 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.

Informative Note: Neither the *proposed envelope performance factor* nor the *base envelope performance factor* 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*

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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.

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 design building envelope* and the *base design building envelope*.

C3.1.4 Simulation Program Testing Requirements

C3.1.4.1 The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8, of Standard 140. The required tests shall include *building* thermal envelope and fabric load tests (Sections 5.2.1, 5.2.2, and 5.2.3), ground coupled slab-on-*grade* analytical verification tests (Section 5.2.4), *space*-cooling *equipment* performance tests (Section 5.3), *space*-heating *equipment* performance tests (Section 5.4), and air-side HVAC *equipment* analytical verification tests (Section 5.5), along with the associated reporting (Section 6).

C3.1.4.2 The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the *simulation program* and input files used for generating the results along with the results of the other *simulation programs* included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values and for omitted results.

C3.1.4.3 The testing shall be performed for the version of the *simulation program* used to calculate the *proposed envelope performance factor* and *base envelope performance factor*.

Informative Notes:

1. There are no pass/fail criteria established by this requirement.
2. Based on the Section 3 definition, *simulation program* includes the simulation engine and the corresponding user interface. The testing of a *simulation program* only meets the requirements of Section C3.1.4 for that *simulation program* and cannot be used as proxy for documenting compliance of another *simulation program* that uses the same simulation engine.

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 design building envelope* 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. Semiexterior 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: $0.1063/kWh
b. Heating: $0.98/therm

Exception to C3.3: 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 C3.5.11.

C3.5.1 Space Conditioning. All *conditioned spaces* in the *proposed design* shall be simulated as being both heated and cooled, even if no cooling or heating *system* is being installed. Temperature control *set points* 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 *set point* shall be 50°F for all hours.

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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 and Figure 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.

1 Schedules and internal loads by *building* area type are found at http://sspc901.ashraepcs.org/documents.php.

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C3.5.5 Building Envelope. The *building envelope* shall reflect the information specified in Section C1.

Exception to C3.5.5: 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 in the lowered position when either the transmitted luminance is greater than 200 cd/ft^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 Air Leakage. The *air leakage* rate of the *building envelope* (I_{75Pa}) at a pressure differential of 75 Pa (0.30 in. of water) shall be 0.35 cfm/ft^2 of *building envelope* area when *air leakage* compliance is based on whole-*building* pressurization testing and shall be 0.45 cfm/ft^2 of *building envelope* area when *air leakage* compliance is based on verification. The *air leakage* of the *building envelope* shall be converted to the appropriate units to describe the *air leakage* as a function of the area of *walls* that separate *conditioned spaces* and *semiheated spaces* from the exterior as follows:

$$I_{AGW} = 0.112 \times I_{75Pa} \times S/A_{AGW}$$

where

I_{75Pa} = *air leakage* rate of the *building envelope* (cfm/ft^2) at a fixed *building* pressure differential of 75 Pa (0.30 in. of water)

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_{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*

A_{AGW} = the total area of *above-grade walls* that comprise the *building envelope*, ft^2

Exception to C3.5.5.3: If the *simulation program* cannot simulate *air leakage* as a function of the area of *walls* that separate *conditioned spaces* and *semiheated spaces* from the exterior, the *air leakage* of the *building envelope* shall be converted to the appropriate units to describe the *air leakage* as a function of *gross 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* (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

C3.5.5.3.1 Air Leakage Schedule. To simulate *air leakage* as described in Section 5.4.3, 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.

C3.5.5.4 Thermal Bridges. *Linear* and *point thermal bridges* in the *proposed design* shall be either of the following:

a. Not modeled where option (a) or (c) is selected in Section C1.2.7.
b. Entered as individual *thermal bridge* inputs of length or count where option (b) is selected in Section C1.2.7 and addressed as follows:
   1. Individual *thermal bridges* in the *proposed design* that are indicated to comply with the requirements of Sections 5.5.5.1 through 5.5.5.5 need not be modeled.
   2. Individual *thermal bridges* in the *proposed design* that are indicated to not comply with the requirements of Sections 5.5.5.1 through 5.5.5.5 shall be modeled.
   3. Individual *thermal bridges* in the *proposed design* that are indicated to be not applicable with the requirements of Sections 5.5.5.1 through 5.5.5.5 need not be modeled.

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.

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C3.5.7 Lighting. The modeled lighting power shall be determined using the *lighting power density* allowances in Table 9.5.1 for the applicable *building* area type. The modeled 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 at the minimum light output and scaled linearly to 100% of lighting power 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 *EER* from Table 6.8.1-1, based on requirements for split-*system* air conditioners with heating section type "all other" between 65,000 Btu/h and 135,000 Btu/h. The *EER* shall be adjusted to remove the fan power in accordance with Section 12.5.2(c).
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. *Air economizers*, except in Climate Zones 0 and 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 in cooling.
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 power shall be 0.3 W/cfm, and the fan *energy* shall 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 *U-factor* not greater than that 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·°F. All other *opaque* assemblies shall be modeled with the same *HC* as the *proposed 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. *Thermal bridges*:
    1. Where option (a) is selected in Section C1.2.7, no modifications to the assembly *U-factors* are required.
    2. Where option (b) is selected in Section C1.2.7, the *U-factor* of the assembly interrupted shall be modified per Section A10.2 using the default values in Table A10.1 for the appropriate *class of construction*. Each of the *linear thermal bridges* or *point thermal bridges* identified in Sections 5.5.5.1 through 5.5.5.5 shall be modeled in the simulation model for calculating the proposed envelope performance. Where the balcony length in the *proposed design* is greater than allowed by Section 5.5.5.2.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.5.2.2 is met.
    3. Where option (c) is selected in Section C1.2.7, no modifications to the assembly *U-factors* are required.
c. The exterior *roof* surfaces shall be modeled with a solar reflectance and thermal *emittance* as required in Section 5.5.3.1.4(a). All other *roofs*, including *roofs* exempted from the requirements in Section 5.5.3.1.4, shall be modeled the same as in the *proposed design*. The *above-grade wall* surfaces of *buildings* shall be

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modeled with a solar reflectance and thermal *emittance* as required in Section 5.5.3.2.2 and Section 5.5.3.2.2(a). All other *above-grade walls*, including those exempt from the requirements in Section 5.5.3.2.2, shall be modeled the same as the *proposed design*.

d. *Fenestration* shall be assumed to be flush with the *wall* or *roof*. *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*. The *fenestration area* for new *buildings* or *additions* shall be modeled the same as the proposed *building* unless the following apply:
   1. Where the *fenestration area* 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.
   2. Where the *fenestration area* facing west or east of the *proposed design* 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 and averaging the results of the four simulations.
   3. Where the Normative Appendix C calculation is being used to determine *energy* credits in accordance with Section 11.5.2.1, for *building* use types included in Table G3.1.1-1 where the proposed *fenestration area* is less than the value in Table G3.1.1-1, *vertical fenestration* areas 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. Follow additional *fenestration* modeling requirements for *baseline building performance* in Table G3.1.

e. 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.

f. *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(d).

g. The *air leakage* rate of the *building envelope* (I_{75Pa}) at a fixed *building* pressure differential of 75 Pa (0.30 in. of water) shall be 0.35 cfm/ft^2 and shall be converted to units for the *energy* model using the same method as the *proposed envelope performance factor*.

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INFORMATIVE APPENDIX D
(RETAINED FOR FUTURE USE)

Climatic data are no longer contained in this appendix. See Section 5.1.4 for requirements. Annex 1 of this standard contains extracts of material from ASHRAE Standard 169.

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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 13, "Normative References," because there are other citations of those documents within the standard that are normative.

Address/Contact Information

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ASHRAE
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Peachtree Corners, GA 30092)

Associated Air Balance Council (AABC)
1015 18th St. NW Suite 603
Washington, DC 20036

ASTM International
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P.O. Box C700
West Conshohocken, PA 19428-2959

BC Hydro
Corporate Head Office
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Vancouver, B. C. V6B 5R3

Cooling Technology Institute (CTI)
3845 Cypress Creek Parkway, Suite 420
Houston, TX 77068
P.O. Box 681807, Houston, TX 77268

CWEC Climate Data
Environment Canada Engineering Climate Datasets
climate.weather.gc.ca/prods_servs/engineering_e.html

Hydraulic Institute (HI)
6 Campus Drive, First Floor North,
Parsippany, NJ 07054-4405
pumps.org

Illuminating Engineering Society (IES)
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New York, NY 10005-4001
(212) 248-5000
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International Electechnical Commission (IEC)
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International Standards Organization (ISO)
Chemin de Blandonnet 8
CP 401-1214 Vernier, Geneva, Switzerland

Midwest Insulation Contractors Association (MICA)
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Omaha, NE 68130
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National Environmental Balancing Bureau (NEBB)
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www.nebb.org

National Institute of Building Sciences (NIBS)
1090 Vermont Avenue NW, Suite 700
Washington, DC 20005-4950

National Renewable Energy Laboratory
NREL/RReDC
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Reference		Section
IES RP-8-18	Recommended Practice for Design and Maintenance of Roadway and Parking Facility Lighting	3.2
2021 ASHRAE Handbook—Fundamentals	Appendix A, Chapter 26, or Chapter 33	5.5.5.5
NIBS Guideline 3-2012	Building Enclosure Commissioning Process BECx, Annex O	5.7.3.2, H1
ASTM E2947-21a	Standard Guide for Building Enclosure Commissioning, Section 9.4	5.7.3.2, H1
ASTM E2947-21a	Standard Guide for Building Enclosure Commissioning	5.9.1, H1
ASTM E2813-18	Standard Practice for Building Enclosure Commissioning	5.9.1, H1
CTI STD-201 OM (19)	Operations Manual for Thermal Performance Certification of Evaporative Heat Rejection Equipment Cooling Technology Institute	6.4.1
MICA Insulation Standards, 9th Edition	National Commercial and Industrial Insulation Standards	6.4.4.1.1
SMACNA Duct Construction Standards, 4th Ed. (2021)	HVAC Duct Construction Standards, Metal and Flexible	6.4.4.2.1
SMACNA 016-2012	HVAC Air Duct Leakage Test Manual (Sections 3, 5, and 6)	6.4.4.2.2
ASHRAE Guideline 36-2021	High-Performance Sequences of Operation for HVAC Systems	6.5.3.8
ASHRAE Guideline 4-2019	Preparation of Operations and Maintenance Documentation for HVAC&R Systems	6.7.3.2
AABC, 7th Ed (2018)	Associated Air Balance Council, National Standards for Total System Balance	6.7.3.3.1
ANSI/ASHRAE Standard 111-2008 (RA 2017)	Measurement, Testing, Adjusting and Balancing of Building HVAC Systems	6.7.3.3.1
ANSI/ASHRAE Standard 202-2018	Commissioning Process for Buildings and Systems	6.9.2, H1
ASHRAE Guideline 0-2019	The Commissioning Process	6.9.2, H1
ASHRAE Guideline 1.1-2007	HVAC&R Technical Requirements for the Commissioning Process	6.9.2, H1
NEBB Procedural Standards, 9th Ed. (2019)	Procedural Standards for Building Systems Commissioning	6.9.2
2019 ASHRAE Handbook—HVAC Applications	Chapter 51, Service Water Heating/ASHRAE	7.4.1, 7.5
ANSI/ASHRAE Standard 188-2021	Legionellosis: Risk Management for Building water Systems	7.4.4
ASHRAE Guideline 12-2020	Managing the Risk of Legionellosis Associated with Building Water Systems	7.4.4
ANSI/ASABE S640-2017	Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)	9.4.4
IES RP-6-20	Recommended Practice for Sports and Recreational Area Lighting	9.5.2
ANSI/IES RP-28-20	Lighting and the Visual Environment for Senior Living	9.5.2
ANSI/IES/AVIXA RP-38-17	Recommended Practice: Lighting Performance for Small to Medium Sized Videoconferencing Rooms	9.5.2, 9.5.2.2
ISO 25745-2:2015	Energy performance of lifts, escalators and moving walks—Part 2: Energy calculation and classification for lifts (elevators)	10.4.3.4
ISO 27327-1:2012	Air Curtain Units—Part 1: Laboratory Methods of Testing for Aerodynamic Performance Rating	10.4.5

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Reference		Section
ANSI/AMCA Standard 220-05 (R2012)	Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating	10.4.5
ANSI/HI 1.1-1.2-2014	Rotodynamic Centrifugal Pumps for Nomenclature and Definitions	10.4.7
ANSI/HI 2.1-2.2-2014	Rotodynamic Vertical Pumps or Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions	10.4.7
www.ies.org/standards/lighting-library/the-interactive-illuminance-selector (includes recommended illuminance levels from the following standards):	The Interactive Illuminance Selector	11.5.2.5
ANSI/IES RP-1-2020	Recommended Practice: Lighting Offices Spaces	
ANSI/IES RP-2-2020	Recommended Practice: Lighting Retail Spaces	
ANSI/IES RP-3-2020	Recommended Practice: Lighting Educational Facilities	
ANSI/IES RP-4-2020	Recommended Practice: Lighting Library Spaces	
ANSI/IES RP-6-2020	Recommended Practice: Lighting Sports and Recreational Areas	
ANSI/IES RP-7-2020	Recommended Practice: Lighting Industrial Facilities	
ANSI/IES RP-8-2021	Recommended Practice: Lighting Roadway and Parking Facilities	
ANSI/IES RP-9-2020	Recommended Practice: Lighting Hospitality Spaces	
ANSI/IES RP-10-2020	Recommended Practice: Lighting Common Applications	
ANSI/IES RP-11-2020	Recommended Practice: Lighting for Interior and Exterior Residential Environments	
ANSI/IES RP-28-2020	Recommended Practice: Lighting and the Visual Environment for Older Adults and the Visually Impaired	
ANSI/IES RP-29-2020	Recommended Practice: Lighting Hospital and Healthcare Facilities	
ANSI/IES RP-30-2020	Recommended Practice: Lighting Museums	
ANSI/IES RP-38-2017	Recommended Practice: Lighting Performance for Small to Medium Sized Videoconferencing Rooms	
ANSI/IES RP-41-2020	Recommended Practice: Lighting Theaters and Worship Spaces	
IES Lighting Measurements (LM) 83-12	Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)	11.5.2.5.3
ANSI/ASHRAE Standard 209-2018	Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings	12.1.1, G1.2.2
CWEC	Canadian Weather for Energy Calculations	12.4.2
IWEC2 (ASHRAE)	International Weather for Energy Calculations, Generation 2	12.4.2
TMY3	Typical Meteorological Year, Generation 3	12.4.2
ASHRAE Transactions 101(2).	Hogan, J.F. 1995. Approach for opaque envelope U-factors for ASHRAE/IESNA 90.1-1989R	A1.1
ASHRAE Handbook—Fundamentals (2021)		A9.4
ASHRAE Transactions 116(1):10–017	Choudhary, M.K., C. Kasprzak, R.H. Larson, and R. Venuturumilli. 2010. ASHRAE Standard 90.1 metal building U-factors—Part 1: Mathematical modeling and validation by calibrated hot box measurements	A9.4.6

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Reference		Section
ASHRAE Transactions 116(1):10–018	Choudhary, M.K., and C.P. Kasprzak. 2010. ASHRAE Standard 90.1 Metal building U-factors—Part 2: A system based approach for predicting the thermal performance of single layer fiberglass batt insulation assemblies	A9.4.6
ASHRAE Transactions 116(1):10–019	McBride, M.F., and P.M. Gavin. 2010. ASHRAE Standard 90.1 metal building U-factors—Part 3: Equations for double layers of fiberglass batt insulation in roof and wall assemblies	A9.4.6
ASHRAE Transactions 116(1):10–020	Christianson, L. 2010. ASHRAE Standard 90.1 metal building U-factors—Part 4: Metal building U-factors for walls and roof based on experimental measurements.	A9.4.6
ASHRAE Transactions 118(1):12–006	Choudhary, M.K., C.P. Kasprzak, D.E. Musick, M.J. Henry, and N.D. Fast. 2012. ASHRAE Standard 90.1 metal building U-factors—Part 5: Mathematical modeling of wall assemblies and validation by calibrated hot box measurements	A9.4.6
ASHRAE Transactions 122(1):16–014	Choudhary, M.K 2016. A general approach for predicting the thermal performance of metal building fiberglass insulation assemblies	A9.4.6
BC Hydro New Construction Program Orientation Manual (June 2016)	https://www.bchydro.com/powersmart/business/programs/new-construction.html#thermal	A10.1
ASHRAE Research Project 1365	The Impact of Thermal Bridges on Effective Thermal Resistance and Energy Use in Mid and High Rise Buildings	Table A10.1
2021 ASHRAE Handbook—Fundamentals	Chapter 19	G2.2.3
ISO/IEC 17024:2012	Community Assessment—General Requirements for Bodies Operating Certification of Persons	H1

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INFORMATIVE APPENDIX F
U.S. DEPARTMENT OF ENERGY MINIMUM ENERGY EFFICIENCY REQUIREMENTS, TEST PROCEDURES, AND DEFINITIONS

In the United States, the U.S. Department of Energy (U.S. DOE) establishes *efficiency* standards for products that it defines as "residential covered products." Since these products are used in *buildings* covered by this standard, U.S. DOE *efficiency* requirements are shown here for convenience. All U.S. DOE *efficiency* requirements for *residential* products are found in the U.S. *Code of Federal Regulations*, 10 CFR 430.32.

DOE also establishes definitions and test procedures for covered products. These are found in 10 CFR 430.2 and 10 CFR 430.23, respectively.

F1. U.S. DOE MINIMUM ENERGY EFFICIENCY REQUIREMENTS FOR SINGLE-PHASE AIR CONDITIONERS AND HEAT PUMPS

These standards became effective on January 1, 2015. In the United States, some of the standards are regional in nature. The U.S. has been divided into 3 regions: (a) the north, comprising states with a population weighted heating *degree days* (HDD) equal to or greater than 5000; (b) the southeast, comprising states with a population weighted HDD less than 5000; and (c) the southwest, comprising Arizona, California, Nevada, and New Mexico. The regions are shown in Figure F-1.

The U.S. federal minimum *energy efficiency* standards for single-phase air conditioners and heat pumps are shown in Table F-1. The standards apply to *residential* single-phase air conditioners and heat pumps that are rated at less than 65,000 Btu/h of cooling capacity.

F2. U.S. DOE MINIMUM ENERGY EFFICIENCY REQUIREMENTS FOR WATER HEATERS AND POOL HEATERS

These standards for Uniform Energy Factor became effective on December 29, 2017, and apply to products manufactured on or after that date and the thermal *efficiency* requirements for gas fired *pool* heaters manufactured on or after April 16, 2013 (Table F-2).

F3. U.S. DOE TEST PROCEDURE AND DEFINITIONS FOR CEILING FANS

U.S. DOE definitions for *ceiling fans* are found in 10 CFR 430.2 and 10 CFR Part 430, Subpart B, Appendix U. On or after January 23, 2017, *manufacturers* of *ceiling fans* must make any representations with respect to *energy* use or *efficiency* in accordance with the test procedure in 10 CFR Part 430, Subpart B, Appendix U. DOE also specifies, in 10 CFR 430.32, design requirements for *ceiling fans*, and for *ceiling fans* manufactured on or after January 21, 2020, minimum *efficiency* requirements.

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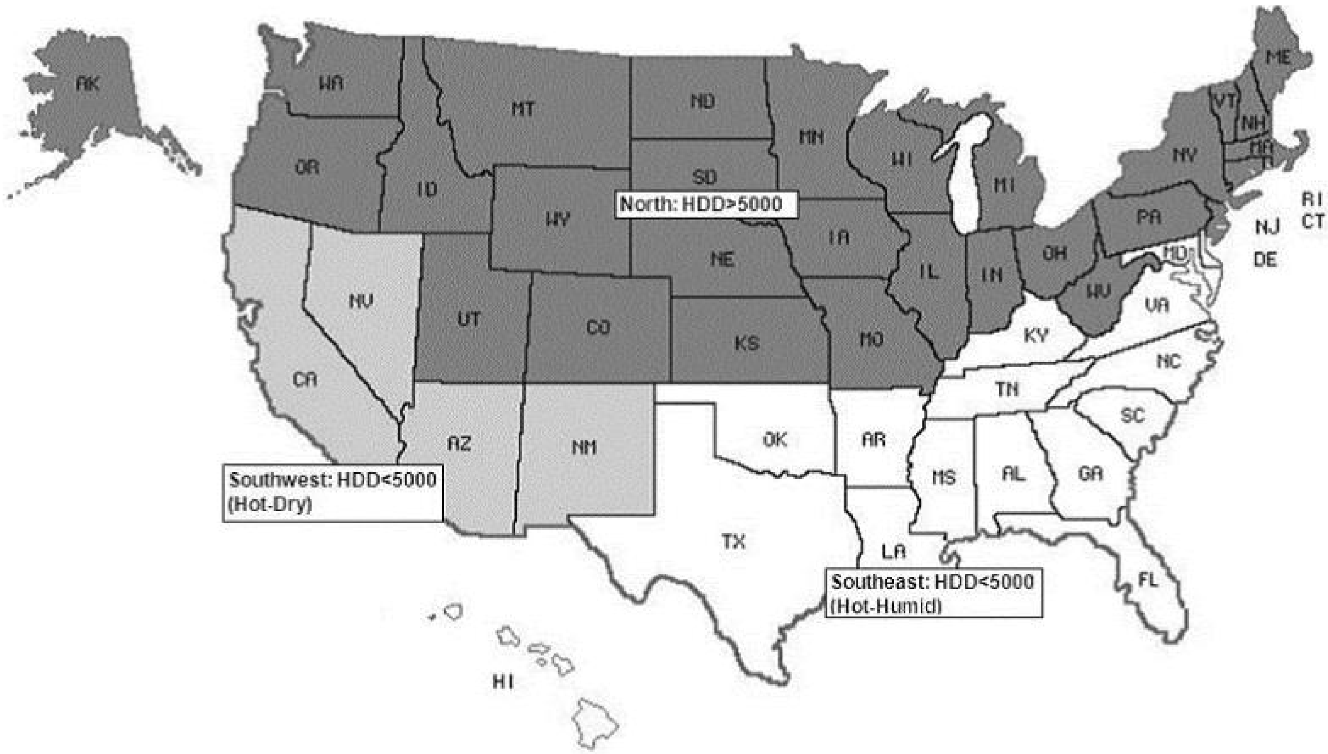

Figure F-1 Map of the regions for the analysis of central air conditioners and heat pumps.
(Source: *Federal Register* 76 FR 37431, June 7, 2018)

Table F-1 Minimum Efficiency Requirements for Single-Phase Central Air Conditioners and Heat Pumps for Applications in the U.S.

Product Class	Capacity Range	National Standards	Southeastern Region Standards[a]	Southwestern Region Standards[b]	Test Procedure[f]
Central Air Conditioners and Heat Pumps[c]					
Split-system air conditioners for U.S. applications	<45,000 Btu/h *single phase*	*SEER* = 13.0 $P_{W,OFF} \leq 30$ W before 1/1/2023 *SEER2* = 13.4 $P_{W,OFF} \leq 30$ W after 1/1/2023	*SEER* = 14.0 $P_{W,OFF} \leq 30$ W before 1/1/2023 *SEER2* = 14.3 $P_{W,OFF} \leq 30$ W after 1/1/2023	*SEER* = 14.0 *EER* = 12.2 $P_{W,OFF} \leq 30$ W before 1/1/2023 *SEER2* = 14.3 *EER2* = 11.7/9.8[d] $P_{W,OFF} \leq 30$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Split-system air conditioners	≥45,000 Btu/h and <65,000 Btu/h *single phase*	*SEER* = 13.0 $P_{W,OFF} \leq 30$ W before 1/1/2023 *SEER2* = 13.4 $P_{W,OFF} \leq 30$ W after 1/1/2023	*SEER* = 14.0 $P_{W,OFF} \leq 30$ W before 1/1/2023 *SEER2* = 13.8 $P_{W,OFF} \leq 30$ W after 1/1/2023	*SEER* = 14.0 *EER* = 11.7[d] $P_{W,OFF} \leq 30$ W before 1/1/2023 *SEER2* = 13.8 *EER2* = 11.2/9.8[e] $P_{W,OFF} \leq 30$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023

a. The Southeastern region for central air conditioners and heat pumps contains the following States: Alabama, Arkansas, Delaware, Florida, Georgia, Hawaii, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia, and the District of Columbia.
b. The Southwestern region for central air conditioners contains the States of Arizona, California, Nevada, and New Mexico.
c. *SEER* is *seasonal energy efficiency ratio*; *EER* is *energy efficiency ratio*; *HSPF* is *heating seasonal performance factor*; and Btu/h is British thermal units per hour. *SEER2* is *seasonal energy efficiency ratio* reflecting the new higher static that is effective 1/1/2023; *EER2* is *energy efficiency ratio* also reflecting the higher static; and *HSPF2* is new *heating seasonal performance factor* reflecting the new higher static and load line. Test and rating procedure defined in AHRI 210/240-2017 for *EER*, *SEER*, and *HSPF* and AHRI 210/240-2023 for *EER2*, *SEER2*, and *HSPF2*. The added "2" in the metric names reflects the new higher static (all metrics) and load line (*HSPF2* only) for the new metrics effective 1/1/2023.
d. The 11.7 *EER2* standard applies to products with a certified *SEER2* less than 15.2. The 9.8 *EER2* standard applies to products with a certified *SEER2* greater than or equal to 15.2.
e. The 11.2 *EER2* standard applies to products with a certified *SEER2* less than 15.2. The 9.8 *EER2* standard applies to products with a certified *SEER2* greater than or equal to 15.2.
f. Section 13 contains a complete specification of the referenced test procedures, including the referenced year version of the test procedure.

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Table F-1 Minimum Efficiency Requirements for Single-Phase Central Air Conditioners and Heat Pumps for Applications in the U.S.

Product Class	Capacity Range	National Standards	Southeastern Region Standards[a]	Southwestern Region Standards[b]	Test Procedure[f]
Central Air Conditioners and Heat Pumps[c]					
Split-system heat pumps	<65,000 Btu/h *single phase*	$SEER$ = 14.0 $HSPF$ = 8.2 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 14.3 $HSPF2$ = 7.5 $P_{W,OFF} \le 33$ W after 1/1/2023	$SEER$ = 14.0 $HSPF$ = 8.2 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 14.3 $HSPF2$ = 7.5 $P_{W,OFF} \le 33$ W after 1/1/2023	$SEER$ = 14.0 $HSPF$ = 8.2 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 14.3 $HSPF2$ = 7.5 $P_{W,OFF} \le 33$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Single-package air conditioners	<65,000 Btu/h *single phase*	$SEER$ = 14.0 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 13.4 $P_{W,OFF} \le 30$ W after 1/1/2023	$SEER$ = 14.0 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 13.4 $P_{W,OFF} \le 30$ W after 1/1/2023	$SEER$ = 14.0 EER = 11.0 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 13.4 $EER2$ = 10.6 $P_{W,OFF} \le 30$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Single-package heat pumps	<65,000 Btu/h *single phase*	$SEER$ = 14.0 $HSPF$ = 8.0 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 13.4 $HSPF2$ = 6.7 $P_{W,OFF} \le 33$ W after 1/1/2023	$SEER$ = 14.0 $HSPF$ = 8.0 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 13.4 $HSPF2$ = 6.7 $P_{W,OFF} \le 33$ W after 1/1/2023	$SEER$ = 14.0 $HSPF$ = 8.0 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 13.4 $HSPF2$ = 6.7 $P_{W,OFF} \le 33$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Small-duct high-velocity *systems*	<65,000 Btu/h *single phase*	$SEER$ = 12.0 $HSPF$ = 7.2 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 12.0 $HSPF2$ = 6.1 $P_{W,OFF} \le 30$ W after 1/1/2023	$SEER$ = 12.0 $HSPF$ = 7.2 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 12.0 $HSPF2$ = 6.1 $P_{W,OFF} \le 30$ W after 1/1/2023	$SEER$ = 12.0 $HSPF$ = 7.2 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 12.0 $HSPF2$ = 6.1 $P_{W,OFF} \le 30$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Space-constrained products— air conditioners [a]	<65,000 Btu/h *single phase*	$SEER$ = 12.0 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 11.7 $P_{W,OFF} \le 30$ W after 1/1/2023	$SEER$ = 12.0 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 11.7 $P_{W,OFF} \le 30$ W after 1/1/2023	$SEER$ = 12.0 $P_{W,OFF} \le 30$ W before 1/1/2023 $SEER2$ = 11.7 $P_{W,OFF} \le 30$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Space-constrained products— heat pumps [a]	<65,000 Btu/h *single phase*	$SEER$ = 12.0 $HSPF$ = 7.4 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 11.9 $HSPF2$ = 6.3 $P_{W,OFF} \le 33$ W after 1/1/2023	$SEER$ = 12.0 $HSPF$ = 7.4 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 11.9 $HSPF2$ = 6.3 $P_{W,OFF} \le 33$ W after 1/1/2023	$SEER$ = 12.0 $HSPF$ = 7.4 $P_{W,OFF} \le 33$ W before 1/1/2023 $SEER2$ = 11.9 $HSPF2$ = 6.3 $P_{W,OFF} \le 33$ W after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023

a. The Southeastern region for central air conditioners and heat pumps contains the following States: Alabama, Arkansas, Delaware, Florida, Georgia, Hawaii, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia, and the District of Columbia.
b. The Southwestern region for central air conditioners contains the States of Arizona, California, Nevada, and New Mexico.
c. *SEER* is *seasonal energy efficiency ratio*; *EER* is *energy efficiency ratio*; *HSPF* is *heating seasonal performance factor*; and Btu/h is British thermal units per hour. *SEER2* is *seasonal energy efficiency ratio* reflecting the new higher static that is effective 1/1/2023; *EER2* is *energy efficiency ratio* also reflecting the higher static; and *HSPF2* is new *heating seasonal performance factor* reflecting the new higher static and load line. Test and rating procedure defined in AHRI 210/240-2017 for *EER*, *SEER*, and *HSPF* and AHRI 210/240-2023 for *EER2*, *SEER2*, and *HSPF2*. The added "2" in the metric names reflects the new higher static (all metrics) and load line (*HSPF2* only) for the new metrics effective 1/1/2023.
d. The 11.7 *EER2* standard applies to products with a certified *SEER2* less than 15.2. The 9.8 *EER2* standard applies to products with a certified *SEER2* greater than or equal to 15.2.
e. The 11.2 *EER2* standard applies to products with a certified *SEER2* less than 15.2. The 9.8 *EER2* standard applies to products with a certified *SEER2* greater than or equal to 15.2.
f. Section 13 contains a complete specification of the referenced test procedures, including the referenced year version of the test procedure.

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Table F-2 Minimum Energy Efficiency Requirements for Water Heaters and Pool Heaters

Source: 10 CFR Part 430, Energy Conservation Program: Energy Conservation Standards for Water Heaters

Product Class	Rated Storage Volume and input Rating (if applicable)	Draw Pattern	Uniform Energy Factor (UEF) or Thermal Efficiency (E_t)	Test Procedure
Gas-fired storage water heater	≥20 gal and ≤55 gal	Very small	UEF = 0.3456 – (0.0020 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 0.5982 – (0.0019 × V_r)	
		Medium	UEF = 0.6483 – (0.0017 × V_r)	
		High	UEF = 0.6920 – (0.0013 × V_r)	
	>55 gal and ≤100 gal	Very small	UEF = 0.6470 – (0.0006 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 0.7689 – (0.0005 × V_r)	
		Medium	UEF = 0.7897 – (0.0004 × V_r)	
		High	UEF = 0.8072 – (0.0003 × V_r)	
Oil-fired storage water heater	≤50 gal	Very small	UEF = 0.2509 – (0.0012 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 0.5330 – (0.0016 × V_r)	
		Medium	UEF = 0.6078 – (0.0016 × V_r)	
		High	UEF = 0.6815 – (0.0014 × V_r)	
Electric storage water heaters	≥20 gal and ≤55 gal	Very small	UEF = 0.8808 – (0.0008 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 0.9254 – (0.0003 × V_r)	
		Medium	UEF = 0.9307 – (0.0002 × V_r)	
		High	UEF = 0.9349 – (0.0001 × V_r)	
	>55 gal and ≤120 gal	Very small	UEF = 1.9236 – (0.0011 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 2.0440 – (0.0011 × V_r)	
		Medium	UEF = 2.1171 – (0.0011 × V_r)	
		High	UEF = 2.2418 – (0.0011 × V_r)	
Tabletop water heater	≥20 gal and ≤120 gal	Very small	UEF = 0.6323 – (0.0058 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 0.9188 – (0.0031 × V_r)	
		Medium	UEF = 0.9577 – (0.0023 × V_r)	
		High	UEF = 0.9884 – (0.0016 × V_r)	
Instantaneous gas-fired water heater	<2 gal and >50,000 Btu/h	Very small	UEF = 0.80	10 CFR 430 Appendix E
		Low	UEF = 0.81	
		Medium	UEF = 0.81	
		High	UEF = 0.81	
Instantaneous electric water heater	<2 gal	Very small	UEF = 0.91	10 CFR 430 Appendix E
		Low	UEF = 0.91	
		Medium	UEF = 0.91t	
		High	UEF = 0.92	
Grid-enabled water heaters	>75 gal	Very small	UEF = 1.0136 – (0.0028 × V_r)	10 CFR 430 Appendix E
		Low	UEF = 0.9984 – (0.0014 × V_r)	
		Medium	UEF = 0.9853 – (0.0010 × V_r)	
		High	UEF = 0.9720 – (0.0007 × V_r)	
Pool heater gas			82% E_t	10 CFR 430 Appendix P

a. V_r is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.
b. Standards for electric storage water heaters apply to both *electric resistance* water heaters and heat-pump water heaters.

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Table F-3 Minimum Efficiency Requirements for Room Air Conditioners for U.S. Applications

Product Class	Capacity Range	Efficiency Requirements[a]	Test Procedure[b]
Room air conditioners without reverse cycle with louvered sides	<6,000 Btu/h	$CEER$ = 11.0	10 CFR 430 Appendix F
	≥6,000 Btu/h and <8,000 Btu/h	$CEER$ = 11.0	
	≥8,000 Btu/h and <14,000 Btu/h	$CEER$ = 10.9	
	≥14,000 Btu/h and <20,000 Btu/h	$CEER$ = 10.7	
	≥20,000 Btu/h and <28,000 Btu/h	$CEER$ = 9.4	
	≥28,000 Btu/h	$CEER$ = 9.0	
Room air conditioners without reverse cycle without louvered sides	<6,000 Btu/h	$CEER$ = 10.0	10 CFR 430 Appendix F
	≥6,000 Btu/h and <8,000 Btu/h	$CEER$ = 10.0	
	≥8,000 Btu/h and <11,000 Btu/h	$CEER$ = 9.6	
	≥11,000 Btu/h and <14,000 Btu/h	$CEER$ = 9.5	
	≥14,000 Btu/h and <20,000 Btu/h	$CEER$ = 9.3	
	≥20,000 Btu/h	$CEER$ = 9.4	
Room air conditioners with reverse cycle with louvered sides	<20,000 Btu/h	$CEER$ = 9.8	10 CFR 430 Appendix F
	≥20,000 Btu/h	$CEER$ = 9.3	
Room air conditioners with reverse cycle without louvered sides	<14,000 Btu/h	$CEER$ = 9.3	10 CFR 430 Appendix F
	≥14,000 Btu/h	$CEER$ = 8.7	
Room air conditioners, casement only	All	$CEER$ = 9.5	10 CFR 430 Appendix F
Room air conditioners, casement slider	All	$CEER$ = 10.4	10 CFR 430 Appendix F

a. Source: Federal Register 76 FR 37431, June 27, 2011.
b. Section 13 contains a complete specification of the referenced test procedures.

Table F-4 Residential Furnaces—Minimum Efficiency Requirements for U.S. Applications (see 10 CFR 430)

Product Class	Size Category (input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Furnace, gas fired	<225,000 Btu/h	Nonweatherized excluding mobile home	80% AFUE	10 CFR 430 Appendix N
		Nonweatherized mobile home	80% AFUE	
		Weatherized	81% AFUE	
Furnace oil fired	<225,000 Btu/h	Nonweatherized excluding mobile home	83% AFUE $P_{W,SB} \leq 11$ W $P_{W,OFF} \leq 11$ W	10 CFR 430 Appendix N
		Nonweatherized mobile home	75% AFUE $P_{W,SB} \leq 11$ W $P_{W,OFF} \leq 11$ W	
		Weatherized	78% AFUE	
Electric furnace	<225,000 Btu/h	All	78% AFUE $P_{W,SB} \leq 10$ W $P_{W,OFF} \leq 10$ W	10 CFR 430 Appendix N

a. Section 13 contains a complete specification of the referenced test procedure.

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Table F-5 Residential Boiler [a] Minimum Efficiency Requirements for U.S. Applications (see 10 CFR 430)

Product Class	Minimum Efficiency [b]	Standby Mode and Off-Mode Power Consumption	Design Requirements
Gas-fired hot-water *boiler*	84% AFUE	$P_{W,SB} \le 9$ W $P_{W,OFF} \le 9$ W	Constant burning pilot not permitted. Automatic means for adjusting water temperature required (except for *boilers* equipped with tankless domestic water heating coils) [d].
Gas-fired steam *boiler*	82% AFUE	$P_{W,SB} \le 8$ W $P_{W,OFF} \le 8$ W	Constant burning pilot not permitted.
Oil-fired hot-water *boiler*	86% AFUE	$P_{W,SB} \le 11$ W $P_{W,OFF} \le 11$ W	Automatic means for adjusting temperature required (except for *boilers* equipped with tankless domestic water heating coils) [d].
Oil-fired steam *boiler*	85% AFUE	$P_{W,SB} \le 11$ W $P_{W,OFF} \le 11$ W	None
Electric hot-water *boiler*	None	$P_{W,SB} \le 8$ W $P_{W,OFF} \le 8$ W	Automatic means for adjusting temperature required (except for *boilers* equipped with tankless domestic water heating coils) [d].
Electric steam *boiler*	None	$P_{W,SB} \le 8$ W $P_{W,OFF} \le 8$ W	None

a. Has a heat input rate of less than 300,000 Btu per hour for electric boilers and low-pressure steam or hot-water boilers (per § 430.2).
b. Annual Fuel Utilization Efficiency, as determined in § 430.23(n)(2).
c. Standby mode and off-mode electric power consumption as determined in § 430.23(n)(5).
d. See § 430.32(e)(2)(iv) for additional details regarding automatic means for adjusting water temperature.

Table F-6 Ceiling Fan Efficiency Requirements for U.S. Applications (see 10 CFR 430)

Equipment Type	Size Category	Minimum Efficiency	Test Procedure
Large-diameter ceiling fan	Blade span ≥ 84.5 in.	*CFEI* ≥ 1.00 at high (maximum) speed; and *CFEI* ≥ 1.31 at 40% of high speed or the nearest speed that is not less than 40% of high speed	10 CFR 430 Appendix U

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(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX G
PERFORMANCE RATING METHOD

G1. GENERAL

G1.1 Performance Rating Method Scope. This appendix offers an alternative path for minimum standard compliance in accordance with Section 4.2.1.1 when administered by a *building official*. It is also provided for those who wish to use this appendix to quantify performance that exceeds the requirements of this standard when administered by a *rating authority* and not seeking minimum standard compliance in accordance with Section 4.2.1.1. 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*. In the case where this appendix is administered solely by a *building official* to determine compliance with this standard in accordance with Section 4.2.1.1, all references to "*rating authority*" shall be replaced with "*building official.*"

Informative Note: To fully utilize the investment made to create a *building energy* model during the design process, the methodology described in ASHRAE Standard 209 should be considered.

G1.2 Performance Rating

G1.2.1 Mandatory Provisions. The *proposed building design* shall comply with all of the following:

a. Sections 5.2.1, 6.2.1, 7.2.1, 8.2.1, 9.2.1, and 10.2.1.
b. Interior lighting power shall not exceed the *interior lighting power allowance* determined using either
   1. Tables G3.7-1 and G3.7-2 and the methodology described in Section 9.5.2, or
   2. Table G3.8 and the methodology described in Section 9.5.1.
c. Energy *efficiency* levels of installed components and *systems* shall meet or exceed the *efficiency* levels used to calculate the *proposed building performance*.
d. For new *buildings*, one of the following shall be met:
   1. The *building envelope* complies with Section 5.5, "Prescriptive Building Envelope Compliance Path."
   2. Using Section 5.6, "Building Envelope Trade-Off Compliance Path," the *proposed envelope performance factor* shall not exceed the *base envelope performance factor* by more than 15% in multifamily *residential*, hotel/motel, and dormitory *building* area types. For all other *building* area types, the limit shall be 7%. For *buildings* with both *residential* and *nonresidential* occupancies, the limit shall be based on the area-weighted average of the *gross conditioned floor area*.
e. Verification, testing, and *commissioning* requirements of Section 4.2.5 shall be met.
f. Proposed *building systems*, controls, or *building envelope* documented in Section G1.3(c) that do not have criteria in Sections 5 through 10 shall have verification or testing to document proper installation and operation in accordance with Section 4.2.5.

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*

Both the *proposed building performance* and the *baseline building performance* shall include all end-use load components within and associated with the *property* when calculating the Performance Cost Index.

Exception to G1.2.2: Energy used to recharge or refuel vehicles that are used for off-*site* transportation purposes shall not be modeled in the *baseline building performance* or the *proposed building performance*.

Informative Notes:

1. 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.
2. See Informative Appendix I for using other metrics, including site *energy*, source *energy*, and carbon emissions, in conjunction with the Normative Appendix G *Performance Rating Method* when approved by the *rating authority*.

G1.3 Submittals

G1.3.1 General. Compliance documentation and supplemental information shall be submitted in accordance with Section 4.2.2 of this standard.

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G1.3.2 Application Documentation. The following documentation shall be submitted to the *rating authority:*

a. The *simulation program* used, the version of the *simulation program*, and the results of the *energy* analysis, including the calculated values for baseline *building* unregulated *energy* cost (BBUEC), baseline *building* regulated *energy* cost (BBREC), *building* performance factor (BPF), *baseline building performance*, the *proposed building performance*, Performance Cost Index (PCI), and Performance Cost Index Target (PCI_t).
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, and 10.4 (mandatory provisions).
e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of Sections 5.5, 6.5, 7.5, and 9.5 (prescriptive provisions).
f. A list identifying those aspects of the *proposed design* that are more stringent than the requirements of Sections 5 through 10.
g. A table with a summary by end use of the *proposed building performance* and *baseline building performance*, with each end use separated into regulated and unregulated components.
h. A *site* plan showing all adjacent *buildings* and topography that may shade the proposed *building* (with estimated height or number of *stories*).
i. *Building* elevations and *floor* plans.
j. A diagram showing the *thermal blocks* used in the computer simulation.
k. An explanation of any significant modeling assumptions.
l. 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)(a).
m. Reports from the *simulation program* showing
   1. 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*);
   2. the amount of *unmet load hours* for both the *proposed design* and *baseline building design*; and
   3. a description of *energy*-related features of the *budget building design* and the *proposed design* to support requirements of Section G1.3.2(c).
n. *Purchased energy rates* used in the simulations.
o. An explanation of any error messages noted in the *simulation program* output.
p. 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.
q. The reduction in *proposed building performance* associated with *on-site renewable energy*.
r. The version of the software and the link to the website that contains the ASHRAE Standard 140 results for the version used in accordance with Section G2.2.4.
s. Simulation input files for the *budget building design* and the *proposed design* shall be made available if requested by the *building official.*

G1.3.3 Completion Requirements. Completion requirements shall be in compliance with Sections 5.7.3, 6.7.3, 7.7.3, 8.7.3, 9.7.3, and 10.7.3.

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

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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.

Informative Note: For the ease of use and consistent application, the *simulation program* should automatically implement the requirements of this appendix to generate the baseline design and *proposed design* models based on the user model of the *proposed design*.

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*, humidity *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 directly determine the *proposed building performance* and *baseline building performance* or 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.

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 Section 6.4.2.1 for both the *proposed design* and *baseline building design*.

G2.2.4 Simulation Program Testing Requirements

G2.2.4.1 The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The required tests shall include *building* thermal envelope and fabric load tests (Sections 5.2.1, 5.2.2, and 5.2.3), ground coupled slab-on-*grade* analytical verification tests (Section 5.2.4), *space*-cooling *equipment* performance tests (Section 5.3), *space*-heating *equipment* performance tests (Section 5.4), and air-side HVAC *equipment* analytical verification tests (Section 5.5), along with the associated reporting (Section 6).

G2.2.4.2 The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the *simulation program* and input files used for generating the results along with the results of the other *simulation programs* included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values and for omitted results.

G2.2.4.3 The testing shall be performed for the version of the *simulation program* used to calculate the *proposed building performance* and *baseline building performance*.

Informative Notes:

1. There are no pass/fail criteria established by this requirement.
2. Based on the Section 3 definition, *simulation program* includes the simulation engine and the corresponding user interface. The testing of a *simulation program* only meets the requirements of Section G2.2.4 for that *simulation program* and cannot be used as proxy for documenting compliance of another *simulation program* that uses the same simulation engine.

G2.3 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 *site* in which the *proposed design* is to be located. For locations for which several climatic data sources are available or 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* shall be subtracted from the *proposed*

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design energy consumption prior to calculating the *proposed building performance*, provided that the *building* owner

a. owns the *on-site renewable energy system* or
b. has signed a lease agreement for *the on-site renewable energy system* for at least 15 years or
c. has signed a contractual agreement to purchase *energy* generated by the *on-site renewable energy system* for at least 15 years.

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 U.S. 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, except where the baseline *energy* source is prescribed in Tables G3.1.1-2 and G3.1.1-3. Where the *proposed design* includes *on-site electricity generation systems* other than *on-site renewable energy systems*, the baseline design shall include the same generation *systems* excluding its *site-recovered energy*.

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 website (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. Theoretical and empirical information verifying the method's accuracy, and 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 that are estimated 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 Cost Index calculated with and without the exceptional calculation method.

G3. CALCULATION OF THE PROPOSED DESIGN AND BASELINE BUILDING PERFORMANCE

G3.1 Building Performance Calculations

G3.1.1 Scope. The simulation model for calculating the *proposed building performance* and *baseline building performance* shall be developed in accordance with Sections G3.1.2, G3.1.3, or G3.1.4 as applicable.

G3.1.2 New Buildings. The simulation model for calculating the *proposed building performance* and *baseline building performance* for new *buildings* shall be developed in accordance with the requirements in Section G3.2.

G3.1.3 Additions. The simulation model for calculating the *proposed building performance* and *baseline building performance* for *additions* shall be developed in accordance with the requirements in Section G3.2.

G3.1.4 Alterations. The simulation model for calculating the *proposed building performance* and *baseline building performance* for *alterations,* excluding *additions,* shall be developed in accordance with the applicable subparagraph (a) or (b).

a. In accordance with Section G3.2 for *alterations* that include replacement of two or more of the following:
   1. *HVAC systems* that account for more than 50% of the capacity serving either the heating or cooling loads of the *alteration* area. This includes HVAC unitary *systems*, HVAC *terminal* units, or components of HVAC central heating or cooling *equipment*. HVAC *terminal* units, for the purposes of this section, can include *VAV* boxes, fan-coil units, *VRF* room units, or water-loop heat pumps;
   2. 50% or more of the *luminaires* in the *alteration* area;
   3. 25% or more of the *building envelope* area of the *alteration* portion of the *building*, including new exterior cladding, *fenestration*, or insulation.
b. In accordance with Section G3.3 for all other *alterations.*

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G3.2 Performance Calculations for New Buildings, Additions and Substantial Alterations

G3.2.1 Baseline HVAC System Type and Description. HVAC *systems* in the *baseline building design* shall be selected based on the *building* area types and criteria described in Section G3.2.1.1 and shall be adjusted, when applicable, based on the requirements in Section G3.2.1.2 and modeled in the *baseline building design* per Section G3.2.1.3.

G3.2.1.1 Baseline HVAC System Types based on Building Area Types. *HVAC system* types in the *baseline building design* shall be determined as follows:

a. Determine the combined area of the *gross conditioned floor area* and *semiheated floor area* of each of the following *building* area types in the *proposed design:*
   1. **Residential.** *HVAC zones* that include *dwelling units*, guest rooms, living quarters, private living *spaces*, and sleeping quarters, and *residential associated HVAC zones* shall be classified as *residential*. Other *space* types, including patient rooms in hospitals, shall not be classified as *residential.*
   2. **Public Assembly.** Houses of worship, auditoriums, movie theaters, performance theaters, concert halls, arenas, enclosed stadiums, ice rinks, gymnasiums, convention centers, exhibition centers, and natatorium *buildings* shall be classified as public assembly. *HVAC zones* that include these area types in other *buildings* shall also be classified as public assembly.
   3. **Heated-Only Storage.** Nonrefrigerated warehouse *buildings* and heated parking garages that are not mechanically cooled, shall be classified as heated-only storage.
   4. **Retail.** Grocery stores, retail stores, and supermarket *buildings* with two *floors* or fewer shall be classified as retail.
   5. **Hospitals.** Hospital *building* area types, including patient rooms, shall be classified as hospitals.
   6. **Other Nonresidential.** *Buildings* and areas within *buildings* that are not classified as *residential*, public assembly, heated-only storage, hospital, or retail shall be classified as other *nonresidential*.

b. Classify the *nonresidential building* area type with the largest combined area from Section G3.2.1.1(a) as the predominant *nonresidential building* area type. Add the combined area of any remaining *nonresidential building* area types with less than 20,000 ft^2 to the combined area of the predominant *nonresidential building* area type.

c. Select a baseline *HVAC system* type from Table G3.1.1-3 for each of the following *building* area types included in the *proposed design*:
   1. *Residential* based on Section G3.2.1.1(a)
   2. Predominant *nonresidential* based on Section G3.2.1.1(b)
   3. Each additional *nonresidential building* area type with more than 20,000 ft^2 of combined area based on Section G3.2.1.1(a)

G3.2.1.2 Additional and Adjusted Baseline HVAC System Types. Baseline HVAC *systems* shall be added or adjusted for individual *HVAC zones* based on the following criteria.

a. If the baseline *HVAC system* type is 5, 6, 7, or 8 use separate *single-zone systems* conforming with the requirements of *system* 3 or *system* 4 for any *HVAC zones* that have occupancy, or internal gains that differ significantly from the rest of the *HVAC zones* served by the *system*. Total peak internal gains that also differ by 12 Btu/h·ft^2 or more from the average of other *HVAC zones* served by the *system*, or occupied hours that are more than 40 hours per week higher than the average of other *HVAC zones* served by the *system,* are considered to differ significantly. Examples where this exception may be applicable include, but are not limited to, commercial kitchens, auditoriums, natatoriums, and continually occupied security areas. This exception does not apply to *computer rooms*.

b. 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 *HVAC zones* that include the laboratory *spaces*. The lab exhaust fan shall be modeled as constant horsepower reflecting constant-volume stack discharge with *outdoor air* bypass.

c. *HVAC 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*.

d. If the baseline *HVAC system* type is 9 or 10, use additional *system* types for all *HVAC zones* that are mechanically cooled in the *proposed design*. The baseline *HVAC system* types for such zones shall be determined based on the *building* area type determined in accordance with Section G3.2.1.1(a) and the requirements of Section G3.2.1.1(c).

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance

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 *property* shall be modeled, including but not limited to exhaust fans, parking garage *ventilation* fans, snow-melt and freeze-protection *equipment*, facade 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 modeled in the *proposed design* to comply with but not exceed the requirements of this standard as described in Table G3.1, Nos. 6, 10, 11, and 12. 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 *gross 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 *systems* and *equipment* shall be modeled identically in the *proposed design* and *baseline building design*. Where the *baseline building systems* and *equipment* are permitted to be different from the *proposed design* but are not prescribed in this appendix, the baseline must be determined based on the following, in the order of priority: a. Requirements in Sections 5 through 10 b. Requirements of other efficiency or *equipment* codes or standards applicable to the design of the *building* systems and *equipment*
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	
The *space* use classification within each *thermal block* shall be determined using the *space* type lighting classifications in accordance with Section 9.5.2 **Exception:** Where *space* types neither exist nor are designated in design documents, use type shall be specified in accordance with Section 9.5.1 The user may simplify the placement of the various *space* types within the *building* model, provided that *building* total areas and *orientation* of glazed exterior walls for each *space* type are accurate.	Same as *proposed design*.

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

Proposed Building Performance	Baseline Building Performance
4. Schedule	
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 System Fan Schedules.** Schedules for *HVAC system* 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 system* 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 system* fans shall remain on during occupied and unoccupied hours in *systems* primarily serving *computer rooms*. 4. Dedicated *outdoor air* supply fans shall stay off during unoccupied hours.	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). 3. *HVAC system* fan schedules may be allowed to differ when Section G3.2.1.2(a) applies. 4. For *Systems* 6 and 8, only the *terminal*-unit fan and *reheat* coil shall be energized to meet heating *set point* during unoccupied hours
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*. All *opaque building envelope* components shall be modeled accounting for thermal mass effects. **Exception:** The following *building* elements are permitted to differ from architectural drawings: 1. Each *linear thermal bridge* and *point thermal bridge* as identified in Section 5.5.5 shall be modeled using either of the following techniques: a. A separate model of the assembly within the *energy* simulation model. b. Adjustment of the clear-field *U-factor* in accordance with Section A10.2. 2. Each uninsulated assembly not identified in Section 5.5.5 shall be modeled using either of the following techniques: a. A separate model of the assembly within the *energy* simulation model. b. The *U-factors* of uninsulated assemblies can be averaged with larger adjacent surfaces of the same *class of construction* using an area-weighted average method. This average *U-factor* is modeled within the *energy* simulation model. 3. Any other *building envelope* assembly, not subject to the requirements of Section 5.5.5, that covers less than 5% of the total area of that *class of construction* need not be separately described, provided that it is similar to an assembly being modeled. If not separately described, the *U-factors* of these assemblies shall be averaged with larger adjacent surfaces using an area-weighted average method. This average *U-factor* is modeled within the *energy* simulation model. 4. 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. 5. 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. **Space Conditioning Categories.** *Space conditioning categories* used to determine applicability of the envelope requirements in Tables G3.4-1 through G3.4-8 shall be the same as in the *proposed design*. **Exception:** Envelope components of the HVAC zones that are semiheated in the *proposed design* must meet conditioned envelope requirements in Tables G3.4-1 through G3.4-8 if, based on the sizing runs, these zones are served by a baseline system with sensible cooling output capacity ≥5 Btu/h·ft^2 of floor area, or with heating output capacity greater than or equal to the criteria in Table G3.4-9, or that are *indirectly conditioned spaces*. c. **Linear and Point Thermal Bridges.** Where *linear thermal bridges* and *point thermal bridges*, as identified in Section 5.5.5 are modeled in the *proposed design*, they shall not be modeled in the *budget building design*. d. **Opaque Assemblies.** *Opaque* assemblies used for new *buildings*, *existing buildings*, or additions shall conform with assemblies detailed in Normative Appendix A and shall match the appropriate assembly maximum *U-factors* in Tables G3.4-1 through G3.4-8:

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

Proposed Building Performance	Baseline Building Performance
5. Building Envelope (continued)	
6. *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. 7. *Automatically* controlled *dynamic glazing* may be modeled. Manually controlled *dynamic glazing* shall use the average of the minimum and maximum *SHGC* and *VT*. 8. The above-grade wall surface shall be modeled using the initial solar reflectance and thermal *emittance* determined in accordance with the test methods identified in Section 5.5.3.2.2(a). Where initial test data are unavailable, the wall surface may be modeled with a solar reflectance of 0.25 and a thermal *emittance* of 0.90. b. To simulate *air leakage*, infiltration shall be modeled using the same methodology 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* shall be converted to appropriate units for the *simulation program* using one of the methods in Section G3.2.1.7. 1. When whole-*building* pressurization testing is required or specified during design, and completed in accordance with Section 5.4.3.1.4, the measured *air leakage* rate of the *building envelope* (I_{75Pa}) at a fixed *building* pressure differential of 75 Pa (0.30 in. of water) shall be modeled for purposes of demonstrating compliance with this standard. ***Informative Note:*** Before the start of pressurization testing, the maximum *air leakage* rate of the *building envelope* (I_{75Pa}) specified in Section 5.4.3.1.4 or as specified in design documents may be simulated to estimate the *energy* impact of *building envelope air leakage*. The final measured value is used for compliance; therefore, care should be taken when using estimated *air leakage* as a trade-off for performance-based code compliance. 2. For *buildings* providing verification in accordance with Section 5.9.1.2, the *air leakage* rate of the *building envelope* (I_{75Pa}) at a fixed *building* pressure differential of 75 Pa (0.30 in. of water) shall be 0.45 cfm/ft^2.	• *Roofs* with insulation entirely above deck (A2.2). • *Above-grade walls—steel-framed* (A3.3). • *Below-grade walls*—concrete block (A4). • *Floors—steel-joist* (A5.3). • *Slab-on-grade floors* shall match the *F-factor* for unheated slabs from the same tables (A6). • *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). e. **Vertical Fenestration Areas.** For *building* area types included in Table G3.1.1-1, *vertical fenestration areas* for new *buildings* and additions shall equal the percentage in Table G3.1.1-1 multiplied by the gross area of *above-grade walls* that are part of the *exterior building envelope* and *semiexterior building envelope*. Where a *building* has multiple *building* area types, each type shall use the values in the table. 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 area of *above-grade walls* that are part of the *exterior building envelope* and *semiexterior building envelope*, whichever is smaller, and shall be distributed on each face of the *building* in the same proportions in the *proposed design*. The *vertical fenestration* shall be distributed on each face of the *building* in the same proportion as in the *proposed design*. If this would cause the combined *vertical fenestration* and *opaque door area* on a given face to exceed the *gross above-grade wall* area on that face, then the *vertical fenestration area* on other faces shall be increased in proportion to the *gross above-grade wall* area of these faces such that the total baseline *building vertical fenestration area* is equal to that calculated following Table G3.1.1-1. 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*. f. **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 Tables G3.4-1 through G3.4-8 for the applicable glazing percentage for U_{all}. • *Fenestration SHGCs* shall match the appropriate requirements in Tables G3.4-1 through G3.4-8 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. • Automatic *fenestration* shading devices shall not be modeled. g. **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 Tables G3.4-1 through G3.4-8 using the value and the applicable *skylight* percentage. h. **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. i. The *air leakage* rate of the *building envelope* (I_{75Pa}) at a fixed *building* pressure differential of 0.3 in. of water shall be 1.0 cfm/ft^2. j. **Wall Solar Reflectance and Thermal Emittance.** *Above-grade wall* surfaces shall be modeled with a solar reflectance of 0.25 and a thermal *emittance* of 0.90.

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

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 complete *lighting system* has been designed and submitted with design documents, 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. Where *space* types are known, lighting power shall be determined in accordance with the Space-by-Space Method. Where *space* types are not known, 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*). e. For *dwelling units*, hotel/motel guest rooms, and other *spaces* in which *lighting systems* are connected via receptacles and are not shown on *design documents*, lighting power used in the simulation shall be equal to the lighting power allowance in Tables 9.5.2.1-1 and 9.5.2.1-2 for the appropriate *space* type or as designed, whichever is greater. For the *dwelling units*, lighting power used in the simulation shall be equal to 0.60 W/ft^2 or as designed, whichever is greater. **Exception:** Lighting use can be reduced for the portion of the *space* illuminated by the specified *fixtures* provided that they maintain the same illuminance level as in the baseline. Such reduction shall be demonstrated by calculations. f. Exterior lighting power and lighting power for parking garages shall be modeled. g. 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 (h) and (i). h. *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. i. 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 Tables G3.7-1 and G3.7-2 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 Tables G3.7-1 and G3.7-2. However, where lighting neither exists nor is submitted with design documents, and the *proposed design* lighting power is determined in accordance with the *Building* Area Method, the *baseline building design* lighting power shall be determined in accordance with Table G3.8. Where retail display lighting is included in the *proposed building design* in accordance with Section 9.5.2.2(b), the *baseline building design* retail display lighting additional power shall be equal to the limits established by Section 9.5.2.2(b) or same as proposed, whichever is less. 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 that are designed to be illuminated and 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,* or all of the zones have peak internal loads that differ by less than 10 Btu/h·ft^2 from the average. 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*. 4. All of the zones have schedules that differ by 40 or less equivalent full-load hours per week.	Same as *proposed design*.

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

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 *proposed design HVAC system* shall be modeled using *manufacturers'* full- and part-load data for the *HVAC system* without fan power. **Exception to (a) and (b):** Where part-load performance of chillers in the *proposed design* is not available, and design temperature across the condenser is 10°F, the performance curves in Normative Appendix L, as referenced in Table J-1, shall be modeled for the specified chiller. When using performance curves from Normative Appendix L, chiller minimum part-load ratio (ratio of load to available capacity at a given simulation time step) and minimum compressor unloading ratio (part-load ratio below which the chiller capacity cannot be reduced by unloading and chiller is false loaded) shall be equal to 0.25. *Simulation programs* that do not use performance curves are permitted to use an alternative simulation method that results in the same performance as the curves described in Normative Appendix L. 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.	The *HVAC systems* in the *baseline building design* shall be of the type and description specified in Section G3.2.1, shall meet the general *HVAC system* requirements specified in Section G3.2.2, and shall meet any *system*-specific requirements in Section G3.2.3 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 *site* as determined by the *rating authority*, the baseline *HVAC systems* shall be modeled using propane as their *fuel*.

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

Proposed Building Performance	Baseline Building Performance
10. HVAC Systems (continued)	
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.	
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: a. Where a complete *service water-heating system* exists, the *proposed design* shall reflect the actual *system* type using actual component capacities and efficiencies. 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. d. For *buildings* that will have no *service water-heating* loads, no *service water-heating system* 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. f. Piping losses shall not be modeled.	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 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 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*. c. For *buildings* that will have no *service water-heating* loads, no *service water-heating* shall be modeled. d. 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*. e. *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. f. 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. g. *Service* water loads and use shall be the same for both the *proposed design* and *baseline building design* and shall be documented by the calculation procedures described in Section 7.4.1. **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, but are not limited to, low-flow shower heads and dishwashers. Such reduction shall be demonstrated by calculations. The baseline flow rates shall be determined as described in Table G3.1, No. 1, and the calculation methodology shall be approved by the *authority having jurisdiction*. 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.

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

Proposed Building Performance	Baseline Building Performance
11. Service Water-Heating Systems (continued)	
	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. h. Gas storage *water heaters* shall be modeled using natural gas as their *fuel*. **Exception:** Where natural gas is not available for the proposed *site*, as determined by the *rating authority*, gas storage *water heaters* shall be modeled using propane as their *fuel*. i. Piping losses shall not be modeled.
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. **Exception:** When receptacle controls installed in *spaces* where not required by Section 8.4.2 are included in the *proposed building design*, the hourly receptacle shall be reduced as follows: $RPC = RC \times 10\%$ where RPC = receptacle power credit EPS_{pro} = $EPS_{bas} \times (1 - RPC)$ RC = percentage of all controlled receptacles EPS_{bas} = *baseline equipment* power hourly schedule (fraction) EPS_{pro} = *proposed equipment* power hourly schedule (fraction) 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 be modeled as having 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*. Receptacle schedules shall be the same as the *proposed design* before the receptacle power credit is applied. **Exception:** 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 described in Table G3.1(1), or 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.
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*.	Same as *proposed design*.

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Table G3.1 Modeling Requirements for Calculating Proposed Building Performance and Baseline Building Performance *(Continued)*

Proposed Building Performance	**Baseline Building Performance**
14. Exterior Conditions (continued)	
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.	
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. A *transformer* with a *kVA* rating not listed in the table shall have its minimum *efficiency* level calculated by a linear interpolation of the *kVA* and *efficiency* values listed in the table immediately above and below its *kVA* rating. If modeled, the *efficiency* requirements from Table 8.4.4 or the interpolated *efficiency* requirements 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*.
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	
Where refrigeration *equipment* in the *proposed design* is rated in accordance with AHRI 1200, the rated *energy* use shall be modeled. Otherwise, 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*.
18. On-Site Renewable Energy	
On-site renewable energy in the *proposed building performance* shall be determined as follows: a. Where a complete *system* providing *on-site renewable energy* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where a *system* providing *on-site renewable energy* has been designed, the *system* model shall be consistent with design documents. c. Where no *system* exists or is specified to provide *on-site renewable energy*, no *system* shall be modeled.	*On-site renewable energy* shall not be included in the *baseline building performance*.

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d. The baseline *HVAC system* serving *HVAC zones* that include *computer rooms* shall be modeled in accordance with one of the following:
   1. Baseline *System* 11 shall be used for such *HVAC zones* in *buildings* with a total *computer room* peak cooling load greater than 3,000,000 Btu/h.
   2. Baseline S*ystem* 11 shall be used for such *HVAC zones* in *buildings* where the baseline *HVAC system* type is 7 or 8 and the total *computer room* peak cooling load is greater than 600,000 Btu/h.
   3. Baseline *System* 3 or 4 shall be used for all other *HVAC zones* that include *computer rooms* based on climate zone.

e. *Residential associated HVAC zones* shall use *system* type 3 or 4 based on climate zone.

G3.2.1.3 For baseline *HVAC systems* 1, 2, 3, 4, 9, 10, 11, 12, and 13, each *HVAC zone* or *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 *HVAC zones* or *thermal blocks* can be grouped for modeling purposes.

Exception to G3.2.1.3: Baseline *system* 5 or 7 serving laboratory *spaces* in accordance with Section G3.2.1.2(b).

G3.2.1.4 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 design*. 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*.

G3.2.1.5 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 design*. 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*.

G3.2.1.6 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 system* types in Table G3.1.1-4 shall be used.

G3.2.1.6.1 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*.

G3.2.1.6.2 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.

G3.2.1.6.3 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.

G3.2.1.6.4 On-Site Distribution Pumps. All on-*site* distribution *pumps* shall be modeled in both the *proposed design* and *base building design*.

G3.2.1.7 Modeling Building Envelope Air Leakage. The *air leakage* rate of the *building envelope* (I_{75Pa}) at a pressure differential of 75 Pa (0.30 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,

$$I_{FLR} = 0.112 \times I_{75Pa} \times S/A_{FLR}$$

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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 75 Pa (0.30 in. of water)

Q = volume of air in cfm flowing through the *building envelope* when subjected to a pressure differential of 75 Pa (0.30 in. of water), in accordance with ASTM E 779, ASTM E1827, or ASTM E3158

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

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 to G3.2.1.7: 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.

G3.2.2 General Baseline HVAC System Requirements. *HVAC systems* in the *baseline building design* shall conform with the general provisions in this section.

G3.2.2.1 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 G3.5.1 through G3.5.6. Where multiple *HVAC zones* are combined into a single *thermal block* in accordance with Table G3.1, the efficiencies (for baseline HVAC System Types 3, 4, 9, and 10) taken from Tables G3.5.1, G3.5.2, and G3.5.5 shall be based on the *equipment* capacity of the *thermal block* divided by the number of *HVAC zones*. HVAC System Types 5 or 6 efficiencies taken from Table G3.5.1 shall be based on the cooling *equipment* capacity of a single *story* when grouping identical *stories* in accordance with Section G3.2.1.1(a)(4). Fan *energy* shall be modeled separately according to Section G3.2.1.7.

$COP_{nfcooling}$ 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.

The sets of performance curves specified in Table J-2 should be used to represent part-load performance of chillers in the *baseline building design.* When using performance curves from Normative Appendix J, chiller minimum part-load ratio (ratio of load to available capacity at a given simulation time step) and minimum compressor unloading ratio (part-load ratio below which the chiller capacity cannot be reduced by unloading and chiller is false loaded) shall be equal to 0.25. *Simulation programs* that do not use performance curves are permitted to use an alternative simulation method that results in the same performance as the curves described in Normative Appendix J.

G3.2.2.2 Equipment Capacities. *System* coil capacities for the *baseline building design* shall be based on sizing runs for each *orientation* in accordance with Table G3.1, No. 5[a] and Section G3.2.2.2.1, and shall be oversized by 15% for cooling and 25% for heating. 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. Plant capacities shall be based on coincident loads.

G3.2.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine baseline *equipment* capacities shall be based on design days developed using *heating design temperatures*, *cooling design temperature*, and *cooling design wet-bulb temperature*. For cooling sizing runs, schedules for internal loads,

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including those used for infiltration, occupants, lighting, gas and electricity using *equipment*, shall be equal to the highest hourly value used in the annual simulation runs and applied to the entire design day. For heating sizing runs, schedules for internal loads, including those used for occupants, lighting, gas and electricity using *equipment*, shall be equal to the lowest hourly value used in the annual simulation runs, and schedules for infiltration shall be equal to the highest hourly value used in the annual simulation runs and applied to the entire design day.

Exception to G3.2.2.2.1: For cooling sizing runs in *residential dwelling units*, the infiltration, occupants, lighting, gas and electricity using *equipment* hourly schedule shall be the same as the most used hourly weekday schedule from the annual simulation.

G3.2.2.3 Unmet Loads. *Unmet load hours* for the *proposed design* or *baseline building design* 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.

G3.2.2.4 Ventilation. Minimum *ventilation system outdoor air* intake flow shall be the same for the *proposed design* and *baseline building design*.

Exceptions to G3.2.2.4:

1. When modeling *demand control ventilation* in the *proposed design* in *systems* with *outdoor air* capacity less than or equal to 3000 cfm serving areas with an average *design capacity* of 100 people per 1000 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, 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*, 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*.

G3.2.2.5 Economizers. *Air economizers* shall not be included in baseline *HVAC Systems* 1, 2, 9, and 10. Integrated *air economizer* control shall be included in baseline *HVAC Systems* 3 through 8, and 11, 12, and 13 based on climate as specified in Table G3.2.2.5.

Exceptions to G3.2.2.5: 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 Standard 62.1, Section 6.1.2. 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 G3.2.2.5.1.

G3.2.2.5.1 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*.

G3.2.2.6 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb fixed switch with *set-point* temperatures in accordance with the values in Table G3.2.2.6.

G3.2.2.7 Design Airflow Rates

G3.2.2.7.1 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

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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 to G3.2.2.7.1:

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*.

G3.2.2.7.2 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 *set point* of 105°F and the design *space*-heating temperature *set point*, 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 or fans 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*.

G3.2.2.8 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,

$$P_{fan} = \text{CFM}_s \times 0.3$$

For *Systems* 3 through 8, and 11, 12, and 13,

$$P_{fan} = \text{bhp} \times 746/\text{fan motor } \textit{efficiency}$$

For *Systems* 9 and 10 (supply fan),

$$P_{fan} = \text{CFM}_s \times 0.3$$

For *Systems* 9 and 10 (non-*mechanical cooling* fan if required by Section G3.2.2.7.2),

$$P_{fan} = \text{CFM}_{nmc} \times 0.054$$

where

P_{fan}	=	electric power to fan motor, W
bhp	=	brake horsepower of baseline fan motor fromTable G3.2.2.8
fan motor *efficiency*	=	the *efficiency* for the next motor size greater than the bhp from Table G3.2.2.8
CFM_s	=	the baseline *system* maximum design supply fan airflow rate, cfm
CFM_{nmc}	=	the baseline non-*mechanical cooling* fan airflow, cfm

G3.2.2.8.1 The calculated *system* fan power shall be distributed to supply, return, exhaust, and relief fans in the same proportion as the *proposed design*.

G3.2.2.9 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.

Exceptions to G3.2.2.9: If any of these exceptions apply, exhaust air *energy* recovery shall not be included in the *baseline building design*:

1. *Systems* serving *spaces* that are not cooled and that are heated to less than 60°F.
2. *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*.
3. 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*.
4. Heating *systems* in Climate Zones 0 through 3.

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5. Cooling *systems* in Climate Zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
6. Where the largest exhaust source is less than 75% of the design *outdoor airflow*. This exception shall only be used if exhaust air *energy* recovery is not used in the *proposed design*.
7. *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*.
8. *Systems* serving laboratory *HVAC zones* with a total laboratory exhaust volume greater than 15,000 cfm.

G3.2.3 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.

G3.2.3.1 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.

G3.2.3.2 Type and Number of Boilers (Systems 1, 5, 7, 11, and 12). The *boiler* plant shall be natural draft, except as noted in Section G3.2.1.4. The *baseline building design boiler* plant shall be modeled as having a single *boiler* if the *baseline building design* plant serves a *gross 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.

G3.2.3.3 Hot-Water Supply Temperature (Systems 1, 5, 7, 11, and 12). Hot-water design supply temperature shall be modeled as 180°F and design return temperature as 130°F.

G3.2.3.4 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 to G3.2.3.4: *Systems* served by purchased heat.

G3.2.3.5 Hot-Water Pumps (Systems 1, 5, 7, 11, and 12). 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 *pumps* shall only be enabled when a load exists on the associated hot-water loop. 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 to G3.2.3.5: The *pump* power for *systems* using purchased heat shall be 14 W/gpm.

G3.2.3.6 Piping Losses (Systems 1, 5, 7, 8, 11, 12, and 13). *Piping* losses shall not be modeled in either the *proposed design* or *baseline building design* for hot-water, chilled-water, or steam *piping*.

G3.2.3.7 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 G3.2.3.7 based on the peak coincident cooling load of baseline *HVAC systems* using chilled water.

Exception to G3.2.3.7: *Systems* using purchased chilled water shall be modeled in accordance with Section G3.2.1.6.

G3.2.3.8 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.

G3.2.3.9 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.

Exception to G3.2.3.9:

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 *set point* 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.

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G3.2.3.10 Chilled-Water Pumps (Systems 7, 8, 11, 12, and 13). 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. Chilled-water *pumps* shall only be enabled when a load exists on the associated chilled-water loop. 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 13 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 to G3.2.3.10: 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.

G3.2.3.11 Heat Rejection (Systems 7, 8, 11, 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 10°F:

$$\text{Approach}_{10°F}\ \text{Range} = 25.72 - (0.24 \times \text{WB})$$

where WB is the 0.4% *evaporation design wet-bulb temperature* (°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 G3.2.3.11, 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 *fluid economizer*, the *baseline building design* condenser-water-*pump* power shall be increased by 3 W/gpm for flow associated with the *fluid economizer*. Each chiller shall be modeled with separate condenser-water and chilled-water *pumps* interlocked to operate with the associated chiller.

G3.2.3.12 Supply Air Temperature Reset (Systems 5 through 8 and 11). The air temperature for cooling shall be *reset* higher by 5°F under the minimum cooling load conditions.

G3.2.3.13 VAV Minimum Flow Set Points (Systems 5 and 7). Minimum volume *set points* 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 to G3.2.3.13: *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.

G3.2.3.14 Fan Power and Control (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 *set points* 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 *set point* shall be constant at the *design condition*.

G3.2.3.15 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 G3.2.3.15.

G3.2.3.16 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%

G3.2.3.17 System 11 Supply Air Temperature and Fan Control. Minimum volume *set point* 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 *set point* shall be *reset* from minimum supply air temperature at 50% cooling

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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.

G3.2.3.18 Dehumidification (Systems 3 through 8 and 11, 12, and 13). If the *proposed design HVAC systems* have *humidistatic controls*, then the *baseline building design* shall use *mechanical cooling* for dehumidification and shall have *reheat* available to avoid overcooling. When the *baseline building design HVAC system* does not comply with any of the exceptions in Section 6.5.2.3, then only 25% of the *system reheat energy* shall be included in the *baseline building performance*. The *reheat* type shall be the same as the *system* heating type.

G3.2.3.19 Preheat Coils (Systems 5 through 8). The baseline *system* shall be modeled with a preheat coil controlled to a fixed *set point* 20°F less than the maximum design heating temperature *set point* of the *HVAC zones* served by the *system.*

G3.3 Performance Calculations for Other Alterations

G3.3.1 Proposed Building Performance. The simulation model for calculating the *proposed building performance* shall be developed in accordance with the requirements in Table G3.1, Proposed Building Performance column and the following additional requirements:

a. New and retrofitted *systems* and *equipment* shall be consistent with design documents.
b. Systems and *equipment* excluded from the scope of retrofit shall reflect the existing conditions.

G3.3.2 Baseline Building Performance

G3.3.2.1 General Approach. *System* and *equipment* included in the scope of retrofit shall be modeled at *efficiency* levels meeting the mandatory and prescriptive requirements in Sections 5 through 10 and as described in this section. All other baseline *systems* and *equipment* shall be modeled the same as in the *proposed design.*

G3.3.2.2 Schedules. Schedules modeled in the *baseline design* are allowed to differ from the *proposed design* following Table G3.1(4), Baseline Building Performance column, Exceptions 1 through 3.

G3.3.2.3 Opaque Assemblies. *Opaque* assemblies shall be modeled with *U-factors* meeting the requirements in Section 5.1.3.

G3.3.2.4 Fenestration. *Fenestration U-factor*, *SHGC*, and *VT* shall be modeled as meeting the requirements in Section 5.1.3.

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.*

G3.3.2.5 Air Leakage. When Section 5.4.3.1.3 applies, the *air leakage* rate of the *building envelope* (I_{75Pa}) shall be equal to 0.35 cfm/ft^2 of *building envelope* area at a pressure differential of 75 Pa (0.30 in. of water). The *air leakage* rate shall be converted to appropriate units for the simulation software using the same method as the *proposed design*.

G3.3.2.6 Interior Lighting. Interior *lighting power density* shall be modeled as meeting Section 9.1.1.3.1 using applicable allowances in Section 9.5.2.1. Lighting controls shall be modeled as meeting Section 9.1.1.3.1.

G3.3.2.7 Exterior Lighting. Tradable exterior lighting shall be modeled as meeting Section 9.1.1.3.2.

G3.3.2.8 HVAC Systems

a. Baseline *HVAC system* types shall be the same as the *proposed design*.

   Exception to G3.3.2.8(a): If the *proposed design* includes variable refrigerant flow heat pumps or *single-zone systems* with *electric resistance* heat, then air source heat pumps shall be used in the *baseline design*.
b. *Baseline systems* shall meet the requirements in Section 6.1.3. Chillers shall meet the *efficiency* requirements in Table 6.8.1-3 using Path A or Path B, the same as the *proposed design*. If the *proposed design* meets both Path A and Path B requirements, Path A shall be used.
c. Where the *efficiency* rating includes supply fan *energy*, calculate the minimum $COP_{nfcooling}$ and $COP_{nfheating}$ in accordance with Section 12.5.2(c).
d. Fan *system efficiency* (bhp per cfm of supply air, including the effect of belt losses but excluding motor and motor drive losses) shall be the same as the *proposed design* or up to the limit prescribed in Section 6.5.3.1, whichever is smaller. If this limit is reached, each fan shall be proportionally reduced in brake horsepower until the limit is met. Fan electrical power shall then be determined by adjusting the calcu-

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lated fan hp by the minimum motor *efficiency* prescribed by Section 10.4.1 for the appropriate motor size for each fan.

Exception to G3.3.2.8(d): When a *proposed design* includes *energy* recovery but it is not required in the *baseline building design* per Section 6.5.6, the fan power of the baseline *system* shall be equal to either the *proposed design system* or the fan power limit in Section 6.5.3.1 calculated without fan power credit for *energy* recovery, whichever is less.

e. The *equipment* capacities for the *baseline design* shall be sized proportionally to the capacities in the *proposed design* based on sizing runs—i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the *proposed design* and *budget building design*.

G3.3.2.9 Service *Water Heating Systems.* *Service water heating systems* shall be modeled as meeting Section 7.1.4. *Service water heating energy* use can be documented to be reduced as allowed in Table G3.1(11) Baseline Building Performance column exceptions to (g).

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Table G3.1.1-1 Baseline Building Vertical Fenestration

Building Area Types[a]	Baseline Building Vertical Fenestration Area as a Percentage of 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
Automotive facility	Gas storage *water heater*
Convenience store	*Electric resistance water heater*
Convention center	*Electric resistance* storage *water heater*
Courthouse	*Electric resistance* storage *water heater*
Dining: Bar lounge/leisure	Gas storage *water heater*
Dining: Cafeteria/fast food	Gas storage *water heater*
Dining: Family	Gas storage *water heater*
Dormitory	Gas storage *water heater*
Exercise center	Gas storage *water heater*
Fire station	Gas storage *water heater*
Grocery store	Gas storage *water heater*
Gymnasium	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*
Performing arts theater	Gas storage *water heater*
Police station	*Electric resistance* storage *water heater*
Post office	*Electric resistance* storage *water heater*
Religious *facility*	*Electric resistance* storage *water heater*
Retail	*Electric resistance* storage *water heater*
School/university	Gas storage *water heater*
Sports arena	Gas storage *water heater*
Town hall	*Electric resistance* storage *water heater*
Transportation	*Electric resistance* storage *water heater*
Warehouse	*Electric resistance* storage *water heater*
Workshop	*Electric resistance* storage *water heater*
All others	Gas storage *water heater*

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Table G3.1.1-3 Baseline HVAC System Types

Building Area Types [a], Number of Stories [b], and Combined Floor Area [c]	Climate Zones 3B, 3C, and 4 to 8	Climate Zones 0 to 3A
Residential	*System* 1—*PTAC*	*System* 2—*PTHP*
Public assembly area smaller than 120,000 ft^2	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Public assembly area equal to or larger than 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 in a *building* that is 1 or 2 *stories*	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Hospital that is either • larger than 150,000 ft^2 or • in a *building* greater than 5 *stories*.	*System* 7—*VAV* with *reheat*	*System* 7—*VAV* with *reheat*
Hospital—all other	*System* 5—Packaged *VAV* with *reheat*	*System* 5—Packaged *VAV* with *reheat*
Other *Nonresidential* area that is both • smaller than 25,000 ft^2 and • in a *building* 3 *stories* or fewer.	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Other *Nonresidential* area that is both • smaller than 25,000 ft^2 and • in a *building* with 4 or 5 *stories*.	*System* 5—Packaged *VAV* with *reheat*	*System* 6—Packaged *VAV* with PFP boxes
Other *nonresidential* area that is both • 25,000 ft^2 to 150,000 ft^2 and • in a *building* that is 5 *stories* or fewer.	*System* 5—Packaged *VAV* with *reheat*	*System* 6—Packaged *VAV* with PFP boxes
Other *Nonresidential* area that is either • larger than 150,000 ft^2 or • in a *building* greater than 5 *stories*.	*System* 7—*VAV* with *reheat*	*System* 8—*VAV* with PFP boxes

a. *Building* area type determined in accordance with Section G3.2.1.1.
b. The total number of *stories* in a *building,* including above-grade and below-grade *stories* but not including *stories* solely devoted to parking.
c. Combined *gross conditioned floor area* and *semiheated floor area,* of the *building* area type, based on the requirements of Section G3.2.1.1.

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*

a. For purchased chilled water and purchased heat, see Section G3.2.1.3.
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*.

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Table G3.2.2.5 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.

Table G3.2.2.6 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

Table G3.2.2.8 Baseline Fan Brake Horsepower

Baseline Fan Motor Brake Horsepower		
Constant-Volume Systems 3, 4, 12, and 13	**Variable-Volume Systems 5 to 8**	**Variable-Volume System 11**
$CFM_s \times 0.00094 + A$	$CFM_s \times 0.0013 + A$	$CFM_s \times 0.00062 + A$

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 G3.2.2.9.

Table G3.2.3.7 Type and Number of Chillers

Peak Coincident Cooling Load of Baseline HVAC Systems Using Chilled Water	Number and Type of Chillers
≤300 tons	1 liquid-cooled screw chiller
>300 tons, <600 tons	2 liquid-cooled screw chillers sized equally
≥600 tons	2 liquid-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

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Table G3.2.3.11 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

Table G3.2.3.15 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	0.83
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 and

PLR_{fan} = fan part-load ratio (current cfm/design cfm)

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Table G3.4-1 Performance Rating Method Building Envelope Requirements for Climate Zones 0 and 1 (A,B)

Opaque Elements	Nonresidential			Residential			Semiheated		
	Assembly Maximum			Assembly Maximum			Assembly Maximum		
Roofs									
Insulation entirely above deck	U-0.063			U-0.063			U-1.282		
Walls, Above-Grade									
Steel-framed	U-0.124			U-0.124			U-0.352		
Wall, Below-Grade									
Below-grade wall	C-1.140			C-1.140			C-1.140		
Floors									
Steel-joist	U-0.350			U-0.350			U-0.350		
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-1.450			U-1.450		
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-1.36	$SHGC_{all}$-0.36	VT_{all}-0.40	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-2 Performance Rating Method Building Envelope Requirements for Climate Zone 2 (A,B)*

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-0.124	U-0.352
Wall, Below-Grade			
Below-grade wall	C-1.140	C-1.140	C-1.140
Floors			
Steel-joist	U-0.052	U-0.052	U-0.350
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-1.450	U-1.450

Fenestration	Nonresidential Assembly Max. U	Nonresidential Assembly Max. SHGC	Nonresidential Visible Transmittance	Residential Assembly Max. U	Residential Assembly Max. SHGC	Residential Visible Transmittance	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC	Semiheated Visible Transmittance
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-1.36	$SHGC_{all}$-0.36	VT_{all}-0.40	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-3 Performance Rating Method Building Envelope Requirements for Climate Zone 3 (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-0.084			U-0.352		
Wall, Below-Grade									
Below-grade wall	C-1.140			C-1.140			C-1.140		
Floors									
Steel-joist	U-0.052			U-0.052			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**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-0.57	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-0.57	$SHGC_{all}$-0.25	VT_{all}-0.28	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.69	$SHGC_{all}$-0.36	VT_{all}-0.40	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-0.69	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-0.69	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
Fenestration (for Zone 3C)	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-1.22	$SHGC_{all}$-0.61	VT_{all}-0.67	U_{all}-1.22	$SHGC_{all}$-0.61	VT_{all}-0.67	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-1.22	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.61	VT_{all}-0.67	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-1.22	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-1.22	$SHGC_{all}$-0.34	VT_{all}-0.37	U_{all}-1.22	$SHGC_{all}$-0.34	VT_{all}-0.37	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-1.36	$SHGC_{all}$-0.61	VT_{all}-0.67	U_{all}-1.36	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-1.36	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.36	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-4 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**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.58	$SHGC_{all}$-0.36	VT_{all}-0.40	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-0.69	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.58	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-5 Performance Rating Method Building Envelope Requirements for Climate Zone 5 (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-0.173
Walls, Above-Grade			
Steel-framed	U-0.084	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	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.69	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-0.69	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.69	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-6 Performance Rating Method Building Envelope Requirements for Climate Zone 6 (A,B)*

Opaque Elements	Nonresidential	Residential	Semiheated
	Assembly Maximum	Assembly Maximum	Assembly Maximum
Roofs			
Insulation entirely above deck	U-0.063	U-0.063	U-0.173
Walls, Above-Grade			
Steel-framed	U-0.084	U-0.064	U-0.124
Wall, Below-Grade			
Below-grade wall	C-1.140	C-0.119	C-1.140
Floors			
Steel-joist	U-0.038	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-0.500	U-0.700
Nonswinging	U-0.500	U-0.500	U-1.450

Fenestration	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.58	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-0.69	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.58	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-7 Performance Rating Method Building Envelope Requirements for Climate Zone 7*

Opaque Elements	Nonresidential	Residential	Semiheated
	Assembly Maximum	Assembly Maximum	Assembly Maximum
Roofs			
Insulation entirely above deck	U-0.063	U-0.063	U-0.173
Walls, Above-Grade			
Steel-framed	U-0.064	U-0.064	U-0.124
Wall, Below-Grade			
Below-grade wall	C-0.119	C-0.119	C-1.140
Floors			
Steel-joist	U-0.038	U-0.038	U-0.052
Slab-on-Grade Floors			
Unheated	F-0.730	F-0.540	F-0.730
Opaque Doors			
Swinging	U-0.700	U-0.500	U-0.700
Nonswinging	U-0.500	U-0.500	U-1.450

Fenestration	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.57	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of *Roof*									
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.68	VT_{all}-0.75	U_{all}-0.69	$SHGC_{all}$-0.64	VT_{all}-0.70	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-0.69	$SHGC_{all}$-0.64	VT_{all}-0.70	U_{all}-0.69	$SHGC_{all}$-0.64	VT_{all}-0.70	U_{all}-1.36	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-8 Performance Rating Method Building Envelope Requirements for Climate Zone 8*

Opaque Elements	Nonresidential			Residential			Semiheated		
	Assembly Maximum			Assembly Maximum			Assembly Maximum		
Roofs									
Insulation entirely above deck	U-0.048			U-0.048			U-0.093		
Walls, Above-Grade									
Steel-framed	U-0.064			U-0.055			U-0.124		
Wall, Below-Grade									
Below-grade wall	C-0.119			C-0.119			C-1.140		
Floors									
Steel-joist	U-0.038			U-0.032			U-0.052		
Slab-on-Grade Floors									
Unheated	F-0.540			F-0.520			F-0.730		
Opaque Doors									
Swinging	U-0.500			U-0.500			U-0.700		
Nonswinging	U-0.500			U-0.500			U-1.450		
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**	**Assembly Max. U**	**Assembly Max. SHGC**	**Visible Transmittance**
Vertical Glazing, % of *Wall*									
0% to 10.0%	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
10.1% to 20.0%	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
20.1% to 30.0%	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
30.1% to 40.0%	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-0.46	$SHGC_{all}$-0.40	VT_{all}-0.44	U_{all}-1.22	$SHGC_{all}$-0.40	VT_{all}-0.44
Skylight All, % of Roof									
0% to 2.0%	U_{all}-0.58	$SHGC_{all}$-0.55	VT_{all}-0.61	U_{all}-0.58	$SHGC_{all}$-0.55	VT_{all}-0.61	U_{all}-0.81	$SHGC_{all}$-0.55	VT_{all}-0.61
2.1%+	U_{all}-0.58	$SHGC_{all}$-0.55	VT_{all}-0.61	U_{all}-0.58	$SHGC_{all}$-0.55	VT_{all}-0.61	U_{all}-0.81	$SHGC_{all}$-0.55	VT_{all}-0.61

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Table G3.4-9 Heated Space Criteria

Climate Zone	Heating Output, Btu/h·ft^2
0, 1, 2	>5
3	>10
4, 5	>15
6,7	>20
8	>25

Table G3.5.1 Performance Rating Method Air Conditioners (efficiency ratings excluding supply fan power)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Efficiency	Test Procedure
Air conditioners, air-cooled	<65,000 Btu/h	All	Single-package	3.0 $COP_{nfcooling}$	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h		Split-*system* and single-package	3.5 $COP_{nfcooling}$	AHRI 340/360
	≥135,000 Btu/h and <240,000 Btu/h			3.4 $COP_{nfcooling}$	
	≥240,000 Btu/h and <760,000 Btu/h			3.5 $COP_{nfcooling}$	
	≥760,000 Btu/h			3.6 $COP_{nfcooling}$	

Table G3.5.2 Performance Rating Method Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements (efficiency ratings excluding supply fan power)

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	3.0 $COP_{nfcooling}$	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h		Split-*system* and single-package	3.4 $COP_{nfcooling}$	AHRI 340/360
	≥135,000 Btu/h and <240,000 Btu/h			3.2 $COP_{nfcooling}$	
	≥240,000 Btu/h			3.1 $COP_{nfcooling}$	
Air-cooled (heating mode)	<65,000 Btu/h (cooling capacity)		Single-package	3.4 $COP_{nfheating}$	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h (cooling capacity)		47°F db/43°F wb *outdoor air*	3.4 $COP_{nfheating}$	AHRI 340/360
			17°F db/15°F wb *outdoor air*	2.3 $COP_{nfheating}$	
	≥135,000 Btu/h (cooling capacity)		47°F db/43°F wb *outdoor air*	3.4 $COP_{nfheating}$	
			17°F db/15°F wb *outdoor air*	2.1 $COP_{nfheating}$	

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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
Liquid-cooled, electrically operated, positive displacement (rotary screw and scroll)	<150 tons	*kW*/ton	0.7903 FL 0.6763 *IPLV*.IP	AHRI 550/590
	≥150 tons and <300 tons		0.7178 FL 0.6280 *IPLV*.IP	
	≥300 tons		0.6395 FL 0.5719 *IPLV*.IP	
Liquid-cooled, electrically operated, centrifugal	<150 tons	*kW*/ton	0.7034 FL 0.6699 *IPLV*.IP	AHRI 550/590
	≥150 tons and <300 tons		0.6337 FL 0.5961 *IPLV*.IP	
	≥300 tons		0.5766 FL 0.5495 *IPLV*.IP	

Table G3.5.4 Performance Rating Method Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps (efficiency ratings excluding supply fan power)

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
PTAC (cooling mode)	All capacities	95°F db *outdoor air*	3.2 $COP_{nfcooling}$	AHRI 310/380
PTHP (cooling mode)	All capacities	95°F db *outdoor air*	3.1 $COP_{nfcooling}$	AHRI 310/380
PTHP (heating mode)	All capacities		3.1 $COP_{nfheating}$	AHRI 310/380

Table G3.5.5 Performance Rating Method 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

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Table G3.5.6 Performance Rating Method 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 Performance Rating Method Lighting Power Densities for Building Exteriors

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 ft wide	1.0 W/linear foot
	Walkways 10 ft wide or greater	0.2 W/ft^2
	Plaza areas	
	Special feature areas	
	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

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Table G3.7-1 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]
Atrium		
<20 ft in height	0.0375 per foot in total height	10%
≥20 ft and ≤40 ft in height		
>40 ft in height	0.50 + 0.025 per foot in total height	10%
Audience Seating Area		
Auditorium	0.90	10%
Convention center	0.70	10%
Gymnasium	0.40	10%
Motion picture theater	1.20	10%
Performing arts theater	2.60	10%
In a sports arena	0.40	10%
All other audience seating area	0.90	10%
Banking Activity Area	1.50	10%
Classroom/Lecture Hall/Training Room		
Preschool through 12th grade, laboratory, and shop classrooms	1.40	30%
All other classroom/lecture hall/training room	1.40	None
Computer Room	2.14	35%
Conference/Meeting/Multipurpose Room	1.30	None
Copy/Print Room	0.90	10%
Corridor	0.50	25%
Courtroom	1.90	10%
Dining Area		
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%
Equipment Room	1.20	10%
Food Preparation Area	1.20	30%
Guest Room	1.14	45%
Laboratory		
Preschool through 12th grade, laboratory, and shop classrooms	1.40	30%
All other laboratory except in or as a classroom	1.40	10%

a. In cases where both a common *space* type and a *building*-specific *space* type are listed, the *building*-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%.

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Table G3.7-1 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]
Laundry/Washing Area	0.60	10%
Loading Dock, Interior	0.59	10%
Lobby		
Elevator	0.80	25%
Hotel	1.10	25%
Motion picture theater	1.10	25%
Performing arts theater	3.30	25%
All other lobbies	1.30	25%
Locker Room	0.60	25%
Lounge/Breakroom		
Mother's/wellness room	1.13	24%
All other lounge/breakroom	1.20	None
Office		
Enclosed and ≤250 ft^2	1.10	30%
Enclosed and >250 ft^2	1.10	30%
Open plan	1.10	15%[c]
Parking Area, Interior		
Daylight transition zone	1.75	30%
All other parking areas and drive areas	0.18	30%
Pharmacy Area	1.20	10%
Restroom	0.90	45%
Sales Area	1.70	15%
Seating Area, General	0.68	10%
Security Screening		
Airport/bus/ship/train/transportation screening	1.53	0%
Airport/bus/ship/train/transportation screening queue	0.92	0%
General security screening	1.06	0%
Stairwell	0.60	75%
Storage Room		
≥50 ft^2	0.80	45%
<50 ft^2	0.80	45%
Vehicular Maintenance Area	0.70	10%
Workshop		
Preschool through 12th grade, laboratory, and shop classrooms	1.40	30%
All other workshops	1.90	10%

a. In cases where both a common *space* type and a *building*-specific *space* type are listed, the *building*-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%.

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Table G3.7-2 Performance Rating Method Lighting Power Density Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method

Building-Specific Space Types[a]	Lighting Power Density, W/ft^2	Occupancy Sensor Reduction[b]
Casino—Gaming Area		
Betting/sportsbook/keno/bingo area	1.34	0%
High-limit game area	2.78	0%
Slot machine/digital gaming area	0.90	0%
Table games area	1.80	0%
Convention Center—Exhibit Space	1.30	35%
Correctional Facilities		
Audience seating area	0.70	10%
Classroom	1.30	None
Confinement cells	0.90	10%
Dining area	1.30	35%
Dormitory—Living Quarters	1.11	10%
Facility for the Visually Impaired		
Chapel (used primarily by residents)	2.77	10%
Corridor (used primarily by residents)	1.15	25%
Dining (used primarily by residents)	3.32	35%
Lobby (used primarily by residents)	2.26	25%
Recreation room (used primarily by residents)	3.02	10%
Restroom (used primarily by residents)	1.52	45%
Fire Station—Sleeping Quarters	0.30	10%
Gymnasium/Fitness Center		
Exercise area	0.90	35%
Playing area	1.40	35%
Health Care Facility		
Control room (MRI/CT/Radiology/PET)	2.14	10%
Exam/treatment room	1.50	10%
Hospital corridor	1.00	25%
Lounge	0.80	None
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%

a. In cases where both a common *space* type and a *building*-specific *space* type are listed, the *building*-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%.

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Table G3.7-2 Performance Rating Method Lighting Power Density Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method *(Continued)*

Building-Specific Space Types[a]	Lighting Power Density, W/ft^2	Occupancy Sensor Reduction[b]
Physical therapy room	0.90	10%
Recovery room	0.80	10%
Telemedicine	2.21	10%
Library		
Reading area	1.20	15%
Stacks	1.70	15%
Manufacturing Facility		
Detailed manufacturing area	2.10	10%
Low bay area (<25 ft floor-to-ceiling height)	1.20	10%
High bay area (25 to 50 ft floor-to-ceiling height)	1.70	10%
Extra-high bay area (>50 ft floor-to-ceiling height)	1.32	10%
Museum		
General exhibition area	1.00	10%
Restoration room	1.70	10%
Performing Arts Theater—Dressing Room	0.64	0%
Post Office—Sorting Area	1.20	10%
Religious Facility		
Audience seating area	1.70	10%
Fellowship hall	0.90	10%
Worship/pulpit/choir area	2.40	10%
Retail Facilities		
Dressing/fitting room	0.89	10%
Hair care	1.04	10%
Manicure/pedicure	0.70	10%
Mall concourse	1.70	10%
Massage	0.81	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%
Natatorium		
Class I facility	3.57	0%

a. In cases where both a common *space* type and a *building*-specific *space* type are listed, the *building*-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%.

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Table G3.7-2 Performance Rating Method Lighting Power Density Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method *(Continued)*

Building-Specific Space Types[a]	Lighting Power Density, W/ft^2	Occupancy Sensor Reduction[b]
Class II facility	2.38	0%
Class III facility	1.42	0%
Class IV facility	0.48	0%
Transportation Facility		
Airport hanger	2.25	0%
Baggage/carousel area	1.00	10%
Airport concourse	0.60	10%
Passenger loading area	1.11	10%
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*-specific *space* type are listed, the *building*-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%.

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Table G3.8 Performance Rating Method Lighting Power Densities Using the Building Area Method

Building Area Type	Lighting Power Density, 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/motel	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 facility	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

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Table G3.9.1 Performance Rating Method Motor Efficiency Requirements

Shaft Input Power	Full-Load Motor Efficiency for Modeling, %
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 G3.9.3

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

Shaft Input Power	Full-Load Motor Efficiency for Modeling, %
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.

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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	
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.

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(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 H
ADDITIONAL GUIDANCE FOR VERIFICATION, TESTING, AND COMMISSIONING

This appendix provides guidance on best practices for stand-alone *functional performance testing* (*FPT*) and *commissioning* processes (including *FPT*) that relate to Sections 4.2.5, 5.9, 6.9, 7.9, 8.9, 9.9, 10.9, 12.2(e), and G1.2.1(e) of Standard 90.1. This appendix also contains information on the typical overall *commissioning* process that goes beyond the requirements of Standard 90.1. It also addresses how to integrate suggested *commissioning* and testing activities that are specific to ANSI/ASHRAE/IES Standard 90.1 required controls, *systems*, and assemblies into the typical *commissioning* process. The requirements for verification, testing, and *commissioning* in Standard 90.1 focus specifically on direct support of Standard 90.1 requirements; however, there are additional items often included in a more comprehensive *commissioning* process that support Standard 90.1 requirements, with these examples:

a. *Commissioning building envelope* moisture integrity is not required by Standard 90.1; however, preventing moisture damage to the envelope assembly supports the goals of Standard 90.1.
b. *Commissioning* HVAC controls to ensure comfort are not required by Standard 90.1; however, controls that maintain comfort properly result in longer term operation of *automatic energy efficiency* control elements that support the goals of Standard 90.1.
c. *Commissioning* daylight responsive controls beyond functional testing of stepped lighting reduction for *energy efficiency* is not required by Standard 90.1; however, designing and *commissioning* a *continuous dimming* daylight *system* with nondistracting operation and proper illumination levels reduces occupant disruption or complaints and helps ensure the longevity of the savings provided by the Standard 90.1 daylight responsive control requirements.

The information in this appendix provides suggested activities that will improve the likelihood that the *energy* performance defined by Standard 90.1 is achieved. *Commissioning* for full performance of the *systems* installed for *energy efficiency* avoids a significant investment being lost due to occupants disabling *energy efficiency* components due to disruption or not meeting non-*energy* criteria. The actual *energy efficiency* of a *building*, designed to meet or exceed the requirements of Standard 90.1, is dependent on its operational performance. Many provisions in Standard 90.1 rely on proper execution and verification in design, *construction*, and operation for their *energy* savings to occur, especially the proper operation of control *systems*. *Commissioning* can have a positive impact on *building* performance and compliance with Standard 90.1 by providing additional oversight and guidance to the design and *construction* team.

H1. BENEFITS OF AND RESOURCES FOR BUILDING COMMISSIONING

Common problems in *buildings* include incorrect installation of *building* insulation, discontinuity of air and thermal barriers, and nonfunctioning or poorly functioning lighting, HVAC, and other control *systems* that either are not properly configured or perform outside of intended parameters. These problems adversely affect *building energy efficiency* and increase *building* operating expenses. Achieving the intent of Standard 90.1 requires the *building*'s design, *construction*, and operation be in accordance with the standard and includes design and *construction* performance verification. Using the *commissioning* process, as defined in ASHRAE Standard 202 and Guideline 0, to verify that a new or renovated *building* performs in accordance with Standard 90.1 will improve the expected operational performance of the *building*. See Informative Appendix E for the following references to *commissioning* standards and guidelines:

a. ANSI/ASHRAE/IES Standard 202, *Commissioning Process for Buildings and Systems*, provides a standard overall approach for the *commissioning* process.
b. ASHRAE Guideline 0, *The Commissioning Process*, provides more detailed guidelines for steps in the *commissioning* process.
c. ASHRAE Guideline 1.1, *HVAC&R Technical Requirements for the Commissioning Process*, provides more detailed guidelines on the *commissioning* technical process and functional testing of *HVAC systems*.
d. IES DG 29, *The Commissioning Process Applied to Lighting and Control Systems*, provides more detailed guidelines on the *commissioning* technical process and functional testing of *lighting systems*.
e. ASTM Standard E2947, *Standard Guide for Building Enclosure Commissioning*, provides an overall guide for the process of testing of *building* enclosures.

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f. ASTM Standard E2813, *Standard Practice for Building Enclosure Commissioning*, provides more detailed guidelines on the verification and *commissioning* technical process and testing of *building* enclosure assemblies.
g. NEBB Procedural Standards, *Procedural Standards for Building Systems Commissioning*, establishes a uniform and systematic set of criteria for performing the technical *commissioning* process when applied to new *building systems*, such as mechanical, electrical, and *building envelope systems*.

Specific *functional performance tests*, statistical testing methods, or verification methods for selected items are not listed in this appendix, as they are covered in other *commissioning* industry documents and resources. They can be selected as the *commissioning* plan is developed by the owner and *commissioning provider*. Verification of many of the *system* controls can be streamlined by setting up trends in the *building* control *system* and observing control performance in actual operation. *Building* operation can also benefit from ongoing *commissioning* activity that is not covered here. Several *commissioning* organizations or government agencies make resources available to support the *commissioning* process:

a. ACG—Associated Air Balance Council Commissioning Group—AABC National Headquarters
b. ASHRAE—A leading organization in the development of standardized *commissioning* standards and guidelines
c. Association of Energy Engineers (AEE)
d. Building Commissioning Association (BCxA)—A leading professional association for membership and certification of *building commissioning* practitioners
e. Building Services Commissioning Association (Japan)
f. Commissioning Specialists Association (UK)
g. Hong Kong Building Commissioning Centre
h. National Conference on Building Commissioning (U.S.)
i. National Environmental Balancing Bureau (NEBB)—Certification program and manuals
j. National Institute of Building Sciences (NIBS)—Total *building commissioning*
k. California Commissioning Collaborative—A group of government, utility, and *building*-services professionals committed to developing and promoting *commissioning* practices in California
l. Energy Design Resources—Sponsored by Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison, and Southern California Gas
m. Federal Energy Management Program—Offers programs and resources for *energy efficiency* in operation of federal facilities
n. Oregon Department of Energy—Benefits of Commissioning, case study, tool kit of new and existing *commissioning* application materials, and the full text of *Commissioning for Better Buildings in Oregon*
o. U.S. DOE EERE *commissioning*

H2. RECOMMENDED MINIMUM QUALIFICATIONS AND INDEPENDENCE OF COMMISSIONING PROVIDERS AND FUNCTIONAL PERFORMANCE TESTING PROVIDERS

Section 4.2.5 requires *FPT providers* to be qualified and *commissioning providers* to have the necessary training, experience, and *FPT equipment*. The following can ensure the needed qualifications and independence for *building* project testing or *commissioning*:

a. Equipment: The *commissioning provider* or *FPT providers* should use the *equipment* necessary to perform the *commissioning* process and *FPT*. The *equipment* should be periodically calibrated in accordance with *manufacturer*'s specifications.
b. Personnel experience: The *commissioning provider* or *FPT providers* provide personnel experienced in conducting, supervising, or evaluating *function and performance testing*, inspections, and where applicable, performing *commissioning* activities prior to and subsequent to the tests. Where possible, the *commissioning provider* should have completed the *commissioning* process on not less than two projects of equal or larger scope and complexity, or should be able to demonstrate adequate experience and training in the fundamentals and application of the *commissioning* process.
c. Independence: The *FPT providers* and the *commissioning provider* meet independence criteria of Sections 4.2.5.1 and 4.2.5.2. It may be helpful for *commissioning provider* and *FPT providers* to disclose possible conflicts of interest so that objectivity can be confirmed.
d. Registration, licensure, or certification of *commissioning provider*: Where available, a *commissioning provider* should be registered or licensed in a relevant discipline or certified according to the provisions of ISO/IEC 17024 (See Informative Appendix E) or an equivalent certification process. A list of *commissioning* certifications available in the U.S. is maintained by NIST (www.wbdg.org).

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Table H-1 Verification or Commissioning Required by Building Size and Type

Level of Verification or Commissioning Required	Buildings <10,000 ft^2, Warehouse Use Buildings, or Buildings Using the Simplified Approach Option for HVAC Systems in Section 6.3	Other Buildings
Verification and *FPT*	✓	✓
Predesign phase and design phase *commissioning*		✓
Construction phase *commissioning*		✓

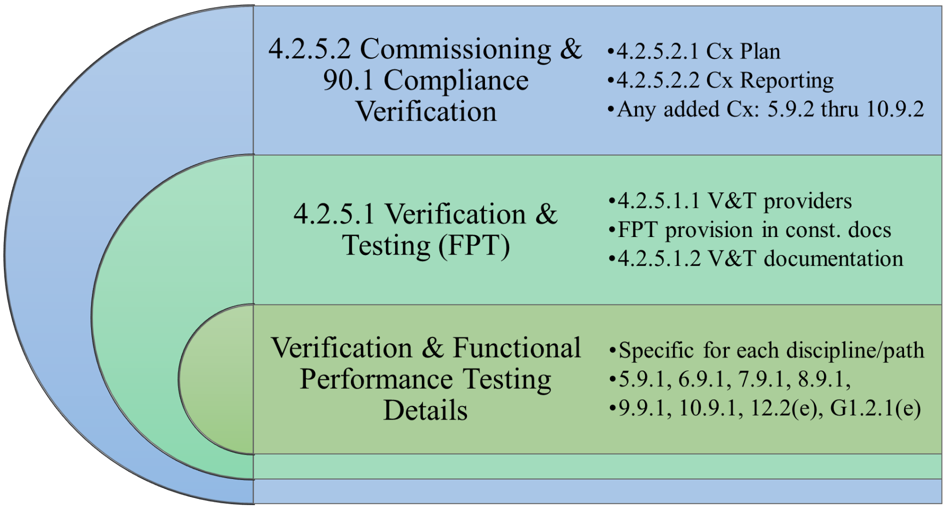

Figure H-1 Coordination of verification/FPT and commissioning requirements.

H3. OVERVIEW OF THE COMMISSIONING PROCESS

Table H-1 provides an overview of general requirements for verification or the *commissioning* process required by Section 4.2.5.

An overview of the relationship between the verification/*FPT* and *commissioning* requirements is shown in Figure H-1.

a. The core verification and *FPT* requirements are specified by discipline in Sections 5.9.1, 6.9.1, 7.9.1, 8.9.1, 9.9.1, 10.9.1, 12.2(e), and G1.2.1(e).
b. Provisions are established in the *construction documents* for verification and *FPT*, and *verification and testing (V&T) providers* are identified as required by Section 4.2.5.1.1.
c. The results of this verification and *FPT* are documented as specified in Section 4.2.5.1.2.

These core V&T requirements and documentation satisfy requirements for smaller *buildings*, warehouses, and *buildings* using the simplified approach for *HVAC systems*, which are exempted from *commissioning*.

In *buildings* where *commissioning* is required, the same verification and *FPT* requirements apply:

a. A *commissioning* plan is developed and completed according to Section 4.2.5.2.1.
b. The current edition of the standard does not require any additional testing for *commissioning* beyond what is required in the base Section 4.2.5.1 verification and *FPT* requirements.
c. In addition, there is a *commissioning* requirement for design review of verification of compliance with Standard 90.1 requirements.
d. The verification and *FPT* documentation is included in the *commissioning* reporting required in Section 4.2.5.2.2.

Table H-2 provides an overview of activities, documentation, and responsibilities that should be included in the *commissioning* process as defined by Standard 202 and Guideline 0. Not all of these activities are required by Standard 90.1, and the requirement sections are referenced in the "90.1 Section" column.

H4. STANDARD 90.1 ITEMS TO INCLUDE IN VERIFICATION, TESTING, OR COMMISSIONING

Table H-3 lists *systems* and requirements included in Standard 90.1 that can benefit from a verification or *commissioning* process. The Standard 90.1 section number and title are included, along with a list of sug-

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Table H-2 Typical Commissioning (Cx) Process Activities, Deliverables and Responsibilities [a]

Item	Activity	Deliverable	90.1 Section	Normally Provided by	Phase
1	Owner's Project Requirements (OPR)	OPR document	NR	Owner with assistance from design and *Cx* teams	Predesign
2	Basis of Design (BoD)	BoD document	NR	Design team	Design through construction
3	*Cx* plan	*Cx* plan document	4.2.5.2.2	*Cx provider* with input from owner, design team, and contractor	Predesign
4	Contractor *Cx* requirements	*Cx* specifications	4.2.5.1.1, 4.2.5.2.1, 6.9.2	Design team and *Cx provider*	Design
5	Design review, including Standard 90.1 compliance review	*Cx* design review report	4.2.5.2, 4.2.5.2.2	*Cx* provider	Design
6	Submittal review	Submittal review report [b]	NR	*Cx* provider	Construction
7	Commission designated systems, inspections, *FPT*	Installation, inspection, functional test reports, performance test reports [b]	4.2.5.1, 4.2.5.2	Contractors, *manufacturers*, *Cx provider,* and *Cx provider team*	Construction
8	Track identified issues to resolution	Issues and resolution log [b]	4.2.5.1, 4.2.5.2	*Cx provider* and team	Construction
9	*Systems* manual	*Systems* manual review	Review NR	Contractors with review by *Cx provider*	Construction
10	Training	Training plan and reports [b]	NR	Contractors and *manufacturers* with review by *Cx provider*	Final
11	Preliminary *Cx* report	Preliminary *Cx* report	4.2.5.2.1, 4.2.5.2.2	*Cx* provider	Construction
12	*Cx* activities during occupancy	Additional information and updates to reports [b]	NR	*Cx provider* and *building* operations	Final
13	Final *Cx* report	Final *Cx* Report	4.2.5.2.2	*Cx* provider	Final

a. NR = not required by Standard 90.1; *Cx* = *commissioning.*
b. Noted interim or partial deliverables are typically included in the preliminary and final *commissioning* reports.

gested items to verify in that section. There are specific verification, *commissioning*, or testing activities required by Standard 90.1 in Sections 4.2.5, 5.9, 6.9, 7.9, 8.9, 9.9, 10.9, 12.2(e), and G1.2.1(e). Table H-3 lists only the items in Standard 90.1 that would be beneficial to include in a *commissioning* scope. While these requirements cover many of the *building* components, they are not comprehensive, and there are benefits available from additional *commissioning* or testing. There are other items outside the scope of Standard 90.1 that would typically be included in a *commissioning* scope that are not covered here but that may improve the quality and reliability of the *building systems* and assemblies.

The suggested *commissioning* activities are intended to be included in a *commissioning* scope based on the *building* owner's perception of desired outcomes relative to the particular *building* program and location and based on the experience of the *commissioning provider*. The activities are summarized in a checklist format and are related to the requirements that are described in the noted subsections of Standard 90.1. The scope of the items to verify should include verification of compliance with Standard 90.1 requirements by documenting each item's applicability, inclusion, or exception. Included items should be verified for installation, proper configuration, and operation. Depending on the comprehensiveness of the *commissioning* effort, verification for certain items may be included at the design phase, *construction* phase, or both. Verification that the design and *construction* meet the requirements of the chosen compliance path in Standard 90.1 could be completed using the verification and compliance forms from the *Standard 90.1 User's Manual*. Table H-3 could be used as a *commissioning* scope development checklist, and for each item the status for the subject *building* could be noted as follows:

NA = not applicable (Either the item is not in the proposed *building*, an exception was used, or the item or prescriptive requirement was traded off in the performance path.)

Cx = commissioned, verified, or tested

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Table H-3 Standard 90.1 Items to Verify

Subsection	Subsection Title	Standard 90.1 Items to Verify for Proper Operation or Inclusion	Status
4.2.5.2	Building Commissioning Requirements	Document in sufficient detail compliance of the *building* and its components, assemblies, controls, and *systems* with required provisions of this standard.	
5.4.1	Insulation	Design details maintain continuity of thermal barrier.	

5.4.3.2	Continuous Air Barrier Design and Installation	Air barriers meet the following:
		• Air barrier design and installation per Section 5.4.3.2 and either
		  • whole-*building air leakage* testing per Section 5.4.3.1 or
		  • design and installation verification program performed in accordance with Section 5.4.3.1 and Section 5.9.1.2.	

5.8.3.1	Testing, Acceptable Materials, and Assemblies	Continuous air barrier materials and assemblies comply with specific *manufacturer* requirements or are tested for leakage resistance.	
5.8.3.2	Fenestration and Doors	*Fenestration* and *doors* have *manufacturer* documentation that *air leakage* does not exceed allowable *air leakage* rates.	
5.5.4.2	Fenestration Area	*Fenestration* to *wall* ratio and *skylight* to *roof* ratio meet either the prescriptive requirements or the *proposed design* in the performance path, depending on the compliance path used.	
5.8.1	Insulation	Insulation material meets design specifications and is continuous.	
5.9	Verification, Testing, and Commissioning	Envelope assemblies and *fenestration* comply with requirements. *Building envelope* performance is tested or verified.	
6.3.2	Criteria	HVAC *equipment* meets *efficiency* criteria and controls function properly.	
6.4.1	Equipment Efficiencies, Verification, and Labeling Requirements	*Equipment* selected meets the minimum *efficiency* requirements and is correctly *labeled.*	
6.4.2	Calculations	HVAC *equipment* matches load and *pump* head calculations.	
6.4.3.1/ 6.4.3.2	Zone Thermostatic Controls/ Set-Point Overlap Restriction	Zoning pattern and *dead band* setting configured properly, including *VAV* zone controls. Heating and cooling *set points* do not overlap.	
6.4.3.3	Off-Hour Controls	Off-hour control, *automatic* shutdown, *setback* controls, optimum start control, and zone isolation are properly configured where applicable.	
6.4.3.4	Ventilation System Controls	Stair and shaft *automatic* damper function, shutoff damper control, damper leakage performance, ventilation fans, and enclosed parking garage control *systems* operate per code.	
6.4.3.5	Heat-Pump Auxiliary Heat Control	Heat-pump auxiliary heat control properly configured.	
6.4.3.6	Humidifier Preheat	*Automatic* shutoff valve with configured controls.	
6.4.3.6	Humidification and Dehumidification Control	No simultaneous humidification and dehumidification operation.	
6.4.3.7	Freeze Protection and Ice/Snow Melt	*Automatic* shutoff based on outdoor temperature or precipitation.	
6.4.3.8	Ventilation Controls for High-Occupancy Areas	*Demand control ventilation (DCV) system* where applicable.	
6.4.3.10	Single-Zone VAV Control	*Single-zone systems* have multispeed or *VAV* control properly configured.	
6.4.4.1	HVAC System Insulation	Insulation for ductwork, *piping*, heating panels, and radiant floor heating *systems* correct and continuous.	
6.4.4.2	Ductwork and Plenum Leakage	Duct sealing complete, and required leakage tests performed.	

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Table H-3 Standard 90.1 Items to Verify *(Continued)*

Subsection	Subsection Title	Standard 90.1 Items to Verify for Proper Operation or Inclusion	Status
6.5.1.1	Air Economizers	*Outdoor air* and return air damper control sequence properly configured. High-limit shutoff set properly. Damper leakage and relief air appropriate. Sensor accuracy and calibration.	
6.5.1.2	Fluid Economizers	Maximum pressure drop (precooling coils, water-to-water heat exchanger). Economizer control integration sequence with heating, *mechanical cooling*, and inside humidity.	
6.5.2.1	Zone Controls	Zone box minimum position and operating sequence, *deadband*, and *set points* configured properly.	
6.5.2.2	Hydronic System Controls	Two-pipe changeover control *dead band* and hydronic heat-pump *system* controls configured properly.	
6.5.2.3/ 6.5.2.4	Dehumidification/ Humidification	*Humidistatic controls* configured properly if applicable.	
6.5.2.5	Preheat Coils	Control sequence configured properly.	
6.5.3.1	Fan System Power and Efficiency	Fans are within power limits or meet *efficiency* requirements.	
6.5.3.2	Fan Control	Fans are equipped with variable-speed drives or multispeed control where required, and control sensors and sequence are properly implemented. *VAV* static pressure *set point* is *reset.*	
6.5.3.3	Multiple-Zone VAV System Ventilation Optimization Control	Proper configuration of ventilation optimization controls for *VAV systems*.	
6.5.3.4	Parallel-Flow Fan-Powered VAV Air-Terminal Control	Check for proper sequence control.	
6.5.3.5	Supply Air Temperature Reset Controls	Proper operation of supply air *reset* controls for multiple zone systems.	
6.5.3.6	Fractional Horsepower Fan Motors	For smaller fans, ECM or equivalent *efficiency* motors have speed control.	
6.5.4.1	Boiler Turndown	Boiler turndown capability and plant load controls for multiple *boilers* or modulating burner operation.	
6.5.4.2	Hydronic Variable Flow Systems	Hydronic systems are variable flow and equipped with *pump* speed controls where required.	
6.5.4.3	Chiller and Boiler Isolation	Offline chillers and *boilers* are properly isolated and *automatic* controls function as required.	
6.5.4.4	Chilled- and Hot-Water Temperature Reset Controls	Hydronic temperature *reset* controls are configured properly where required.	
6.5.6	Energy Recovery	Energy recovery systems implemented where required for exhaust air *energy* recovery and service hot-water heat recovery.	
6.5.7	Exhaust Systems	Proper operation of kitchen and laboratory exhaust air systems where required for demand ventilation including integration of makeup-air units with performance testing at multiple flow rates.	
6.5.8	Radiant Heating Systems	*Radiant heating system* controls operate properly and are coordinated with other zone controls.	
6.5.10	Door Switches	*Door* switches provide proper control integration.	
6.5.11	Refrigeration Systems	Refrigeration control elements are properly configured.	

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Table H-3 Standard 90.1 Items to Verify *(Continued)*

Subsection	Subsection Title	Standard 90.1 Items to Verify for Proper Operation or Inclusion	Status
6.9	Verification, Testing, and Commissioning	HVAC control *systems* receive testing for proper operation in accordance with Sections 6.9 and 4.2.5. See specific items in Sections 6.4 and 6.5.	
7.4.4	Service Water Heating System Controls	Proper configuration of temperature and circulation *pump* controls.	
7.4.5.3	Time Switches	Proper configuration of *pool* heater and *pump* controls.	
8.4.2	Automatic Receptacle Control	Proper control integration of required receptacle and labeling of controlled receptacles.	
8.4.3	Electrical Energy Monitoring	Proper assignment of electrical loads for required end-use monitoring.	
9.4.1.1	Interior Lighting Control	Proper operation of lighting controls, including local control, bilevel control.	
9.4.1.2	Parking Garage Lighting Control	Proper operation of parking lot lighting controls, including *occupancy sensor*, time switch, and daylighting control.	
9.4.1.3	Special Applications	Proper operation of lighting controls, including separate control of display, accent, display case, hotel guest room, nonvisual, and demonstration lighting.	
9.4.1.4	Exterior Lighting Control	Proper operation of exterior lighting controls, including parking area proximity sensors, time switch, and photocell or astronomical time control.	
9.9.1	Verification and Testing	Required functional testing is completed for occupant sensors, *automatic* time switches, and daylight responsive control. Include control items in Sections 9.4.1.1 through 9.4.1.4.	
10.4.2	Service Water Pressure Booster Systems	Required functional testing is completed for service water pressure booster system controls.	
10.4.5	Air Curtains	Functional testing and adjustment per the *manufacturer's* installation requirements	
11.5.1	Energy Credits Required	Adequate *energy* credits are included in the project to meet the requirements of the *building* type and climate zone.	
11.5.2	Energy Credits Achieved	If applicable, test or commission any items in the proposed *building* not already covered in Sections 5 through 10 required to achieve the *energy efficiency* to meet the *energy* credits required for the *building* type and climate zone.	
12.2(d), and G1.2.1(c)	(Energy cost budget and performance paths)	If applicable, test or commission any items in the proposed *building* not already covered in Sections 5 through 10 required to achieve the *energy efficiency* to meet the chosen performance path.	

Commissioning processes and the chosen items to verify can vary based on many factors. Selection of items to verify will be based on the specific project requirements, specific *systems*, *building* configuration, and climate zone. Some items may not apply at all in particular *buildings*. If the Energy Cost Budget Method or *Performance Rating Method* is used for compliance, the items to verify include any additional *efficiency* features of the proposed *building* design that are required for the *building* to comply using the selected performance path. The list in Table H-3 includes both mandatory items and prescriptive items. The prescriptive items may be adjusted or traded off in one of the performance paths.

H5. COMMISSIONING DOCUMENTATION

The *commissioning* process typically results in the deliverables included in this section. There may also be interim partial deliverables (as noted in Table H-2) or online issue tracking systems. Standard 90.1 does not require all of these documents; however, they are all part of a complete *commissioning* process. Where Standard 90.1 has specific requirements, references to the relevant Standard 90.1 sections are included. A document not required by Standard 90.1 is flagged "NR by 90.1." This section provides background on the general content of these documents, with information about how they support the goals of Standard 90.1.

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Detailed information about the recommended contents of each of these documents can be found in ASHRAE Guideline 0 and other *commissioning* resources.

H5.1 Owner's Project Requirements (OPR) (NR by 90.1). The Owner's Project Requirements (OPR) is a document developed by the owner with assistance from the design and *commissioning* teams that details the requirements of a project and the expectations for how it will be used and operated. The OPR should include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. The term "project intent" or "design intent" is used by some owners for their *commissioning* process OPR. The OPR supports the *energy efficiency* goals of Standard 90.1 by clarifying *energy efficiency* goals for the *building* from the owner's perspective. These goals can be referenced when defending against value engineering efforts that may eliminate *efficiency* measures without considering long-term *building* life-cycle cost.

H5.2 Basis of Design (BoD) (NR by 90.1). The Basis of Design (BoD) is a document developed by the design team that records the concepts, calculations, decisions, and product selections used to meet the OPR and to satisfy applicable regulatory requirements, standards, and guidelines. The document should include both narrative descriptions and lists of individual items that support the design process. The BoD supports the *energy efficiency* goals of Standard 90.1 by clarifying the criteria on which the *building system* design is based, so that full-load and part-load *energy efficiency* goals are met. In cases where a BoD is not separately developed, it can be inferred from the preliminary *construction documents* for purposes of developing a *commissioning* plan.

H5.3 Commissioning Plan (See Section 4.2.5.2.2). The *commissioning* plan is a document developed by a *commissioning provider* that supports the *energy efficiency* goals of Standard 90.1 by clarifying the *commissioning* activities throughout the design and *construction* process and how they are integrated into design team and contractor activities. The *commissioning* plan is also useful in providing the *building official* with assurance that required *commissioning* activities will be performed.

H5.4 Contractor Commissioning Requirements (See Sections 4.2.5.1.1, 4.2.5.2.1, and 6.9.2). The *commissioning provider* works with the design team to ensure that contractor requirements for involvement in the *commissioning* process are included in the *construction documents*. The contractor *commissioning* requirements support the *energy efficiency* goals of Standard 90.1 by ensuring that the contractor supports and allows for the *commissioning* activities within the *construction* process.

H5.5 Commissioning Design Review Report and Standard 90.1 Compliance Review (See Sections 4.2.5.2 and 4.2.5.2.2). The *commissioning provider* provides a design review (*commissioning* design review report) to the owner and design teams to report compliance with the OPR and BoD. The review includes verification that the design meets the requirements of the chosen path in Standard 90.1, which could be completed using the verification forms from the *Standard 90.1 User's Manual*. This *commissioning* design review is not intended to replace a design peer review or a code or regulatory review. The design review supports the *energy efficiency* goals of Standard 90.1 by verifying that the design substantially meets the requirements of Standard 90.1. If areas of the design are found to not meet the requirements, the design can be changed at a lower cost before *construction* begins, avoiding costly change orders during *construction*.

H5.6 Record Documents (See Sections 4.2.2.1, 6.7.3.1, 8.7.3.1, 9.7.3.1). Record documents are provided to the owner upon project completion. The *record documents* should be accessible to the *building* operations and maintenance personnel. The *record documents* should be included in or referenced by the *systems* manual. The *record documents* support the *energy efficiency* goals of Standard 90.1 by providing information on the design and *system* criteria so that the operating staff or designers for renovations or upgrades to the *building* in the future can maintain the specified *system efficiency*.

H5.7 Systems Manual (See Sections 4.2.2.3, 6.7.3.2, 8.7.3.2, 9.7.3.2). A *systems* manual supports the *energy efficiency* goals of Standard 90.1 by providing information on *system* maintenance and operation so that the operating staff can maintain the specified *system efficiency*. Including review of the *systems* manual in the *commissioning* process will improve the quality of the manuals and make sure that relevant information to the specific *building systems* operation is included rather than just generic product information. A *systems* manual should be provided before *building* operations training for use in the training process. The owner should make the *systems* manual accessible to the *building* operations and maintenance personnel throughout the life of the *building* and ensure that updates are made as the *building systems* change.

H5.8 Preliminary Commissioning Report (See Section 4.2.5.2.2). A preliminary *commissioning* report is provided by the *commissioning provider* and includes the results of the *commissioning* activities up to the time of occupancy. The results of *FPT* and other verification is included. The preliminary *commissioning* report supports the *energy efficiency* goals of Standard 90.1 by identifying that control sequences related to

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energy efficiency are working properly, the *commissioning* plan is useful in providing the *building official* with assurance that required are in place, where the *building official* may not have to time or expertise to investigate proper operation. Issues that are unresolved are also identified, as are items that will be tested after occupancy.

H5.9 Final Commissioning Report (See Section 4.2.5.2.2). A final *commissioning* report is provided by the *commissioning provider* once all testing is complete. While the final *commissioning* report is delivered after the occupancy permit, the requirement for it in the *construction documents* supports the *energy efficiency* goals of Standard 90.1 by providing a future report that will address issues that cannot be resolved at the time of occupancy permit issuance.

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(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 I USING OTHER METRICS IN CONJUNCTION WITH APPENDIX G PERFORMANCE RATING METHOD WHEN APPROVED BY THE RATING AUTHORITY

I1. GENERAL

This informative appendix describes changes to Section 3, Section 4, and Normative Appendix G for using metrics other than *energy* cost—including *site energy*, source *energy*, and carbon emissions—that may be adopted by the *rating authority* for the Normative Appendix G *Performance Rating Method*. It also provides methodology for determining *building* performance factors (BPFs) that should be used in conjunction with custom *energy* conversion factors other than the national average defaults in Table I5-1.

I2. CHANGES TO SECTION 3

Replace references to "annual energy cost" with the reference to the selected metric in the definitions of *baseline building performance* and *proposed building performance*.

I3. CHANGES TO SECTION 4

a. Replace all references to "*energy* cost" in Section 4.2.1.1 with "*site energy*," "source *energy*," or "carbon emissions," as appropriate, throughout.
b. Replace all references to "Performance Cost Index" in Section 4.2.1.1 with "Performance Index (Site Energy)," "Performance Index (Source Energy)," or "Performance Index (Carbon Emissions)," as appropriate throughout.
c. For *site energy*, replace Table 4.2.1.1 with Table I3-1.
d. For carbon emissions, replace Table 4.2.1.1 with Table I3-2.
e. For source *energy*, replace Table 4.2.1.1 with Table I3-3.

I4. CHANGES TO NORMATIVE APPENDIX G

a. Replace references to "*energy* cost" with references to "*site energy*," "source *energy*," or "carbon emissions" as appropriate in Sections G1.2.2, G1.3.2, G2.1, G2.4.2, and G2.5 section headings.
b. Remove the first sentence and informative note in Section G2.4.2, and replace it with the conversion factors from Table I4-1 for the selected metric.
c. Add an exception to Section G2.4.2 to allow using alternative conversion factors as appropriate for *building* location and as approved by the *adopting authority*.

I5. METHODOLOGY FOR BPF ADJUSTMENT TO ACCOUNT FOR LOCALIZED CONVERSION FACTORS

The BPF values in Table 4.2.1.1, based on *energy* cost, and the values in Tables I3-1, I3-2, and I3-3, are based on the coefficients in Tables I5-2 through I5-4 and the electricity and *fossil fuel* conversion factors in Table I5-1. The values in Table I5-1 represent U.S. national average values. The U.S. national conversion factors may not be appropriate for all locations, and some jurisdictions may want to adopt custom conversion factors other than those shown in Table I5-1. When *energy* conversion factors other than those specified in Table I5-1 are used, the BPFs should also be updated in accordance with Equation I-1.

$$BPF_{i,j} = (EC + A_{i,j} \times GC)/(B_{i,j} \times EC + C_{i,j} \times GC) \quad \text{(I-1)}$$

$A_{i,j}$, $B_{i,j}$, $C_{i,j}$	=	coefficients from Tables I5-2, I5-3, and I5-4 for *building* area type i and climate zone j
EC	=	custom electricity conversion factor expressed using the units shown in Table I5-1 for the selected metric
GC	=	custom natural gas conversion factor expressed using the units shown in Table I5-1 for the selected metric

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Table I3-1 Building Performance Factors (BPF), Site Energy

Building Area Type	Climate Zone																	
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.72	0.71	0.75	0.73	0.76	0.76	0.77	0.75	0.70	0.61	0.71	0.64	0.56	0.63	0.63	0.54	0.57	0.54	0.56
Healthcare/hospital	0.67	0.66	0.68	0.65	0.65	0.61	0.62	0.64	0.63	0.62	0.63	0.61	0.65	0.63	0.68	0.64	0.68	0.69	0.71
Hotel/motel	0.69	0.69	0.72	0.68	0.69	0.68	0.69	0.70	0.71	0.65	0.69	0.68	0.63	0.66	0.67	0.60	0.64	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.47	0.47	0.52	0.48	0.49	0.52	0.49	0.48	0.50	0.43	0.46
Restaurant	0.64	0.61	0.60	0.59	0.60	0.57	0.61	0.62	0.61	0.66	0.65	0.66	0.69	0.69	0.68	0.71	0.71	0.72	0.74
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.44	0.44	0.47	0.45	0.50	0.52	0.47	0.52	0.52	0.50	0.48	0.49
School	0.52	0.57	0.57	0.56	0.52	0.53	0.53	0.52	0.55	0.42	0.49	0.53	0.44	0.50	0.51	0.43	0.42	0.42	0.44
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.18	0.38	0.27	0.31	0.46	0.37	0.31	0.49	0.42	0.43	0.47
All others	0.63	0.62	0.65	0.61	0.56	0.53	0.55	0.55	0.59	0.55	0.55	0.58	0.57	0.57	0.61	0.57	0.57	0.56	0.58

Table I3-2 Building Performance Factors (BPF), Carbon Emission

Building Area Type	Climate Zone																	
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.71	0.69	0.73	0.71	0.74	0.74	0.74	0.75	0.67	0.64	0.73	0.67	0.60	0.67	0.66	0.59	0.61	0.58	0.60
Healthcare/hospital	0.68	0.67	0.69	0.67	0.66	0.63	0.64	0.65	0.63	0.63	0.65	0.62	0.66	0.64	0.67	0.65	0.67	0.69	0.70
Hotel/motel	0.67	0.67	0.70	0.66	0.67	0.66	0.66	0.68	0.68	0.64	0.67	0.65	0.63	0.65	0.65	0.61	0.63	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.48	0.47	0.52	0.48	0.49	0.52	0.49	0.48	0.50	0.45	0.47
Restaurant	0.63	0.60	0.59	0.58	0.58	0.55	0.59	0.58	0.56	0.61	0.60	0.60	0.64	0.63	0.62	0.66	0.66	0.68	0.70
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.43	0.44	0.44	0.44	0.48	0.47	0.45	0.49	0.47	0.46	0.45	0.47
School	0.52	0.57	0.57	0.56	0.52	0.53	0.53	0.51	0.52	0.44	0.48	0.50	0.45	0.48	0.48	0.45	0.43	0.43	0.45
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.18	0.31	0.24	0.27	0.38	0.31	0.26	0.41	0.36	0.37	0.41
All others	0.63	0.61	0.63	0.60	0.55	0.52	0.54	0.54	0.57	0.54	0.53	0.56	0.55	0.55	0.58	0.56	0.56	0.55	0.56

Table I3-3 Building Performance Factors (BPF), Source Energy

Building Area Type	Climate Zone																	
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.70	0.69	0.72	0.71	0.73	0.73	0.73	0.75	0.65	0.66	0.74	0.69	0.63	0.69	0.68	0.61	0.63	0.60	0.63
Healthcare/hospital	0.69	0.68	0.70	0.67	0.66	0.64	0.64	0.66	0.64	0.64	0.65	0.63	0.66	0.64	0.66	0.66	0.67	0.68	0.70
Hotel/motel	0.66	0.67	0.70	0.66	0.66	0.65	0.65	0.67	0.66	0.63	0.66	0.64	0.62	0.64	0.64	0.61	0.62	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.48	0.47	0.53	0.48	0.49	0.52	0.49	0.48	0.50	0.45	0.47
Restaurant	0.63	0.59	0.58	0.57	0.58	0.54	0.58	0.56	0.54	0.59	0.57	0.57	0.61	0.60	0.59	0.64	0.62	0.65	0.68
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.43	0.44	0.43	0.43	0.47	0.45	0.43	0.48	0.45	0.45	0.43	0.45
School	0.52	0.57	0.57	0.56	0.52	0.53	0.53	0.50	0.51	0.44	0.47	0.49	0.46	0.47	0.47	0.45	0.43	0.44	0.45
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.18	0.28	0.23	0.25	0.34	0.28	0.25	0.37	0.32	0.34	0.37
All others	0.62	0.61	0.63	0.60	0.55	0.52	0.54	0.53	0.56	0.54	0.53	0.56	0.54	0.54	0.57	0.55	0.55	0.55	0.56

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Table I4-1 Energy Conversion Factors (see Note 1)

Building Project Energy Source	Units	Carbon Emissions CO_{2e} lb/unit	Site Energy, Btu/unit (see Note 2)	Source Energy, Btu/unit
Electricity	kWh	1.20	3412	9008
Natural gas	Therm (GJ)	19.96	100,000	109,000
Propane	Therm (GJ)	19.080	100,000	115,000
Distillate fuel oil	Gallon (L)	28.330	137,600	163,744

Notes:

1. These conversions are based on national averages for the United States and may not be representative for other locations. Jurisdictions that choose to use localized conversion factors for source *energy* or carbon emissions should update the corresponding BPF table for consistency using methodology in Section I5. Jurisdictions may add conversion factors for other *energy* sources.
2. Site *energy* only accounts for *energy* as measured at the building site. It does not account for the *energy* consumed in the extraction, processing, and transport of primary *energy*, nor *energy* consumed in conversion to electricity in power-generation plants.

Table I5-1 National Average Energy Conversion Factors Used to Calculate BPF

Metric	Site Energy	Carbon Emissions CO_{2e}	Source Energy	Energy Cost
Units	**site kBtu/site kBtu**	**lb/site kBtu**	**source kBtu/site kBtu**	**$/site kBtu**
Electric conversion factors	1.0	0.353	2.64	0.03221
Natural gas conversion factors	1.0	0.200	1.090	0.00802

Table I5-2 Coefficient A Values

Building Area Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.3006	0.3261	0.4321	0.4064	0.5158	0.5445	0.7128	0.6952	1.1709	1.1302	0.8644	1.2685	1.5138	1.1288	1.3067	1.7228	1.5398	1.8543	2.1737
Health care/ hospital	0.1250	0.1412	0.1507	0.1544	0.1979	0.1602	0.2319	0.2098	0.2688	0.3262	0.2596	0.3865	0.4926	0.3624	0.5972	0.6143	0.6194	0.8438	1.0747
Hotel/motel	0.2711	0.2833	0.3267	0.3373	0.3922	0.4544	0.5143	0.6042	0.6922	0.8420	0.7668	0.9723	1.0639	0.9353	1.0888	1.2454	1.1995	1.4783	1.9709
Office	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0425	0.0105	0.2479	0.0868	0.2155	0.4409	0.2496	0.2634	0.6874	0.5018	0.6405	0.9613
Restaurant	0.2210	0.2418	0.3366	0.3120	0.3984	0.4813	0.5416	0.8752	1.0794	1.8987	1.3855	2.0956	2.9552	2.1791	2.6220	3.7419	3.1353	4.8743	7.2168
Retail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0509	0.0056	0.4874	0.1141	0.3074	0.8526	0.3748	0.3778	1.1246	0.6886	1.1802	1.5119
School	0.0346	0.0368	0.0447	0.0461	0.0581	0.0703	0.0791	0.2052	0.2586	0.3806	0.3220	0.7076	0.6664	0.6527	0.7928	0.9529	0.7842	1.1857	2.0419
Warehouse	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1323	0.0158	2.6058	0.8393	1.2916	4.6583	2.2657	1.2302	6.2218	3.8034	5.9278	6.3860
All others	0.1552	0.1668	0.2257	0.2050	0.1784	0.1568	0.2015	0.3111	0.4107	0.7223	0.3880	0.7372	1.0594	0.7105	0.7100	1.2640	0.9793	1.2947	1.8802

Table I5-3 Coefficient B Values

Building Area Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	1.472	1.504	1.440	1.472	1.434	1.433	1.455	1.318	1.701	1.314	1.263	1.305	1.283	1.259	1.288	1.248	1.278	1.251	1.153
Health care/hospital	1.423	1.437	1.400	1.449	1.475	1.506	1.510	1.492	1.546	1.520	1.505	1.548	1.483	1.519	1.572	1.483	1.513	1.488	1.447
Hotel/motel	1.547	1.545	1.480	1.580	1.574	1.623	1.626	1.582	1.627	1.637	1.610	1.665	1.627	1.628	1.677	1.640	1.660	1.688	1.719
Office	1.855	1.869	1.900	1.915	1.913	1.923	1.982	1.845	2.058	2.071	1.883	2.080	2.040	1.936	2.089	2.100	2.033	2.098	2.031
Restaurant	1.622	1.724	1.788	1.807	1.813	1.978	1.837	2.036	2.172	2.086	2.118	2.219	2.122	2.164	2.232	2.113	2.160	2.156	2.192
Retail	1.961	2.057	2.078	2.090	2.286	2.353	2.345	2.372	2.296	2.511	2.360	2.233	2.573	2.486	2.187	2.649	2.516	2.715	2.525
School	1.921	1.748	1.747	1.778	1.941	1.901	1.914	2.074	2.093	2.102	2.192	2.275	2.089	2.256	2.328	2.073	2.241	2.102	2.146
Warehouse	3.885	3.804	4.454	3.994	4.692	4.591	3.967	4.884	5.296	5.724	5.241	5.472	6.045	5.572	5.419	5.962	5.558	5.935	5.477
All others	1.621	1.667	1.632	1.712	1.852	1.973	1.902	1.950	1.863	1.899	1.985	1.870	1.970	1.966	1.866	1.906	1.902	1.881	1.933

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Table I5-4 Coefficient C Values

Building Area Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.3268	0.3547	0.4698	0.4419	0.5608	0.5921	0.7751	0.9461	1.3802	2.1938	1.3725	2.2150	3.1673	2.1109	2.3514	3.7613	3.2073	4.0765	4.5499
Health care/ hospital	0.2538	0.2952	0.2924	0.3186	0.3728	0.3966	0.4705	0.3979	0.4800	0.6318	0.4830	0.7239	0.8189	0.6407	0.7623	1.0245	0.8759	1.1802	1.4851
Hotel/motel	0.3054	0.3192	0.3674	0.3794	0.4401	0.5104	0.5758	0.7070	0.7578	1.1950	0.9496	1.2431	1.6502	1.2861	1.4319	2.0806	1.7910	2.4916	3.3918
Office	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0776	0.0890	0.6078	0.2077	0.4525	0.9224	0.4828	0.4656	1.4263	0.9818	1.6892	2.2766
Restaurant	0.2876	0.3147	0.4309	0.4001	0.5043	0.6085	0.6731	0.9800	1.2400	2.3208	1.5298	2.4918	3.6117	2.4166	3.1189	4.5816	3.6641	5.9587	8.8807
Retail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0268	0.0031	0.6502	0.1292	0.4050	1.0239	0.4191	0.4873	1.4196	0.8469	1.8038	2.5674
School	0.0574	0.0605	0.0716	0.0734	0.0906	0.1091	0.1185	0.2332	0.2124	1.2081	0.5076	0.9354	1.6698	1.0708	1.1824	2.4336	1.9958	3.1587	4.7541
Warehouse	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4289	0.3731	3.7923	1.5264	1.8399	6.1674	3.2986	1.7394	8.7227	5.8554	10.164	10.401
All others	0.2029	0.2198	0.2640	0.2659	0.2354	0.2239	0.2697	0.4152	0.5288	1.2546	0.5421	1.1404	1.6641	1.0498	0.9435	2.0621	1.5669	2.2440	3.0603

I6. SITE ENERGY USE LANGUAGE EXAMPLE

The following example shows the recommended changes to Section 3, Section 4.2.1.1, and Table 4.2.1.1, and Sections G1.2.2, G1.3.2, G2.4.2, and G2.5, if the *site energy* alternative compliance metric is adopted. Example text is highlighted in gray. Example changes are illustrated with strikethrough and underline.

Modify Section 3 as follows:

baseline building performance: the annual *site 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.

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

Modify Section 4.2.1.1 as follows:

[. . .]

When using Normative Appendix G, the Performance ~~Cost~~ Index (~~PCI~~Site Energy) of new *buildings*, *additions* to *existing buildings*, and/or *alterations* to *existing buildings* shall be less than or equal to the Performance ~~Cost~~ Index Target (P~~C~~I$_t$) when calculated in accordance with the following:

$$\underline{\mathrm{PI}_t} = [\mathrm{BBUE}\cancel{\mathrm{C}} + (\mathrm{BPF}_{site} \times \mathrm{BBRE}\cancel{\mathrm{C}}) - \mathrm{PRE}]/\mathrm{BBP}$$

where

P~~C~~I	=	Performance ~~Cost~~ Index (Site *Energy*) calculated in accordance with Section G1.2.
BBUE~~C~~	=	baseline *building* unregulated *site energy* ~~cost~~, the portion of the annual *site energy* ~~cost~~ of a *baseline building design* that is due to *unregulated energy use.*
BBRE~~C~~	=	baseline *building* regulated *site energy* ~~cost~~, the portion of the annual *site energy* ~~cost~~ of a *baseline building design* that is due to *regulated energy use.*
BPF	=	*building* performance factor from Table 4.2.1.1. For *building* area types not listed in Table 4.2.1.1 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 based on their *gross floor area*. Where a project includes an *existing building* and an *addition*, the required BPF shall be equal to the area-weighted average, based on the *gross floor area*, of the *existing building* BPF determined as described in Section 4.2.1.3 and the *addition* BPF from Table 4.2.1.1
BBP	=	baseline *building* performance.
PBP	=	*proposed building performance*, including the reduced, annual ~~purchased~~ *site energy* ~~cost~~ associated with all *on-site renewable energy* generation *systems*.

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PBP_{nre} = *proposed building performance* without any credit for reduced annual *energy* ~~costs~~ from *on-site renewable energy* generation *systems*.

PBP_{pre} = *proposed building performance*, excluding any *renewable energy system* in the *proposed design* and including an *on-site renewable energy system* that meets but does not exceed the requirements of Section 10.5.1.1 modeled following the requirements for a *budget building design* in Table 12.5.1.

PRE = $PBP_{nre} - PBP_{pre}$

When $(PBP_{pre} - PBP)/BBP > 0.05$, new *buildings*, *additions* to *existing buildings*, and/or *alterations* to *existing buildings* shall comply with the following:

$$P\cancel{C}I + [(PBP_{pre} - PBP)/BBP] - 0.05 < P\cancel{C}I_t$$

Informative Notes:

1. PBP_{nre} = *proposed building performance*, no renewable *energy*
2. PBP_{pre} = *proposed building performance*, prescriptive renewable *energy*
3. PRE = prescriptive renewable *energy*

~~Regulated site *energy* cost shall be calculated by multiplying the total site *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.~~

Replace values in Table 4.2.1.1 with the values from Table I3-1 (deleted values not shown):

Table 4.2.1.1 Building Performance Factors (BPF), Site Energy

	Climate Zone																		
Building Area Type	**0A**	**0B**	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**5C**	**6A**	**6B**	**7**	**8**
Multifamily	0.72	0.71	0.75	0.73	0.76	0.76	0.77	0.75	0.70	0.61	0.71	0.64	0.56	0.63	0.63	0.54	0.57	0.54	0.56
Healthcare/hospital	0.67	0.66	0.68	0.65	0.65	0.61	0.62	0.64	0.63	0.62	0.63	0.61	0.65	0.63	0.68	0.64	0.68	0.69	0.71
Hotel/motel	0.69	0.69	0.72	0.68	0.69	0.68	0.69	0.70	0.71	0.65	0.69	0.68	0.63	0.66	0.67	0.60	0.64	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.47	0.47	0.52	0.48	0.49	0.52	0.49	0.48	0.50	0.43	0.46
Restaurant	0.64	0.61	0.60	0.59	0.60	0.57	0.61	0.62	0.61	0.66	0.65	0.66	0.69	0.69	0.68	0.71	0.71	0.72	0.74
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.44	0.44	0.47	0.45	0.50	0.52	0.47	0.52	0.52	0.50	0.48	0.49
School	0.52	0.57	0.57	0.56	0.52	0.53	0.53	0.52	0.55	0.42	0.49	0.53	0.44	0.50	0.51	0.43	0.42	0.42	0.44
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.18	0.38	0.27	0.31	0.46	0.37	0.31	0.49	0.42	0.43	0.47
All others	0.63	0.62	0.65	0.61	0.56	0.53	0.55	0.55	0.59	0.55	0.55	0.58	0.57	0.57	0.61	0.57	0.57	0.56	0.58

Modify Section G1.2.2 as follows:

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

Both the *proposed building performance* and the *baseline building performance* shall include all end-use load components within and associated with the *building* when calculating the Performance ~~Cost~~ Site Energy Index.

Modify Section G1.3.2(a) and G1.3.2(p) as follows:

[. . .]

The following documentation shall be submitted to the *rating authority*:

a. The *simulation program* used, the version of the *simulation program*, and the results of the *energy* analysis including the calculated values for the baseline *building* unregulated site *energy* ~~cost~~ (BBUE~~C~~), baseline *building* regulated site *energy* ~~cost~~ (BBRE~~C~~), *building* performance factor (BPF), *baseline building*

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performance, the *proposed building performance*, Performance ~~Cost~~ Site Energy Index (P~~C~~EI), and Performance ~~Cost~~ Site Energy Index Target (P~~C~~EI$_t$).

[. . .]

p. For any exceptional calculation methods employed, document the predicted *energy* savings by *energy* type, the *site energy* ~~cost~~ savings, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.

Modify Section G2.4.2 as follows:

G2.4.2 Annual ~~Energy Costs~~ Site Energy. ~~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.~~

G2.4.2.1 The *baseline building performance* and *proposed building performance* shall be determined using conversion factors in Table G2.1.

Table G2.1 Units of Fuel to Site Energy Conversion Factors

Building Project Energy Source	Units	Site Energy, Btu/unit
Electricity	kWh	3412
Natural gas	therm	100,000
Propane	therm	100,000
Distillate fuel oil	gal	137,600

G2.4.2.2 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, except where the baseline *energy* source is prescribed in Table G3.1.1-2 and G3.1.1-3. Where the *proposed design* includes *on-site electricity generation systems* other than *on-site renewable energy systems*, the baseline design shall include the same generation *systems* excluding its *site-recovered energy*.

~~***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).~~

Modify Section G2.5(e) as follows:

[. . .]

e. The Performance ~~Cost~~ Index calculated with and without the exceptional calculation method.

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(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX J
SETS OF PERFORMANCE CURVES

J1. GENERAL

J1.1 Description. This appendix provides sets of performance curves that shall be used to represent the part-load performance of chillers in the *budget building design* when using Section 12 and in the *baseline building design* when using Normative Appendix G. They are also permitted to be used for the *proposed building design* when specific chiller performance is not known.

Each set includes three curves: an energy-input-ratio modifier as a function of temperatures (EIR-f-T) and as a function of a chiller's part-load ratio (EIR-f-PLR), and a capacity modifier as a function of temperatures (CAP-f-T). These curves are intended to describe the part-load performance of a chiller when its operating capacity and power (not including cycling degradation) are calculated by the *simulation program* as follows:

$$\text{Operating Capacity} = \text{Rated Capacity} \times \text{CAP-f-T}$$

$$\text{Operating Power} = \text{Operating Capacity} \times \text{EIR-f-T} \times \text{EIR-f-PLR} \times$$
$$\text{Chiller Input Power at Rated Conditions/Chiller Capacity at Rated Conditions}$$

Table J-3 provides the reference values for the curves. Tables J-4 and J-6 are to be used when the *simulation program* uses I-P units to evaluate the performance curves, and Tables J-5 and J-7 are to be used when the *simulation program* uses SI units to evaluate the performance curves.

Table J-1 Sets of Chiller Performance Curves for Section 12

Equipment Type	Size Category	Set Path A	Set Path B
Air-cooled chillers	<150 tons	A	K
	≥150 tons	B	L
Liquid-cooled, electrically operated positive displacement	<75 tons	C	M
	≥75 tons and <150 tons	D	N
	≥150 tons and <300 tons	E	O
	≥300 tons and <600 tons	F	P
	≥600 tons	G	Q
Liquid-cooled, electrically operated centrifugal	<150 tons	H	R
	≥150 tons and <300 tons	H	S
	≥300 tons and <400 tons	I	T
	≥400 tons and <600 tons	J	U
	≥600 tons	J	U

Table J-2 Sets of Chiller Performance Curves for Normative Appendix G

Equipment Type	Size Category	Set
Water-cooled, electrically operated, positive displacement (rotary screw and scroll)	<150 tons	V
	≥150 tons and <300 tons	X
	≥300 tons	Y
Water-cooled, electrically operated, centrifugal	<150 tons	Z
	≥150 tons and <300 tons	AA
	≥300 tons	AB

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Table J-3 Chiller Performance Curves References

Chiller Condenser Type	Output Variable [a]	Curve Type [b]	X [c]	Y [c]	Minimum/ Maximum Value for X (I-P °F)	Minimum/ Maximum Value for Y (I-P °F)	Rated Values for X/Y (I-P °F)
Air	EIR-f-T	T1	CHWT	OAT	39/60	55/126	44/95
Air	CAP-f-T	T1	CHWT	OAT	39/60	55/126	44/95
Air	EIR-f-PLR	T3	PLR		0/1		1
Water	EIR-f-T	T1	CHWT	ECT	39/60	55/104	44/85
Water	CAP-f-T	T1	CHWT	ECT	39/60	55/104	44/85
Water	EIR-f-PLR	T2	PLR		0/1		1

a. EIR-f-T is the energy input ratio modifier as a function of temperatures; CAP-f-T is the capacity modifier as a function of temperatures; and EIR-f-PLR is the energy input ratio modifier as a function of the chiller's part load ratio.
b. T1: Output = Coeff1 + Coeff2 × X + Coeff3 × X^2 + Coeff4 × Y + Coeff5 × Y^2 + Coeff6 × X × Y
T2: Output = Coeff1 + Coeff2 × X + Coeff3 × X^2
T3: Output = Coeff1 + Coeff2 × X + Coeff3 × X^2 + Coeff4 × X^3
c. CHWT : chilled-water temperature
OAT: outdoor-air dry-bulb temperature
ECT: entering condenser temperature
PLR: part-load ratio = load at a given simulation time step/available capacity at given simulation time step

Table J-4 Chiller Performance Curves for Section 12 (Simulation Input Required in I-P units)

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
A	Air-cooled <150 tons, 10.100 FL, 13.700 *IPLV*.IP Path A	EIR-f-T	1.777758	–0.038258	0.000431	–0.005368	0.000118	–0.000115
		CAP-f-T	–1.347697	0.070674	–0.000566	0.016793	–0.000104	–0.000076
		EIR-f-PLR	0.087789	0.185696	1.561411	–0.832304		
B	Air-cooled ≥150 tons, 10.100 FL, 14.00 *IPLV*.IP Path A	EIR-f-T	1.872341	–0.041886	0.000442	–0.006710	0.000123	–0.000086
		CAP-f-T	–1.153535	0.075066	–0.000622	0.009777	–0.000071	–0.000057
		EIR-f-PLR	0.118081	0.107477	1.570838	–0.794051		
C	Liquid-cooled positive displacement <75 tons 0.750 FL, 0.600 *IPLV*.IP Path A	EIR-f-T	2.001725	–0.044957	0.000484	–0.008296	0.000168	–0.000125
		CAP-f-T	–0.907598	0.073300	–0.000653	0.003700	–0.000054	0.000006
		EIR-f-PLR	0.243730	0.165972	0.586099			
D	Liquid-cooled positive displacement ≥75 and <150 tons 0.720 FL, 0.560 *IPLV*.IP Path A	EIR-f-T	1.679306	–0.041960	0.000456	–0.002081	0.000128	–0.000125
		CAP-f-T	–0.857791	0.074596	–0.000670	0.001523	–0.000042	0.000012
		EIR-f-PLR	0.208982	0.224001	0.561479			
E	Liquid-cooled positive displacement ≥150 and <300 tons 0.660 FL, 0.540 *IPLV*.IP Path A	EIR-f-T	1.136125	–0.034608	0.000401	0.008006	0.000058	–0.000131
		CAP-f-T	–0.424942	0.047087	–0.000458	0.006232	–0.000070	0.000058
		EIR-f-PLR	0.246644	0.184576	0.566463			
F	Liquid-cooled positive displacement ≥300 and <600 tons 0.610 FL, 0.520 *IPLV*.IP Path A	EIR-f-T	1.161349	–0.040557	0.000431	0.013567	0.000003	–0.000103
		CAP-f-T	0.012766	0.033086	–0.000350	0.004004	–0.000061	0.000083
		EIR-f-PLR	0.244926	0.218890	0.532972			
G	Liquid-cooled positive displacement ≥600 tons 0.560 FL, 0.500 *IPLV*.IP Path A	EIR-f-T	0.874461	–0.041390	0.000430	0.022262	–0.000058	–0.000097
		CAP-f-T	0.122304	0.024081	–0.000293	0.006302	–0.000081	0.000116
		EIR-f-PLR	0.264371	0.263302	0.471690			

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Table J-4 Chiller Performance Curves for Section 12 (Simulation Input Required in I-P units) *(Continued)*

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
H	Liquid-cooled centrifugal <150 tons 0.610 FL, 0.550 *IPLV*.IP Path A	EIR-f-T	0.474969	–0.036087	0.000223	0.030749	–0.000178	0.000094
	Liquid-cooled centrifugal ≥150 tons <300 tons 0.610 FL, 0.550 *IPLV*.IP Path A	CAP-f-T	–0.454052	0.056252	–0.000669	0.000736	–0.000099	0.000249
		EIR-f-PLR	0.304206	0.073866	0.621457			
I	Liquid-cooled centrifugal ≥300 tons <400 tons 0.560 FL, 0.520 *IPLV*.IP Path A	EIR-f-T	0.596868	–0.022768	0.000131	0.023536	–0.000130	0.000024
		CAP-f-T	0.947009	0.032913	–0.000354	–0.020151	0.000062	0.000148
		EIR-f-PLR	0.276961	0.101749	0.621383			
J	Liquid-cooled centrifugal ≥400 tons <600 tons 0.560 FL, 0.500 *IPLV*.IP Path A	EIR-f-T	0.551957	–0.036196	0.000300	0.028396	–0.000147	0.000029
	Liquid-cooled centrifugal ≥600 tons 0.560 FL, 0.500 *IPLV*.IP Path A	CAP-f-T	–0.702242	0.077132	–0.000785	–0.005637	–0.000033	0.000145
		EIR-f-PLR	0.290891	0.059366	0.649421			
K	Air-cooled <150 tons, 9.700 FL, 15.800 *IPLV*.IP Path B	EIR-f-T	2.054048	–0.042406	0.000450	–0.009813	0.000140	–0.000093
		CAP-f-T	–1.325652	0.074160	–0.000607	0.013871	–0.000088	–0.000069
		EIR-f-PLR	0.036849	0.100792	1.614142	–0.748013		
L	Air-cooled ≥150 tons, 9.700 FL, 16.100 *IPLV*.IP Path B	EIR-f-T	1.673814	–0.041178	0.000429	–0.003424	0.000109	–0.000084
		CAP-f-T	–0.939345	0.074488	–0.000615	0.005127	–0.000048	–0.000048
		EIR-f-PLR	0.095711	0.009903	1.543396	–0.646737		
M	Liquid-cooled positive displacement <75 tons 0.780 FL, 0.500 *IPLV*.IP Path B	EIR-f-T	2.018167	–0.045111	0.000485	–0.008503	0.000168	–0.000124
		CAP-f-T	–0.913752	0.073361	–0.000654	0.003787	–0.000054	0.000006
		EIR-f-PLR	0.107200	0.182611	0.705182			
N	Liquid-cooled positive displacement ≥75 and <150 tons 0.750 FL, 0.490 *IPLV*.IP Path B	EIR-f-T	1.849951	–0.043409	0.000467	–0.005187	0.000146	–0.000123
		CAP-f-T	–0.840342	0.071938	–0.000641	0.002703	–0.000047	0.000007
		EIR-f-PLR	0.183811	–0.044417	0.855660			
O	Liquid-cooled positive displacement ≥150 and <300 tons 0.680 FL, 0.440 *IPLV*.IP Path B	EIR-f-T	1.020192	–0.030046	0.000363	0.008504	0.000053	–0.000135
		CAP-f-T	–0.451749	0.051393	–0.000490	0.004351	–0.000058	0.000050
		EIR-f-PLR	0.090936	0.207812	0.696735			
P	Liquid-cooled positive displacement ≥300 and <600 tons 0.625 FL, 0.410 *IPLV*.IP Path B	EIR-f-T	1.189071	–0.038585	0.000415	0.011574	0.000017	–0.000108
		CAP-f-T	–0.063852	0.038321	–0.000388	0.002935	–0.000054	0.000072
		EIR-f-PLR	0.103665	0.148024	0.744887			
Q	Liquid-cooled positive displacement ≥600 tons 0.585 FL, 0.380 *IPLV*.IP Path B	EIR-f-T	0.916144	–0.041541	0.000436	0.020987	–0.000047	–0.000100
		CAP-f-T	0.131880	0.023312	–0.000286	0.006699	–0.000084	0.000116
		EIR-f-PLR	0.061706	0.261711	0.677017			

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Table J-4 Chiller Performance Curves for Section 12 (Simulation Input Required in I-P units) *(Continued)*

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
R	Liquid-cooled centrifugal <150 tons 0.695 FL, 0.440 *IPLV*.IP Path B	EIR-f-T	0.860442	–0.036414	0.000317	0.022419	–0.000108	0.000001
		CAP-f-T	–0.062772	0.054642	–0.000550	–0.008072	0.000004	0.000101
		EIR-f-PLR	0.072183	0.108650	0.818174			
S	Liquid-cooled centrifugal ≥150 tons <300 tons 0.635 FL, 0.400 *IPLV*.IP Path B	EIR-f-T	0.582513	–0.033786	0.000227	0.027678	–0.000157	0.000067
		CAP-f-T	0.015941	0.049796	–0.000573	–0.007266	–0.000041	0.000219
		EIR-f-PLR	0.064979	0.151829	0.779131			
T	Liquid-cooled centrifugal ≥300 tons <400 tons 0.595 FL, 0.390 *IPLV*.IP Path B	EIR-f-T	0.634610	–0.033472	0.000260	0.026148	–0.000130	0.000015
		CAP-f-T	0.127596	0.046709	–0.000538	–0.006247	–0.000047	0.000195
		EIR-f-PLR	0.082812	0.152816	0.764822			
U	Liquid-cooled centrifugal ≥400 tons <600 tons 0.585 FL, 0.380 *IPLV*.IP Path B	EIR-f-T	0.593414	–0.028948	0.000224	0.024197	–0.000126	0.000027
	Liquid-cooled centrifugal ≥600 tons 0.585 FL, 0.380 *IPLV*.IP Path B	CAP-f-T	–0.487422	0.071558	–0.000737	–0.006964	–0.000032	0.000158
		EIR-f-PLR	0.058583	0.205486	0.736345			

Table J-5 Chiller Performance Curves for Section 12 (Simulation Input Required in SI Units)

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
A	Air-cooled <150 tons, 10.100 FL, 13.700 *IPLV*.IP Path A	EIR-f-T	0.825618	–0.025861	0.001396	–0.002728	0.000381	–0.000373
		CAP-f-T	0.686206	0.057562	–0.001835	0.013810	–0.000338	–0.000247
		EIR-f-PLR	0.087789	0.185696	1.561411	–0.832304		
B	Air-cooled ≥150 tons, 10.100 FL, 14.00 *IPLV*.IP Path A	EIR-f-T	0.807832	–0.029452	0.001431	–0.002832	0.000399	–0.000278
		CAP-f-T	0.794185	0.060199	–0.002016	0.006203	–0.000229	–0.000183
		EIR-f-PLR	0.118081	0.107477	1.570838	–0.794051		
C	Liquid-cooled positive displacement <75 tons 0.750 FL, 0.600 *IPLV*.IP Path A	EIR-f-T	0.836880	–0.032383	0.001568	–0.002806	0.000544	–0.000407
		CAP-f-T	0.838337	0.057024	–0.002117	0.000793	–0.000175	0.000020
		EIR-f-PLR	0.243730	0.165972	0.586099			
D	Liquid-cooled positive displacement ≥75 and <150 tons 0.720 FL, 0.560 *IPLV*.IP Path A	EIR-f-T	0.740920	–0.030144	0.001479	0.003850	0.000416	–0.000404
		CAP-f-T	0.861840	0.057837	–0.002170	–0.001391	–0.000136	0.000040
		EIR-f-PLR	0.208982	0.224001	0.561479			
E	Liquid-cooled positive displacement ≥150 and <300 tons 0.660 FL, 0.540 *IPLV*.IP Path A	EIR-f-T	0.620834	–0.023642	0.001300	0.013555	0.000189	–0.000425
		CAP-f-T	0.800066	0.035377	–0.001482	0.006462	–0.000227	0.000187
		EIR-f-PLR	0.246644	0.184576	0.566463			
F	Liquid-cooled positive displacement ≥300 and <600 tons 0.610 FL, 0.520 *IPLV*.IP Path A	EIR-f-T	0.636828	–0.029245	0.001397	0.018817	0.000008	–0.000332
		CAP-f-T	0.863175	0.023955	–0.001135	0.004955	–0.000197	0.000268
		EIR-f-PLR	0.244926	0.218890	0.532972			

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Table J-5 Chiller Performance Curves for Section 12 (Simulation Input Required in SI Units) *(Continued)*

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
G	Liquid-cooled positive displacement ≥600 tons 0.560 FL, 0.500 *IPLV*.IP Path A	EIR-f-T	0.544967	–0.030491	0.001395	0.027852	–0.000187	–0.000314
		CAP-f-T	0.830804	0.016310	–0.000949	0.008707	–0.000263	0.000377
		EIR-f-PLR	0.264371	0.263302	0.471690			
H	Liquid-cooled centrifugal <150 tons 0.610 FL, 0.550 *IPLV*.IP Path A	EIR-f-T	0.447243	–0.033785	0.000724	0.040274	–0.000577	0.000305
	Liquid-cooled centrifugal ≥150 tons <300 tons 0.610 FL, 0.550 *IPLV*.IP Path A	CAP-f-T	0.837420	0.038528	–0.002167	0.004185	–0.000322	0.000806
		EIR-f-PLR	0.304206	0.073866	0.621457			
I	Liquid-cooled centrifugal ≥300 tons <400 tons 0.560 FL, 0.520 *IPLV*.IP Path A	EIR-f-T	0.647193	–0.024484	0.000426	0.028764	–0.000421	0.000077
		CAP-f-T	1.207878	0.026951	–0.001148	–0.020576	0.000202	0.000479
		EIR-f-PLR	0.276961	0.101749	0.621383			
J	Liquid-cooled centrifugal ≥400 tons <600 tons 0.560 FL, 0.500 *IPLV*.IP Path A	EIR-f-T	0.489242	–0.028851	0.000973	0.035835	–0.000477	0.000096
	Liquid-cooled centrifugal ≥600 tons 0.560 FL, 0.500 *IPLV*.IP Path A	CAP-f-T	0.896806	0.056739	–0.002544	–0.005536	–0.000105	0.000470
		EIR-f-PLR	0.290891	0.059366	0.649421			
K	Air-cooled <150 tons, 9.700 FL, 15.800 *IPLV*.IP Path B	EIR-f-T	0.891872	–0.029821	0.001459	–0.006929	0.000453	–0.000303
		CAP-f-T	0.709195	0.059566	–0.001968	0.010899	–0.000284	–0.000222
		EIR-f-PLR	0.036849	0.100792	1.614142	–0.748013		
L	Air-cooled ≥150 tons, 9.700 FL, 16.100 *IPLV*.IP Path B	EIR-f-T	0.711589	–0.029520	0.001390	0.001554	0.000353	–0.000272
		CAP-f-T	0.879844	0.060415	–0.001994	0.000937	–0.000156	–0.000155
		EIR-f-PLR	0.095711	0.009903	1.543396	–0.646737		
M	Liquid-cooled positive displacement <75 tons 0.780 FL, 0.500 *IPLV*.IP Path B	EIR-f-T	0.844064	–0.032504	0.001571	–0.003076	0.000545	–0.000402
		CAP-f-T	0.835803	0.057057	–0.002119	0.000903	–0.000176	0.000019
		EIR-f-PLR	0.107200	0.182611	0.705182			
N	Liquid-cooled positive displacement ≥75 and <150 tons 0.750 FL, 0.490 *IPLV*.IP Path B	EIR-f-T	0.797371	–0.031361	0.001514	0.000419	0.000473	–0.000398
		CAP-f-T	0.850710	0.056037	–0.002077	–0.000147	–0.000153	0.000023
		EIR-f-PLR	0.183811	–0.044417	0.855660			
O	Liquid-cooled positive displacement ≥150 and <300 tons 0.680 FL, 0.440 *IPLV*.IP Path B	EIR-f-T	0.617871	–0.020110	0.001175	0.013623	0.000172	–0.000439
		CAP-f-T	0.822519	0.038968	–0.001588	0.004048	–0.000188	0.000164
		EIR-f-PLR	0.090936	0.207812	0.696735			
P	Liquid-cooled positive displacement ≥300 and <600 tons 0.625 FL, 0.410 *IPLV*.IP Path B	EIR-f-T	0.656763	–0.027891	0.001343	0.016627	0.000056	–0.000348
		CAP-f-T	0.877218	0.028393	–0.001257	0.003217	–0.000174	0.000232
		EIR-f-PLR	0.103665	0.148024	0.744887			

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Table J-5 Chiller Performance Curves for Section 12 (Simulation Input Required in SI Units) *(Continued)*

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
Q	Liquid-cooled positive displacement ≥600 tons 0.585 FL, 0.380 *IPLV*.IP Path B	EIR-f-T	0.553694	–0.030347	0.001412	0.026568	–0.000153	–0.000325
		CAP-f-T	0.831828	0.015657	–0.000928	0.009067	–0.000272	0.000376
		EIR-f-PLR	0.061706	0.261711	0.677017			
R	Liquid-cooled centrifugal <150 tons 0.695 FL, 0.440 *IPLV*.IP Path B	EIR-f-T	0.627360	–0.028989	0.001027	0.027958	–0.000350	0.000002
		CAP-f-T	0.972517	0.040861	–0.001781	–0.008217	0.000013	0.000328
		EIR-f-PLR	0.072183	0.108650	0.818174			
S	Liquid-cooled centrifugal ≥150 tons <300 tons 0.635 FL, 0.400 *IPLV*.IP Path B	EIR-f-T	0.526475	–0.030843	0.000735	0.035532	–0.000510	0.000216
		CAP-f-T	0.971699	0.036192	–0.001858	–0.005224	–0.000134	0.000709
		EIR-f-PLR	0.064979	0.151829	0.779131			
T	Liquid-cooled centrifugal ≥300 tons <400 tons 0.595 FL, 0.390 *IPLV*.IP Path B	EIR-f-T	0.547810	–0.029470	0.000842	0.032888	–0.000423	0.000048
		CAP-f-T	1.023337	0.033378	–0.001742	–0.005438	–0.000153	0.000633
		EIR-f-PLR	0.082812	0.152816	0.764822			
U	Liquid-cooled centrifugal ≥400 tons <600 tons 0.585 FL, 0.380 *IPLV*.IP Path B	EIR-f-T	0.569569	–0.024700	0.000727	0.030569	–0.000409	0.000087
	Liquid-cooled centrifugal ≥600 tons 0.585 FL, 0.380 *IPLV*.IP Path B	CAP-f-T	0.953580	0.053010	–0.002387	–0.007165	–0.000104	0.000510
		EIR-f-PLR	0.058583	0.205486	0.736345			

Table J-6 Chiller Performance Curves for Normative Appendix G (Simulation Input Required in I-P Units)

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
V	Liquid-cooled positive displacement <150 tons 0.7903 FL, 0.6763 *IPLV*.IP	EIR–f–T	2.044998	–0.047515	0.000505	–0.008787	0.000175	–0.000120
		CAP–f–T	–0.981909	0.076674	–0.000687	0.003920	–0.000058	0.000006
		EIR–f–PLR	0.276037	0.253577	0.466353			
X	Liquid-cooled positive displacement ≥150 and <300 tons 0.7178 FL, 0.6280 *IPLV*.IP	EIR–f–T	1.037805	–0.024695	0.000329	0.003130	0.000102	–0.000159
		CAP–f–T	–0.683858	0.065283	–0.000602	0.002347	–0.000050	0.000036
		EIR–f–PLR	0.250801	0.345915	0.399138			
Y	Liquid-cooled positive displacement ≥300 tons 0.6395 FL, 0.5719 *IPLV*.IP	EIR–f–T	1.188945	–0.039426	0.000413	0.012888	0.000002	–0.000098
		CAP–f–T	–0.160681	0.044390	–0.000429	0.001024	–0.000035	0.000055
		EIR–f–PLR	0.320097	0.074356	0.602938			
Z	Liquid-cooled centrifugal <150 tons 0.7034 FL, 0.6699 *IPLV*.IP	EIR–f–T	0.857485	–0.036148	0.000314	0.022356	–0.000108	0.000001
		CAP–f–T	–0.061958	0.054739	–0.000550	–0.008177	0.000005	0.000101
		EIR–f–PLR	0.281669	0.202762	0.515409			
AA	Liquid-cooled centrifugal ≥150 and <300 tons 0.6337 FL, 0.5961 *IPLV*.IP	EIR–f–T	0.479847	–0.035964	0.000225	0.031377	–0.000183	0.000085
		CAP–f–T	–0.128081	0.050459	–0.000581	–0.004297	–0.000049	0.000200
		EIR–f–PLR	0.339494	0.049090	0.611582			

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Table J-6 Chiller Performance Curves for Normative Appendix G (Simulation Input Required in I-P Units) *(Continued)*

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
AB	Liquid-cooled centrifugal ≥300 tons 0.5766 FL, 0.5495 *IPLV*.IP	EIR–f–T	0.747210	–0.038874	0.000313	0.027638	–0.000133	–0.000008
		CAP–f–T	0.117208	0.042940	–0.000478	–0.003930	–0.000045	0.000155
		EIR–f–PLR	0.309752	0.153649	0.536462			

Table J-7 Chiller Performance Curves for Normative Appendix G (Simulation Input Required in SI Units)

Set	Description	Output Variable	Coeff 1	Coeff 2	Coeff 3	Coeff 4	Coeff 5	Coeff 6
V	Liquid-cooled positive displacement <150 tons 0.7903 FL, 0.6763 *IPLV*.IP	EIR-f-T	0.817024	–0.034213	0.001638	–0.002590	0.000566	–0.000389
		CAP-f-T	0.840898	0.059263	–0.002225	0.000735	–0.000188	0.000020
		EIR-f-PLR	0.276037	0.253577	0.466353			
X	Liquid-cooled positive displacement ≥150 and <300 tons 0.7178 FL, 0.6280 *IPLV*.IP	EIR-f-T	0.627193	–0.015646	0.001067	0.008270	0.000331	–0.000515
		CAP-f-T	0.850133	0.050234	–0.001951	0.000606	–0.000161	0.000118
		EIR-f-PLR	0.250801	0.345915	0.399138			
Y	Liquid-cooled positive displacement ≥300 tons 0.6395 FL, 0.5719 *IPLV*.IP	EIR-f-T	0.664854	–0.029016	0.001339	0.017823	0.000008	–0.000318
		CAP-f-T	0.873130	0.033599	–0.001391	0.000961	–0.000114	0.000178
		EIR-f-PLR	0.320097	0.074356	0.602938			
Z	Liquid-cooled centrifugal <150 tons 0.7034 FL, 0.6699 *IPLV*.IP	EIR-f-T	0.628525	–0.028798	0.001019	0.027867	–0.000349	0.000002
		CAP-f-T	0.973310	0.040996	–0.001782	–0.008340	0.000016	0.000327
		EIR-f-PLR	0.281669	0.202762	0.515409			
AA	Liquid-cooled centrifugal ≥150 and <300 tons 0.6337 FL, 0.5961 *IPLV*.IP	EIR-f-T	0.464330	–0.033834	0.000731	0.040345	–0.000592	0.000277
		CAP-f-T	0.909633	0.035460	–0.001881	–0.001808	–0.000158	0.000648
		EIR-f-PLR	0.339494	0.049090	0.611582			
AB	Liquid-cooled centrifugal ≥300 tons 0.5766 FL, 0.5495 *IPLV*.IP	EIR-f-T	0.563967	–0.034331	0.001015	0.033941	–0.000432	–0.000025
		CAP-f-T	0.988289	0.031128	–0.001550	–0.003349	–0.000147	0.000503
		EIR-f-PLR	0.309752	0.153649	0.536462			

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INFORMATIVE APPENDIX K
INFORMATIVE FIGURES—THERMAL BRIDGES

This appendix contains informative reference figures for Sections 5.5.5.1 through 5.5.5.4 for the convenience of users of Standard 90.1 and not for use as specific details required for compliance. These figures are not intended to include all detailed variations that may meet the requirements. It is not intended that the figures represent all possible compliant configurations. The figures do not show *roof* membrane or wall cladding.

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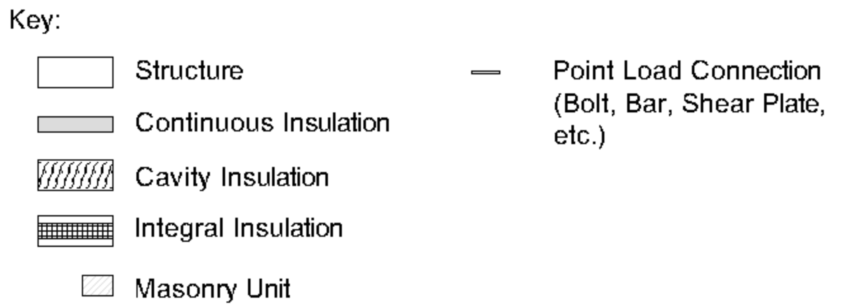
SYMBOLS



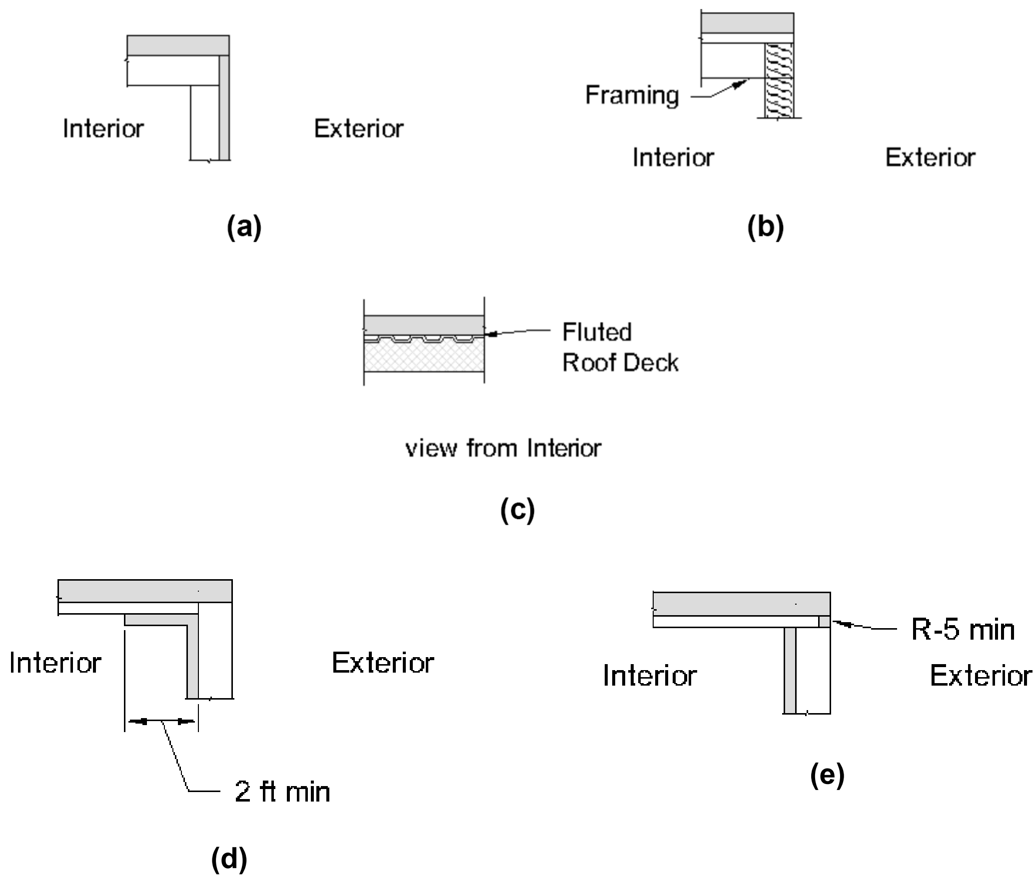


Figure K-1

a. Wall with exterior *continuous insulation* (Section 5.5.5.1.1[a])
b. Wall with cavity insulation (Section 5.5.5.1.1[b])
c. Wall with interior or cavity insulation (Sections 5.5.5.1.1[b] and [c])
d. *Mass wall* with interior insulation (Section 5.5.5.1.1[c][1])
e. *Mass wall* with interior insulation (Section 5.5.5.1.1[c][2])

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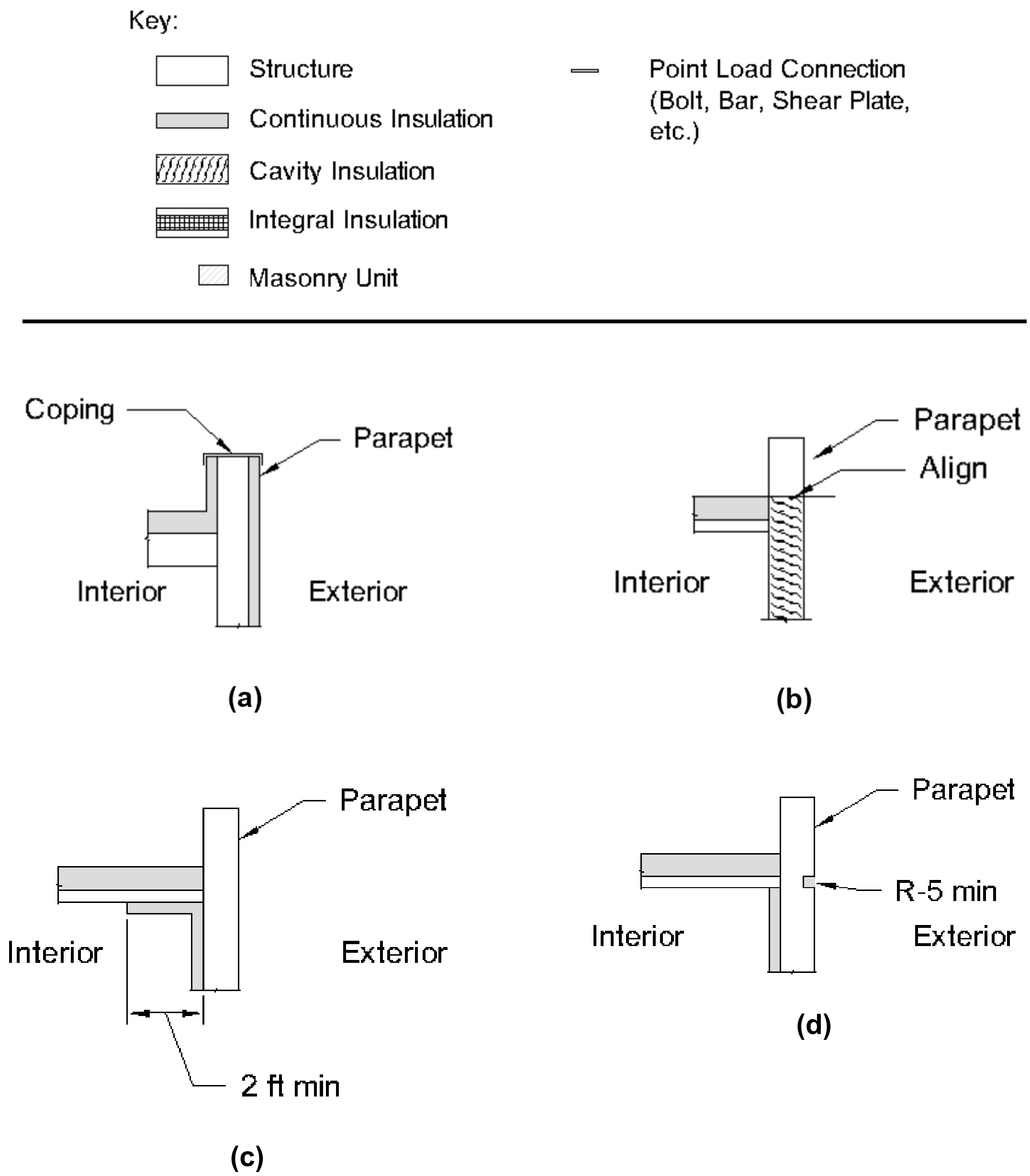

Figure K-2

a. Wall with exterior *continuous insulation* (Section 5.5.5.1.2[a])
b. Wall with cavity insulation (Section 5.5.5.1.2[b][1])
c. *Mass wall* with interior insulation (Section 5.5.5.1.2[c][1])
d. *Mass wall* with interior insulation (Section 5.5.5.1.2[c][2])

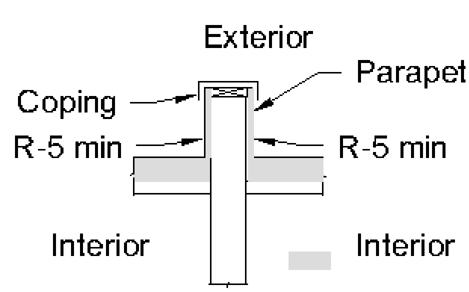

Figure K-3 Parapet within field of roof (Section 5.5.5.1.3).

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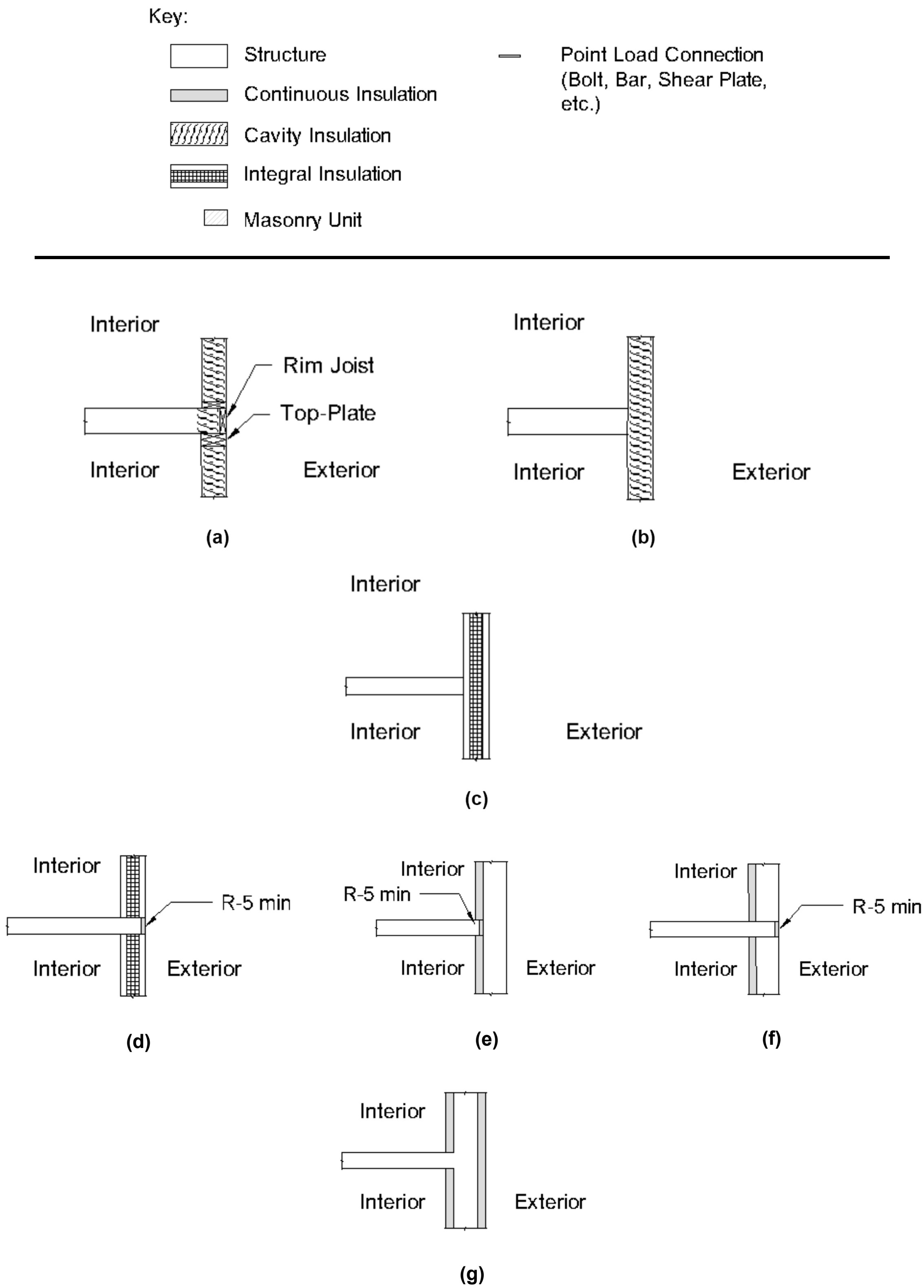

Figure K-4

a. Wall with cavity insulation (Section 5.5.5.2.1[b])
b. Wall with cavity insulation (Section 5.5.5.2.1[b])
c. Wall with integral insulation (Section 5.5.5.2.1[c])
d. *Mass wall* with integral insulation (Section 5.5.5.2.1[c])
e. *Mass wall* with interior insulation (Section 5.5.5.2.1[d][1])
f. *Mass wall* with interior insulation (Section 5.5.5.2.1[d][2])
g. *Mass wall* with exterior *continuous insulation* plus interior insulation (Section 5.5.5.2.1[e])

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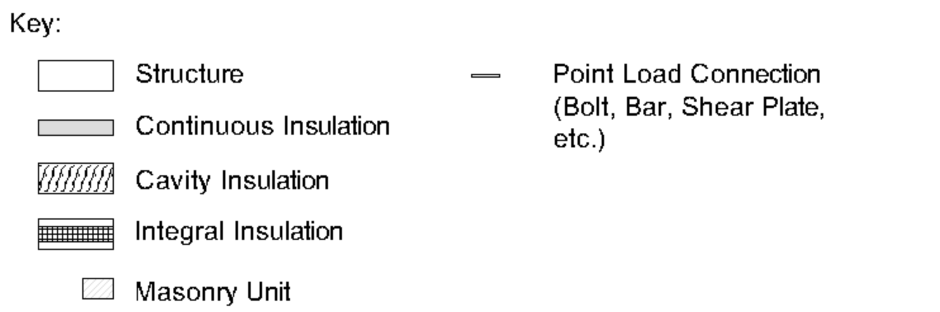

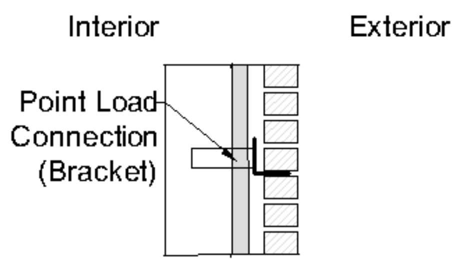

Figure K-5 Shelf angles supporting exterior cladding (Section 5.5.5.3).

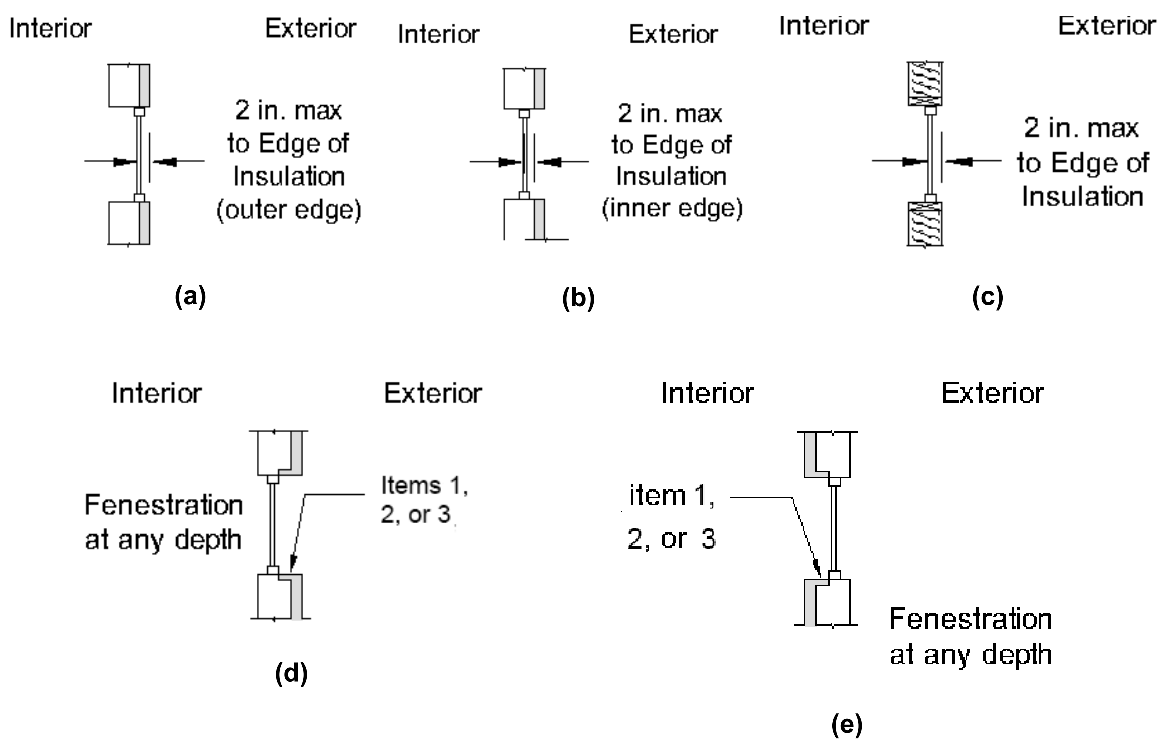

Figure K-6

a. Fenestration and *continuous insulation* (Section 5.5.5.4[a])
b. Fenestration and *continuous insulation* (Section 5.5.5.4[a])
c. Fenestration and no *continuous insulation* (Section 5.5.5.4[b])
d. Insulation between fenestration and wall (Section 5.5.5.4[c], Items [1], [2], or [3])
e. Insulation between fenestration and wall (Section 5.5.5.4[c], Items [1], [2], or [3])

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(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX L
MECHANICAL SYSTEM PERFORMANCE RATING METHOD

L1. GENERAL

L1.1 Scope. This appendix offers an alternative path of compliance for *HVAC systems* in accordance with Section 6.6.2. This appendix establishes the requirements for *HVAC systems* that use the Mechanical System Performance Rating Method and requirements for calculating $TSPR_p$ and $TSPR_r$ to demonstrate compliance in accordance with Section 6.6.2.2. Not all *HVAC systems* are allowed to use the Mechanical System Performance Rating Method as described in Section L1.1.1.

L1.1.1 Allowable HVAC Systems. *HVAC systems* are allowed to use the Mechanical System Performance Rating Method if they comply with all the following criteria:

a. The *HVAC system* type is included in Table L.1.1.1.
b. The *HVAC system* serves a *building* use type included in Section L1.1.1.1.
c. The *HVAC system* is not excluded by Section L1.1.1.2.
d. The *HVAC system* is powered by grid-delivered electricity, renewable electricity, natural gas, propane, renewable thermal *energy*, or distillate *fuel* oil.

Informative Notes:

1. The intention of the scope is to allow most of the *building* to use the *TSPR* path and have portions of the *buildings* that cannot use the *TSPR* path use either the prescriptive path or the *Computer Room System* Path.
2. The allowed *system* types may not be supported by all *simulation program* versions. The *simulation program* is required to support the reference *systems* for the *building* types modeled, and the proposed *system* type(s) must be supported by the *simulation program*.

L1.1.1.1 Allowable Building Use Types. *HVAC systems* that serve the following *building* use types are allowed to use the Mechanical System Performance Rating Method:

a. Large office (*gross conditioned floor area* >150,000 ft^2 or >5 *stories*)
b. Medium office (*gross conditioned floor area* 5000 to 150,000 ft^2 and ≤5 *stories*)
c. Small office (*gross conditioned floor area* ≤5000 ft^2 and ≤5 *stories*)
d. Retail
e. Multifamily (including dormitory)
f. Hotel (including motel)
g. School (including education and university)
h. Other *building* use types that are <1000 ft^2 and <10% of the *building* conditioned floor area unless specifically excluded by Section L1.1.1.2(a)

Informative Note: Item (h) allows for a small sandwich or coffee counter service area but not a restaurant in an office *building* lobby or bookstore, for example.

L1.1.1.2 Excluded HVAC Systems. The following *HVAC systems* are excluded from using the Mechanical System Performance Rating Method:

a. *HVAC systems* serving one of the following excluded *building* areas:
   1. Data centers and *computer rooms* with *equipment* power density exceeding 20 W/ft^2 of conditioned floor area and exceeding 10 *kW* of *equipment* load
   2. Laboratories with fume hoods
   3. Locker rooms with more than four showers
   4. Cafeterias and dining rooms
   5. Restaurants and commercial kitchens with total cooking capacity greater than 100,000 Btu/h (does not include break rooms)
   6. Natatoriums or rooms with saunas
   7. Areas of *buildings* with commercial refrigeration *equipment* exceeding 100 *kW* of power input
b. *HVAC systems* that are not replaced in their entirety as part of an *alteration* and are not serving initial build-out *construction*

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Table L.1.1.1 Proposed Building HVAC Systems Allowed to Use the Mechanical System Performance Rating Method

System No.	System Name
1	*Packaged terminal air conditioner* (with electric or hydronic heat)
2	*Packaged terminal heat pump*
3	Packaged single-zone furnace[a] and/or air-cooled air conditioner (includes split systems [b])
4	Packaged single-zone heat pump (air-to-air only) (includes split systems [b] and electric or gas supplemental heat)
5	*VRF system* (air source)
6	Four-pipe fan coil
7	Water-source heat pump (water loop), water-source *VRF system*, or water-source air conditioner
8	Ground-source heat pump
9	Packaged *VAV system* (DX cooling) [a]
10	*VAV system* (hydronic cooling) [a]
11	*VAV system* with fan-powered *terminal* units
12	DOAS (in conjunction with *systems* 1 through 8)

a. *Reheat* or primary heat may be electric, hydronic, or gas furnace.
b. Condensing units with DX air handlers are modeled as package furnace with air conditioners or heat pumps.
Informative Note: See Section 3.3 for a full list of terms used in this table.

c. *HVAC systems* serving *portions* of the *building* that are also served in parallel by other *HVAC systems* not allowed to use the Mechanical System Performance Rating Method
d. *HVAC systems* using any of the following:
   1. District heating or cooling
   2. Small-duct high-velocity air-cooled, *space*-constrained air-cooled, *single-package vertical air conditioner*, *single-package vertical heat pump*
   3. Double-duct air conditioner or double-duct heat pump as defined in 10CFR part 431, Subpart F
   4. *Packaged terminal air conditioners* and *packaged terminal heat pumps* that have cooling capacity greater than 12,000 Btu/h
   5. *Systems* with a common heating source serving both HVAC and *service water heating equipment*
   6. *HVAC systems* that provide recovered heat for *service water heating*

   Exceptions to L1.1.1.2(a) and (c):
   1. Multiple-zone *HVAC systems* in Table L.1.1.1, including dedicated *outdoor air systems* (DOAS), where 80% or more of *system* supply air serves allowed *building* use types in accordance with Section L1.1.1.1 and 20% or less of *system* supply air serves excluded areas in Items (a) or (c).
   2. Central chiller or *boiler* plants where 80% or more of capacity serves allowed *building* use types in accordance with Section L1.1.1.1 and 20% or less of capacity serves excluded areas in items (a) or (c).

L2. MECHANICAL SYSTEM PERFORMANCE RATING METHOD

L2.1 Compliance

L2.1.1 Mandatory Requirements. All *HVAC systems* in the proposed *building* design shall comply with the requirements in Section 6.2.1.

Informative Note: *Buildings* using the Mechanical System Performance Rating Method are required to meet all mandatory provisions in Section 6.4 in accordance with Section 6.2.1. For example, while *demand control ventilation* (*DCV*) controlled area in the proposed *building* is one of the user entries in the *simulation program*, the minimum entry needs to meet the floor area where *DCV* is required in accordance with Section 6.4.3.8. The intent of this entry is to give credit for *DCV* control in more area than required, but not to allow *DCV* that is a mandatory requirement to be traded off with other *efficiency* improvements.

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L2.1.2 Mechanical System Performance Rating Method Requirements. All *HVAC systems* using the Mechanical System Performance Rating Method shall demonstrate compliance using $TSPR_p$ and $TSPR_r$ in accordance with Section 6.6.2 and the following requirements:

a. $TSPR_p$ and $TSPR_r$ shall be calculated in accordance with Section L2.1.5, "Calculating *TSPR,*" and the requirements of Sections L1, L3, L4, and L5.
b. *Alterations* that include replacement of the entire *HVAC system* shall be modeled as a new *building*.
c. *HVAC systems* shall comply with Section L2.1.4 "Partial Prescriptive Requirements."
d. Initial build-out *construction* shall be modeled in accordance with Section L2.1.3, "Core and Shell/Initial Build-Out Construction Analysis."
e. Compliance documentation and supplemental information shall be submitted in accordance with Sections 4.2.2 and L2.1.6 "*TSPR* Submittals."

L2.1.3 Core and Shell/Initial Build-Out Construction Analysis. Where the *building* permit applies to only a portion of the *HVAC system* in a *building*, and the remaining components will be designed under a future *building* permit or were previously installed, the future or previously installed components shall be modeled as follows:

a. Where the *HVAC zones* that do not include *HVAC systems* in the current permit will be or are served by independent *systems*, the block (see Section L2.2.1) including those zones shall not be included in the model.
b. Where the *HVAC zones* that do not include complete *HVAC systems* in the permit are intended to receive HVAC services from *systems* in the permit, their proposed zonal *systems* shall be modeled with *equipment* that meets but does not exceed the requirements of Sections 6.4 and 6.5.
c. Where the zone *equipment* in the permit receives HVAC services from previously installed *systems* that are not in the permit, the previously installed *systems* shall be modeled with *equipment* matching the certified value of what is installed or *equipment* that meets the requirements of Sections 6.4 and 6.5, whichever has the more efficient *energy* use.
d. Where the central plant heating and cooling *equipment* is completely replaced and *HVAC zones* with *existing systems* receive HVAC services from *systems* in the permit, their proposed zonal *systems* shall be modeled with *equipment* that meets but does not exceed the requirements of Sections 6.4 and 6.5.

Informative Notes:

1. Examples of *HVAC systems* that are intended to receive HVAC services from *systems* in the permit include future zonal water source heat pumps that will receive loop water that is heated by a *boiler* or is cooled by a cooling tower included in the permit, any *system* that will receive outdoor *ventilation* air from a DOAS included in the permit, and future zone *terminal* units that will be connected to a central *VAV system* included in the permit.
2. An initial build-out with heating coils served from a previously installed *system* with a high-*efficiency* condensing *boiler* would use the installed *efficiency* if it exceeded the current requirements. If the installed *boiler* had a lower *efficiency* than the current requirements, the current requirement would be used.
3. A partial central plant upgrade (e.g., chiller but not *boiler* replacement) cannot use this method.

L2.1.4 Partial Prescriptive Requirements. *HVAC systems* using the HVAC *Performance Rating Method* shall meet relevant prescriptive requirements in Section 6.5 as follows:

a. *Air economizers* shall meet the requirements of Sections 6.5.1.1.5 and 6.5.1.1.6.
b. Steam humidifiers shall meet requirements of Section 6.5.2.4.
c. *Variable-air-volume systems* shall meet requirements of Sections 6.5.3.2.2, 6.5.3.2.3, and 6.5.3.3.
d. Hydronic *systems* shall meet the requirements of Section 6.5.4.2.
e. Plants with multiple chillers or *boiler*s shall meet the requirements of Section 6.5.4.3.
f. Chilled-water and heating-water supply temperature *reset* shall meet the requirements of Section 6.5.4.4 without exception.
g. Hydronic (water loop) heat pumps and water-cooled *unitary air conditioners* shall meet the requirements of Section 6.5.4.5.
h. Cooling-tower turndown shall meet the requirements of Section 6.5.5.4.
i. Heating of unenclosed *spaces* shall meet the requirements of Section 6.5.8.1.
j. Hot-gas bypass shall meet the requirements of Section 6.5.9.
k. *Systems* shall meet the *door* switch control requirements of Section 6.5.10.
l. Refrigeration *systems* shall meet the requirements of Section 6.5.11.

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L2.1.5 Calculating TSPR. $TSPR_p$ shall be calculated according to Equation L-1:

$$TSPR_r = \frac{\text{Loads}_r}{\text{HVACinput}_p} \quad \text{(L-1)}$$

where

Loads$_r$ = sum of the annual heating and cooling loads for the *TSPR reference building design* met by the *building HVAC system*, thousand Btu.

HVACinput$_p$ = sum of the annual HVAC *energy* input for heating, cooling, fans, *energy* recovery, *pumps*, and heat rejection for the *proposed design*. The HVAC *energy* input units shall be in accordance with Section L5.

$TSPR_r$ shall be calculated according to Equation L-2:

$$TSPR_r = \frac{\text{Loads}_r}{\text{HVACinput}_r} \quad \text{(L-2)}$$

where

Loads$_r$ = sum of the annual heating and cooling loads for the *TSPR reference building design* met by the *building HVAC system*, thousand Btu.

HVACinput$_r$ = sum of the annual HVAC *energy* input for heating, cooling, fans, *energy* recovery, *pumps*, and heat rejection for the *TSPR reference building design.* The HVAC *energy* input units shall be in accordance with Section L5.

Informative Note: The annual HVAC *energy* uses calculated using the Mechanical System Performance Rating Method are not predictions of whole-*building energy* consumption for an actual proposed *building* after *construction*. Actual experience will differ from these calculations due to variations such as occupancy, *building* operation and maintenance, weather, *energy* use of *systems* and *building* areas not covered by this procedure, changes in *energy* prices between design of the *building* and occupancy, and the precision of the calculation tool.

L2.1.6 TSPR Submittals. Where $TSPR_p$ and $TSPR_r$ are used to demonstrate compliance in accordance with Section 6.6.2, documentation shall be provided to the *building official* including the following:

a. A compliance report, as outlined in Section L3.4, generated by the *simulation program.*
b. A mapping of the actual *building* HVAC component characteristics and those simulated in the *proposed design* showing how individual pieces of HVAC *equipment* identified above have been combined into average inputs as required by the *simulation program*, including (but not limited to) the following:
   1. Fans
   2. Hydronic *pumps*
   3. Air handlers
   4. Packaged cooling *equipment*
   5. Furnaces
   6. Heat pumps
   7. *Boiler*s
   8. Chillers
   9. Heat-rejection *equipment* (open- and closed-circuit cooling towers; dry coolers)
   10. *Electric resistance* coils
   11. Condensing units
   12. Motors for fans and *pumps*
   13. *Energy* recovery devices
c. For each piece of *equipment* identified in item (b), include the following along with the units specified in Table L2.2.3 as applicable:
   1. *Equipment* name or tag consistent with that found on the design documents
   2. Rated *Efficiency* level, full-load *efficiency* as rated in Section 6.8
   3. Rated capacity
   4. Where not provided by the *simulation program* report in item (a), documentation of the calculation of any weighted *equipment efficiencies* input into the program.

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5. Electrical input power for fans and *pumps* (before any speed or frequency *control device*) at design condition and calculation of input value (W/cfm or W/gpm)

d. A floor plan of the *building* identifying how portions of the *building* are assigned to the simulated blocks (See Section L2.2.1) and which areas of the *building* are served by *HVAC systems* required to meet the requirements of Section 6.5 or Section 6.6.1.

Informative Note: The items listed under items (b) and (c) may either be included in the report generated by the *simulation program* or submitted separately. The compliance report required by Section L3.4 includes the composite *systems* entered into the program for the blocks. These may differ from actual *systems* and may be based on capacity *efficiency* weighting per Section L2.2.3.1. The *simulation program* may allow input of individual actual *systems* and perform the weighting, or it may require the user to perform that weighting separately and input the weighted *efficiencies*. In the second case, the weighted *efficiency* calculation would be included under item (c) here.

L2.2 Proposed Building Information Required. The simulation of *HVAC systems* and the *HVAC zones* they serve shall be modeled based on *building* information required by this section.

L2.2.1 Simplified Block Approach. The geometry of *buildings* shall be configured using one or more simplified geometric simulation *building* blocks, referred to as "blocks" in this appendix. Each block contains one or multiple *thermal blocks*. A more complex zoning of the *building* shall be allowed where all thermal *zones* in the reference and proposed model are the same and rules related to block geometry and *HVAC system* assignment to blocks are met with appropriate assignment to thermal *zones*.

L2.2.1.1 Block Geometry. Each block shall define attributes including block dimensions, number of *stories*, floor-to-floor height, and floor-to-ceiling height. The *simulation program* is permitted to allow the use of simplified shapes (such as rectangle, L-shape, H-shape, U-shape, or T-shape) to represent blocks. Where actual *building* shape does not match these predefined shapes, simplifications are permitted providing the following requirements are met:

a. The *gross conditioned floor area* and volume of each block shall match the actual *proposed design* within 10%.
b. The area of each *exterior building envelope* component from Tables 5.5-0 through 5.5-8 is accounted for within 10% of the actual *proposed design*.
c. The area of vertical *fenestration* and *skylights* is accounted for within 10% of the actual *proposed design*.
d. The *orientation* of each component in items (b) and (c) is accounted for within 45 degrees of the actual *proposed design*.

The user shall create multiple blocks, if necessary, to meet these requirements.

L2.2.1.2 Number of Blocks. One or more blocks shall be created per *building* based on the following restrictions:

a. Each block shall have only one *building* use type. At least one single block shall be created for each unique use type, including where one *HVAC system* serves two different use types.
b. Each block shall be served by only one type of primary or zonal *HVAC system*. A DOAS *system* shall be permitted to serve blocks served by other *systems*. A single block shall be created for each unique primary or zonal *HVAC system* type and *building* use type combination. Multiple HVAC units of the same type are permitted to be represented in one block in accordance with Section L2.2.3.1.
c. Each block shall have a single definition of floor-to-floor or floor-to-ceiling heights. Where *story* heights differ by more than 2 ft, unique blocks shall be created for the *stories* with varying heights.
d. Each block can include either above-*grade* or below-*grade* exterior *stories*. For *buildings* with both above-*grade* and below-*grade stories*, separate blocks shall be created for each. For *buildings* with *stories* partially above *grade* and partially below *grade*, if the total *wall* area of the story in consideration is greater than or equal to 50% above *grade*, it shall be simulated as a completely above-*grade* block; otherwise, it shall be simulated as a below-*grade* block.
e. In order to combine multiple *stories* into a single block, each *wall* on a facade of a block shall have similar *vertical fenestration area*. The product of the *proposed design U-factor* times the area of vertical *fenestration* (UA_{VerFen}) on each facade of a given *story* cannot differ by more than 15% of the average UA_{VerFen} for that facade in each block. The product of the *proposed design solar heat gain coefficient* (*SHGC*) times the area of vertical *fenestration* ($SHGCA_{VerFen}$) on each facade of a given *story* cannot differ by more than 15% of the average $SHGCA_{VerFen}$ for that facade in each block. If these conditions are not met, additional blocks shall be created consisting of *stories* with similar *fenestration*.

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f. For a *building* model with multiple blocks, each block facade input shall provide adequate information to identify the outside boundary condition (outside, inside to adjacent block, ground contact, or adiabatic) of each facade or portion of each facade that match the actual *proposed design*.

Informative Note: The *simulation program* may *automatically* identify the adjacent block facade outside boundary conditions through a graphic input process.

L2.2.2 Building Envelope Components. *Building envelope* thermal properties used in the *proposed design* shall be based on the actual *proposed design* using documented user-defined values and shall comply with all of the following:

a. Where different *roof* thermal properties are present in a single block, an area-weighted *U-factor* shall be used.
b. Where different *wall* constructions exist on the facade of a block, an area-weighted *U-factor* shall be used.
c. Where different *below-grade wall* constructions exist in a block, an area-weighted *C- factor* shall be used.
d. Where different *floor* constructions exist in the block*,* an area-weighted *U-factor* shall be used.
e. Where different *slab-on-grade floor* constructions exist in a block, an area-weighted *F-factor* shall be used.
f. Where different vertical *fenestration* types or sill heights exist, area-weighted sill heights, *U-factor*, and *SHGC* values shall be used.
g. Where different *skylight* types exist, area-weighted *U-factor* and *SHGC* values shall be used.
h. Permanent shading devices such as overhangs shall be modeled only if >50% of the area of vertical *fenestration* on a facade is shaded by the same.

L2.2.3 HVAC System Components. The *HVAC system* parameters shall be provided for the *proposed design* at *design conditions* unless otherwise stated with clarifications and simplifications as described in Table L2.2.3 and as follows:

a. All *HVAC zones* within a block shall be served by the same *HVAC system* type as listed in Table L.1.1.1.
b. Where multiple *system* components serve a block, average values weighted by the appropriate metric as described in Section L2.2.3.1 shall be used.
c. The Table L2.2.3 parameter requirements are based on input of full-load.*equipment efficiencies* with adjustment using part-load curves integrated in the *simulation program*. Where other approaches to part-load adjustment are used, it is permitted for specific input parameters to vary.

Informative Note: Table L2.2.3 includes both user-defined parameters and parameters that are fixed in the *simulation program* and may not be changed by the user. They are maintained in one table here so related items can be viewed together in context.

L2.2.3.1 Proposed Building HVAC System Aggregation. Projects using the Mechanical System Performance Rating Method shall comply with all the following requirements.

a. Where multiple fan *systems* serve a single block, fan power shall be based on weighted average using the design supply air (cfm).
b. Where multiple cooling *systems* serve a single block, *COP* shall be based on a weighted average using cooling capacity. DX coils shall be entered as multistage if more than 50% of coil capacity serving the block is multistage with staged controls.
c. Where multiple heating *systems* serve a single block, thermal *efficiency* or heating *COP* shall be based on a weighted average using heating capacity.
d. Where multiple *boiler*s or chillers serve a heating-water or chilled-water loop, *efficiency* shall be based on a weighted average for using heating or cooling capacity.
e. When multiple cooling towers serving a condenser water loop are combined, the cooling tower *efficiency*, cooling tower design approach, and design range are based on a weighted average of the design water flow rate through each cooling tower.
f. Where multiple *pumps* serve a heating-water, chilled-water, or condenser water loop, *pump* power shall be based on a weighted average for using design water flow rate.
g. When multiple *system* types with and without economizers are combined, the economizer maximum *outdoor air* fraction of the combined *system* shall be based on weighted average of 100% supply air for *systems* with economizers and design *outdoor air* for *systems* without economizers.
h. Multiple *systems* with and without ERVs cannot be combined.
i. *Systems* with and without supply air temperature *reset* cannot be combined.
j. *Systems* with different fan control (constant volume, multispeed, or *VAV*) for supply fans cannot be combined.

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L3. SIMULATION PROGRAM

The *simulation program* shall have the following capabilities:

Table L2.2.3 Proposed Building HVAC System Parameters

Category	Parameter	Fixed or User Defined	Required	Applicable Systems [a]
HVAC System Type	*System* type	User defined	Selected from Table L.1.1.1	All
System Sizing	Design-day information	Fixed	99.6% heating design and 1% dry-bulb and 1% wet-bulb cooling design	All
	Zone coil capacity	Fixed	Sizing factors used are 1.25 for heating *equipment* and 1.15 for cooling *equipment.*	All
	Supply airflow	Fixed	Based on the greater of a supply-air-to-room-air temperature *set point* difference of 20°F or required *OA ventilation*	
Outdoor *Ventilation* Air and Filtration	Portion of supply air with proposed filter ≥MERV 13	User defined	Percentage of supply airflow subject to higher filtration (adjusts reference fan power higher; prorated)	All
	Outdoor *ventilation* supply airflow rate adjustments	Fixed	Basis is 1.0 zone air distribution effectiveness	All
	Outdoor *ventilation* supply airflow rate	Fixed	As specified in ASHRAE/IES Standard 90.1 Normative Appendix C, adjusted for proposed *DCV* control (See “Demand Control Ventilation” category below.)	All
System Operation	*Space* temperature *set points*	Fixed	As specified in ASHRAE/IES Standard 90.1 Normative Appendix C, except for hotel/motel, which shall be 70°F heating 72°F cooling	All
	Fan operation—occupied (where DOAS meets *ventilation* requirements)	User defined	Fan either runs continuously during occupied hours or is cycled to meet thermal load.	All (continuous) 1–11 (cycles)
	Fan operation—occupied (where heating and cooling units provide *ventilation*—no DOAS)	Fixed	Fan runs continuously during occupied hours; *VAV* or multispeed fans reduce airflow related to thermal load.	1–11
	Fan operation—night cycle	Fixed	Fan cycles ON to meet *setback* temperatures.	1–11
Packaged *Equipment Efficiency*	DX cooling *efficiency*	User defined	Cooling *COP* without fan *energy* calculated in accordance with Section L4.2.3(d)	1, 2, 3, 4, 5, 7, 8, 9, 11, 12
	DX coil number of stages	User defined	Single stage or multistage	3, 4, 9, 10, 11, 12
	Heat-pump *efficiency*	User defined	Heating *COP* without fan *energy* calculated in accordance with Section L4.2.3(d)	2, 4, 5, 7, 8, 12
	Furnace *efficiency*	User defined	Furnace thermal *efficiency*	1, 3, 9, 12
Heat-Pump Supplemental Heat	Heat source	User defined	*Electric resistance* or gas furnace	2, 4, 7, 8, 12
	Control	Fixed	*Electric* heat locked out above 40°F OAT. Runs as needed in conjunction with compressor between 40°F and 0°F. Gas heat operates in place of the heat pump when the heat pump cannot meet load.	2, 4, 7, 8, 12

a. Applicable *systems* from Table L.1.1.1

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Table L2.2.3 Proposed Building HVAC System Parameters *(Continued)*

Category	Parameter	Fixed or User Defined	Required	Applicable Systems [a]
System Fan Power and Controls	Design fan power, W/cfm	User defined	Input electric power for all fans required to operate at *fan system design conditions* divided by the supply airflow rate. Include any VSD losses at design condition. This is a wire-to-air value, including all drive, motor *efficiency*, and other losses.	All

	Part-load fan controls:
	• Constant volume
	• Two-speed or three-speed, then input:
	  • W/cfm at each speed
	  • % cfm at leach speed
	• *VAV*
		User defined	Static pressure *reset* included for *VAV*	All (constant volume, two speed)
				9, 10, 11 (*VAV*)

Variable-Air-Volume Systems	SAT controls (select): • None • OAT SAT *reset* • Warmest zone SAT *reset*	User defined	If not SAT *reset*, then constant at 55°F. Options for *reset* based on OAT or warmest zone. If OAT *reset*, SAT is *reset* higher to 60°F at outdoor low of 50°F. SAT is 55°F at outdoor high of 70°F. If warmest zone, then the user can specify the minimum and maximum temperatures.	9, 10, 11
	• Zone minimum damper and E_{vs} • Standard 62.1 simple method except for schools	Fixed	• Schools: 1.2 × V_{oz} zone minimum design *ventilation* rate, cfm; E_{vs} = 0.65 • Other *buildings*: Simple Standard 62.1 method is 1.5 × V_{oz} zone minimum design *ventilation* rate, cfm; E_{vs} = 0.75.	9, 10, 11
	Dual *set point* minimum *VAV* damper position	User defined	Heating minimum and maximum airflow fraction	9, 10, 11
	Terminal-unit heating source	User defined	Electric or hydronic	
	FPTU type	User defined	Series or parallel FPTU	11
	Parallel FPTU fan		Sized for 50% peak primary air at 0.35 W/cfm	11
	Series FPTU fan	Fixed	Sized for 50% peak primary air at 0.35 W/cfm	11
Economizer	OSA economizer presence	User defined	Yes or no	3, 4, 5, 6, 9, 10, 11
	Economizer high limit	Fixed	• Lockout on differential dry-bulb temperature (OAT > RAT) in Climate Zones 6A, 5A, All B, and C • Fixed enthalpy > 28 Btu/lb or fixed dry-bulb OAT > 75°F in Climate Zones 0A to 4A	
Energy Recovery	Sensible effectiveness	User defined	Heat exchanger sensible effectiveness at design heating and cooling conditions	3, 4, 9, 10, 11, 12
	Latent effectiveness	User defined	Heat exchanger latent effectiveness at design heating and cooling conditions	3, 4, 9, 10, 11, 12
	Bypass SAT *set point*	User defined	If bypass, target supply air temperature	3, 4, 9, 10, 11, 12
	Fan power reduction when in bypass	User defined	If bypass, specify fan power reduction, W/cfm.	3, 4, 9, 10, 11, 12

a. Applicable *systems* from Table L.1.1.1

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Table L2.2.3 Proposed Building HVAC System Parameters *(Continued)*

Category	Parameter	Fixed or User Defined	Required	Applicable Systems [a]
Demand Control Ventilation	*DCV* application ON/OFF	User defined	Percentage of block floor area under occupied standby controls, ON/OFF only (see Section 6.5.3.8) with no variable control	3, 4, 9, 10, 11, 12
	DCV application CO_2	User defined	Percentage of block *floor* area under variable *DCV* control (CO_2); may include both variable and ON/OFF control	3, 4, 9, 10, 11, 12
Dedicated *Outdoor Air System*	DOAS fan power, W/cfm	User defined	Fan electrical input power in W/cfm of supply airflow	12
	DOAS supplemental heating and cooling	User defined	Heating source, cooling source, *energy* recovery, and respective *efficiencies*	12
	Maximum SAT *set point* (cooling)	User defined	SAT *set point* if DOAS includes supplemental cooling	12
	Minimum SAT *set point* (heating)	User defined	SAT *set point* if DOAS includes supplemental heating	12
Heating Plant	*Boiler efficiency*	User defined	*Boiler* thermal *efficiency*	1, 6, 7, 9, 10, 11, 12
	HW loop configuration	User defined	Variable-flow primary only; variable-flow primary and secondary; constant-flow primary and variable-flow secondary	1, 6, 7, 9, 10, 11, 12
	HW primary *pump* power, W/gpm	User defined	HW constant primary *pump* input W/gpm HW flow	1, 6, 7, 9, 10, 11, 12
	HW secondary *pump* power, W/gpm	User defined	HW variable secondary *pump* input W/gpm HW flow (if primary/secondary)	1, 6, 7, 9, 10, 11, 12
	HW loop temperature	User defined	HW supply and return temperatures, °F	1, 6, 7, 9, 10, 11, 12
	HW temperature *reset* included	User defined	Yes/no	1, 6, 7, 9, 10, 11, 12
	HWST *reset*	Fixed	*Reset* HWST by 27.3% of design temperature difference (HWST – 70°F *space* heating temperature *set point*) between 20°F and 50°F OAT	1, 6, 7, 9, 10, 11, 12
	Boiler type	Fixed	Regular where input thermal *efficiency* is less than 86%; condensing *boiler* otherwise	1, 6, 7, 9, 10, 11, 12
Chilled-Water Plant	Chiller condenser type	User defined	Air-cooled or water-cooled; for water-cooled, positive displacement or centrifugal	6, 10, 11, 12
	Chiller full-load *efficiency*	User defined	Chiller *COP*	6, 10, 11, 12
	Number of chillers	User defined	In simulation, chillers will be sized equally with 1–3 chillers.	6, 10, 11, 12
	CHW coil design temperature difference, °F	User defined	CHWST and CHW return temperature at *design conditions*	6, 10, 11, 12
	CHW loop configuration	User defined	Variable-flow primary only; variable-flow primary and secondary; constant-flow primary and variable-flow secondary	6, 10, 11, 12
	CHW primary *pump* power, W/gpm	User defined	Primary *pump* input, W/gpm; CHW flow	6, 10, 11, 12
	CHW secondary *pump* power, W/gpm	User defined	Secondary *pump* input, W/gpm; CHW flow (if primary/secondary)	6, 10, 11, 12
	CHW temperature *reset* included	User defined	Yes/no	6, 10, 11, 12
	CHW temperature *reset* schedule	Fixed	*OA reset*: Use input CHWST at 80°F *outdoor air* dry-bulb and above and CHWST 10°F at 60°F *OA* dry-bulb and below, ramped linearly between	6, 10, 11, 12

a. Applicable *systems* from Table L.1.1.1

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Table L2.2.3 Proposed Building HVAC System Parameters *(Continued)*

Category	Parameter	Fixed or User Defined	Required	Applicable Systems [a]
Condenser Loop	Condenser water-*pump* power, W/gpm	User defined	*Pump* input, W/gpm; condenser water flow	6, 7, 8, 10, 11, 12
	Condenser water-*pump* control	Fixed	Constant-speed, one *pump* per chiller	6, 7, 8, 10, 11, 12
Heat Rejection	Heat-rejection *equipment efficiency*	User defined	gpm/hp at *design conditions*, where hp is the sum of nameplate fan and integral spray *pump* motor hp, if applicable	6, 7, 8, 10, 11, 12
	Open-circuit cooling tower flow turndown	Fixed	Flow turndown per Section 6.5.5.4	6, 7, 8, 10, 11, 12
	Heat-rejection fan control	User defined	Constant or variable speed	6, 7, 8, 10, 11, 12
	Heat-rejection approach and range	User defined	Design heat-rejection approach and range temperature	6, 7, 8, 10, 11, 12
Heat-Pump Loop	Loop flow and heat-pump control valve	Fixed	Two-position valve with VSD on *pump*	7, 8
	Heat-pump loop flow control	Fixed	Loop flow at 3 gpm/ton	7, 8
	Heat-pump loop minimum and maximum temperature control	User defined	User input; restrict to minimum 20°F and maximum 40°F temperature difference.	7, 8
Ground-Loop Heat-Pump Bore Field		Fixed	Bore depth = 250 ft; bore length 200 ft/ton for greater of cooling or heating load	8
			Bore spacing = 15 ft	
			Bore diameter = 5 in. with 3/4 in. nominal diameter polyethylene pipe	
			Ground and grout conductivity = 4.8 Btu·in./h·ft^2·°F	

a. Applicable *systems* from Table L.1.1.1

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L3.1 Calculation of the TSPR. The *simulation program* shall calculate both the $TSPR_p$ and $TSPR_r$ based only on the input for the *proposed design* and the requirements of this appendix. The calculation procedure shall not allow the user to directly modify either the *building* component characteristics of the *TSPR reference building design* or the HVAC parameters identified as fixed input in Table L2.2.3.

L3.2 TSPR Simulation Program. All components of the *proposed design* for blocks served by *HVAC systems* using this method shall be explicitly modeled by the *simulation program*. The *code official* shall be permitted to approve a *simulation program* for a specified application or limited scope.

L3.2.1 Minimum Capability. The *simulation program* shall be approved by the *code official* 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 blocks*
e. Part-load performance curves or other part-load adjustment methods for mechanical *equipment*
f. Capacity and *efficiency* correction curves or other part-load adjustment methods for *mechanical heating* and *mechanical cooling equipment*
g. *Air economizers* with integrated controls
h. The *energy* use of all *HVAC system* types included in the analysis and *energy* impact from all related fixed and user inputs in Table L2.2.3
i. Ability to automatically generate the *TSPR reference building design* as specified in Section L4.3

Informative Note: The *simulation program* shall include clear prompts or accessible help-topic references defining specific parameters and units for all required *building* and *system* characteristic inputs.

L3.2.2 TSPR Determination. The *simulation program* shall have the ability to either directly determine the $TSPR_p$ and $TSPR_r$ or produce hourly and annual reports of *energy* use by each *energy* source suitable for determining the $TSPR_p$ and $TSPR_r$ using a separate calculation.

L3.2.3 Load Calculations. 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 Section 6.4.2.1 for both the *proposed design* and *TSPR reference building design*.

L3.2.4 Testing

L3.2.4.1 The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The required tests shall include *building* thermal envelope and fabric load tests (Sections 5.2.1, 5.2.2, and 5.2.3), ground coupled slab-on-*grade* analytical verification tests (Section 5.2.4), *space*-cooling *equipment* performance tests (Section 5.3), *space*-heating *equipment* performance tests (Section 5.4), and air-side HVAC *equipment* analytical verification tests (Section 5.5) along with the associated reporting (Section 6).

L3.2.4.2 The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the *simulation program* and input files used for generating the results along with the results of the other *simulation programs* included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values and for omitted results.

Informative Notes:

1. There are no pass/fail criteria established by this testing requirement.
2. Based on the Section 3.2 definition, *simulation program* includes the simulation engine and the corresponding user interface. The testing of a *simulation program* only meets the requirements of Section L1 for that *simulation program* and cannot be used as proxy for documenting compliance of another *simulation program* that uses the same simulation engine.

L3.3 Climatic Data. Climatic data shall meet the requirements of Section G2.3.

L3.4 Compliance Report. The *simulation program* shall generate a report that includes the following:

a. Address of the *building*
b. Name of individual completing the compliance report
c. Name and version of the compliance *simulation program,* the edition of Standard 90.1 the *simulation program* method complies with, and the link to the website that contains the ASHRAE Standard 140 testing results for the version used in accordance with Section L3.2.4
d. The dimensions, *story* heights, and number of *stories* for each block

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e. By block, the *U-factor*, *C-factor*, or *F-factor* for each simulated *opaque building envelope* component and the *U-factor* and *SHGC* for each *fenestration* component
f. By block or by surface for each block, the *fenestration* area and total area of each *opaque building envelope* component
g. By block, a list of the HVAC *equipment* simulated in the *proposed design,* including the *equipment* type, *fuel* type, rated *equipment efficiencies*, rated capacities, and *system* control parameters
h. Annual *site* HVAC *energy* use by end use and *energy* type for the *proposed design* and *TSPR reference building design*
i. Annual sum of hourly heating and cooling loads for the *TSPR reference building design*
j. The HVAC *total system performance ratio* for both the *TSPR reference building design* and the *proposed design* and compliance result in accordance with Section 6.6.2.2

Informative Note: The *simulation program*, at a minimum, will report compliance with the *TSPR* based on the compliance criteria in Section 6.6.2.2. Should a jurisdiction adopt other compliance criteria, then a separate calculation of *TSPR* using the *reference building design* and *proposed design* HVAC *energy* type input may be necessary.

L4. CALCULATION PROCEDURE

Except as specified by this appendix, the *TSPR reference building design* and *proposed design* shall be configured and analyzed using identical methods and techniques.

L4.1 Simulation of the Proposed Design (Non-HVAC). The *proposed design* non-*HVAC systems* shall be configured and analyzed as specified in this section. At a minimum, the *simulation program* shall support the *building* use types included in the analysis. The allowed *building* use types are listed in Section L1.1.1.1.

L4.1.1 Simplified Block Approach. The *simulation program* shall model the *building* using one or more simplified geometric simulation *building* blocks, described in Section L2.1. Each block contains one or multiple *thermal blocks*. The *simulation program* shall provide for simplified input described in Section L2.2 and allow for multiple block simulation.

L4.1.2 Thermal Zoning. Each *story* in a block shall be modeled as a single *thermal block* or as five *thermal blocks* consisting of four perimeter zones and a core zone. Below-*grade stories* shall always be modeled as a single block. If any facade in the block is less than 45 ft in length, there shall only be a single *thermal block* per *story*. Otherwise, each *story* shall be modeled with five *thermal blocks*. A perimeter zone shall be created extending from each facade to a default depth of 15 ft with a user input range of 8 to 20 ft. Where facades intersect, the zone boundary shall be formed by a 45 degree angle with the two facades. The remaining area or each *story* shall be modeled as a core zone with no exterior *walls*.

L4.1.3 Building Use Type. The *building* use type for each block shall be consistent with the *proposed design* and allowed *building* use types in Section L1.1.1.1. The occupant density, heat gain, and schedule shall be as specified by Normative Appendix C.

L4.1.4 Building Envelope Components. *Building envelope* thermal properties used in the *proposed design* shall be modeled based on the actual *proposed design* using inputs described in Section L2.2.2 and shall comply with all of the following:

a. *Roofs* shall be modeled with insulation above a steel *roof* deck. *Roof* solar absorptance shall be modeled at 0.70 and thermal *emittance* at 0.90.
b. *Above-grade walls* shall be modeled as steel-frame construction.
c. Above-*grade* exterior *floors* shall be modeled as steel-frame construction.
d. The area, *U-factor*, and *SHGC* of vertical *fenestration* shall be modeled for each facade based on the actual *proposed design*. The *simulation program* shall model a combined single window centered on each facade based on the area and sill height input by the user.
e. The *skylight* area shall be modeled for each *roof* based on the actual *proposed design*. *Skylights* shall be combined into a single *skylight* centered on the *roof* of each zone based on the area input by the user.

L4.1.5 Lighting. For each block, the interior *lighting power density* shall be equal to the applicable allowance in Table 9.5.1 based on the assigned *building* use type. The lighting profile schedule shall be for the applicable *building* use type as specified by Normative Appendix C. The impact of lighting controls is assumed to be captured by the lighting schedule, and no explicit controls (including daylight responsive controls) shall be modeled. Exterior lighting shall not be modeled.

L4.1.6 Miscellaneous Equipment. The miscellaneous *equipment* schedule and power shall be based on the assigned *building* use type as specified by Normative Appendix C. The impact of miscellaneous *equipment* controls is assumed to be captured by the *equipment* schedule, and no explicit controls shall be modeled.

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Table L4.2.3-1 Fan and Pump Power Curve Coefficients

	Fan Power Coefficients		Pump Power Coefficients	
Equation Term	**VSD (no Static Pressure Reset)**	**VSD + Static Pressure Reset**	**Ride Pump Curve**	**VSD + Differential Pressure/Valve Reset**
b	0.0013	0.0408	0	0
x	0.147	0.088	3.2485	0.0205
x^2	0.9506	–0.0729	–4.7443	0.4101
x^3	–0.0998	0.9437	2.5295	0.5753

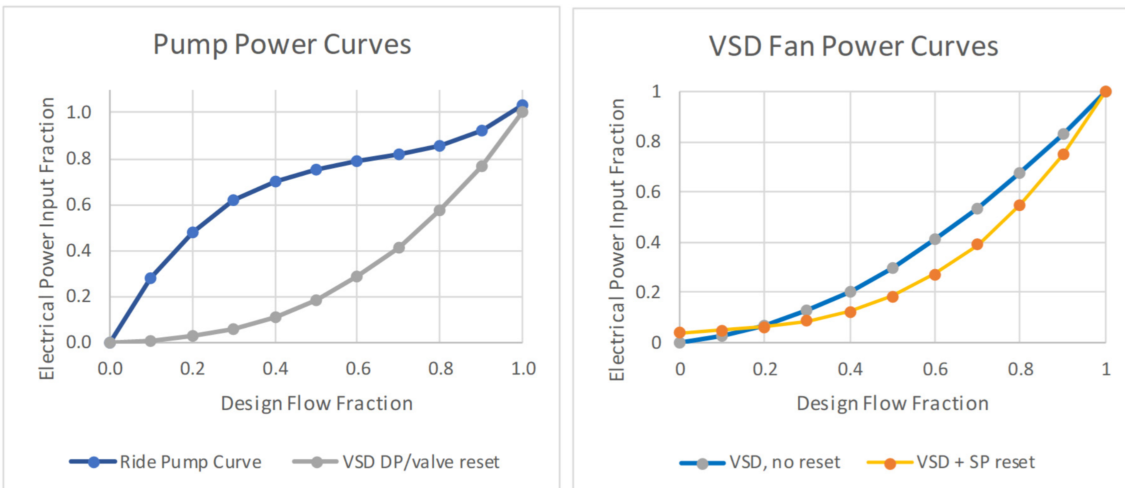

Figure L4.2.3-1 Fan and pump power performance as a function of design water flow or airflow.

L4.1.7 Elevators. Elevators shall not be modeled.

L4.1.8 Service Water-Heating Equipment. *Service water heating* shall not be modeled.

L4.1.9 On-site Renewable Energy Systems. *On-site renewable energy systems* shall not be modeled.

L4.2 Simulation of the Proposed Design (HVAC). The *proposed design HVAC systems* shall be configured and analyzed as specified in this section.

L4.2.1 HVAC Equipment. The *simulation program* shall analyze the control parameters that meet the mandatory requirements of Section 6.4 and the parameters provided by the user or specified as fixed in Section L2.2.3 as applicable for each *HVAC system* included in the *proposed design*.

L4.2.2 Supported HVAC Systems. The *HVAC systems* included in the *proposed design* and the *TSPR reference building design* shall be supported by the *simulation program*. *HVAC systems* permitted are limited to those shown in Table L.1.1.1. The *simulation program* shall support multiple blocks being served by one central *system*.

L4.2.3 Proposed Building HVAC System Simulation. The *HVAC systems* shall be modeled as in the *proposed design* with clarifications and simplifications as described in Table L2.2.3 and the following rules:

a. *System* parameters not described in Table L2.2.3 and the following sections shall be simulated to meet the minimum requirements of Section 6.4.
b. Where multiple *system* components serve a block, average values weighed by the appropriate metric as described in Section L2.2.3.1 shall be used.
c. Heat loss from ducts and pipes shall not be modeled.
d. The *simulation program* shall model part-load HVAC *equipment* performance using either
   1. full-load *efficiency* (adjusted for fan power input that is modeled separately) and typical part-load performance adjustments for the proposed *equipment*;
   2. part-load adjustments based on input of both full-load and part-load metrics, or
   3. *equipment*-specific adjustments based on performance data provided by the *equipment manufacturer* for the proposed *equipment*.

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Table L4.2.3-2 DCV Outdoor Air Reduction Curve Coefficients

Equation Term	DCV OA Reduction (*y*) as a Function of DCV Effective Controlled Floor Area (*x*)			
	Office	**School**	**Hotel, Motel, Multifamily, Dormitory**	**Retail**
b	0	0	0	0
x	0.4053	0.2676	0.5882	0.4623
x^2	–0.8489	0.7753	–1.0712	–0.848
x^3	1.0092	–1.5165	1.3565	1.1925
x^4	–0.4168	0.7136	–0.6379	–0.5895

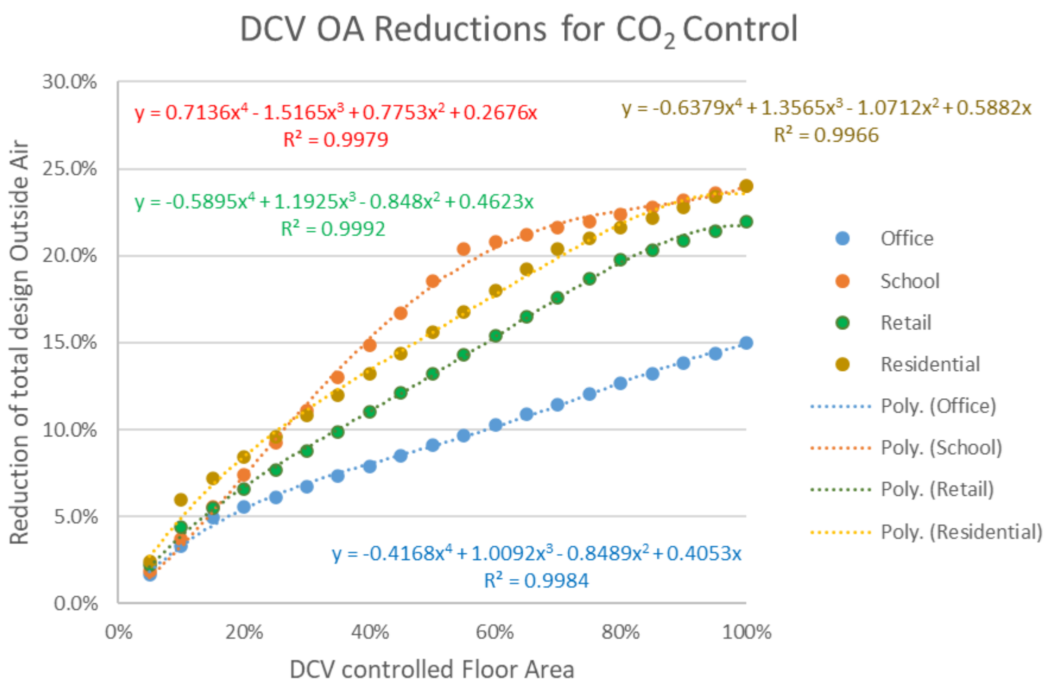

Figure L4.2.3-2 DCV OA reduction as a function of controlled floor area.

e. Part-load variable-speed fan and *pump* power shall be calculated using a cubic function with coefficients as shown in Table L4.2.3-1. The independent variable shall be the fraction of design water flow rate for *pumps* and the fraction of design airflow rate for fans as shown in Figure L4.2.3-1.

f. *Demand control ventilation* shall be modeled using a simplified approach that adjusts the design outdoor supply airflow rate based on the area of the *building* that is covered by *DCV* with coefficients as shown in Table L4.2.3-2. The input shall accommodate two types of *DCV*:

1. Variable control based on people sensor response (CO_2 sensor or other)
2. ON/OFF occupied standby control that closes the *VAV* box primary air damper or shuts off *outdoor air* when the zone is completely unoccupied based on an *occupancy sensor* (See Section 6.5.3.8.)

(Informative Note: Due to lower probability occurrence, the ON/OFF controls are given 1/3 the reduction of the CO_2 sensor *DCV*. The *outdoor air* reduction factor shall be based on a smaller area of control being applied to higher density *spaces* first, adjusted for *building* type, with *outdoor air* reduction factors and an application formula as shown.)

For office, school, and retail:

$$DCV \text{ Effective Controlled Floor Area} = \text{Area}_{VarDCV} + 1/3 \times \text{Area}_{ON\text{-}OFF} \text{ AND Area}_{ON\text{-}OFF} < 1 - \text{Area}_{VarDCV}$$

For hotel, motel, dormitory, and multifamily:

$$DCV \text{ Effective Controlled Floor Area} = \text{Area}_{VarDCV} + \text{Area}_{ON\text{-}OFF}$$

where

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$Area_{VarDCV}$	=	fraction of block floor area with variable sensor-based *DCV* control
$Area_{ON\text{-}OFF}$	=	fraction of block floor area with only occupied standby control as defined in Section 6.5.3.8 that does not also have variable sensor-based *demand control ventilation*.

L4.3 Simulation of the TSPR Reference Building Design. The *TSPR reference building design* shall be configured and analyzed as specified in this section.

L4.3.1 Non-HVAC Inputs. Utility rates, blocks, *HVAC zones*, *building* use types, schedules, occupant density, heat gains, *building envelope* components, lighting power, and miscellaneous *equipment loads* shall be modeled the same as in the *proposed design.*

Elevators, *service water-heating equipment*, and *on-site renewable energy systems* shall not be modeled; same as in the *proposed design*.

L4.3.2 HVAC Equipment. The *TSPR reference building design* HVAC *equipment* consists of separate *space* conditioning *systems* and DOASs as described in Tables L4.3.2-1 through L4.3.2-3 for the appropriate *building* use types. Variable-speed drive fan and *pump* power shall be modeled using parameters in Tables L4.3.2-1. HVAC *equipment* shall be modeled at minimum *efficiency* based on specified *efficiency* metrics in Tables L4.3.2-1 through L4.3.2-3. Where available in Normative Appendix G, *equipment*-type-specific part-load performance adjustments shall be used; otherwise, typical part-load performance adjustments shall be used.

L5. TSPR METRIC FOR SITE HVAC ENERGY INPUT

For purposes of calculating *TSPR* for the *proposed design* and the *TSPR reference building design*, the calculated HVAC *energy* input of each *building* project *energy* source shall be converted to cost using the *energy* cost prices from Table L5-1.

Informative Notes:

1. The blended heating prices in Table L5-1 that are used for *fossil fuels* are not intended to represent actual average prices, but to represent a consistent blended price per 1000 Btu used. This will avoid requiring the *simulation program* to run the reference *systems* with a *fossil fuels* type that matches the proposed *building*. The common price per *site fuel* Btu allows proposed *system efficiency* to be properly compared with the reference *system*.
2. Informative Tables L5-2 through L5-5 include values for alternate *energy* input metrics that may be adopted by a jurisdiction. If so, the jurisdiction should replace the *TSPR energy* input of *energy* cost in Section L5 with the alternate metric and should include appropriate metric values from Informative Table L5-2 into Table L5-1. The jurisdiction should replace the MPF values in Table 6.6.2.2 with one of the following:
   - For carbon emissions, replace Table 6.6.2.2 MPF values with those in Informative Table L5-3. This table allows users to compare the quantity of carbon dioxide emissions generated by the *proposed design building* to the target *building*. For compliance purposes, it is intended for use in voluntary standards and in jurisdictions where the use of a carbon emissions metric is not preempted by U.S. federal law.
   - For source *energy*, replace Table 6.6.2.2 MPF values with those in Informative Table L5-4.
   - For *site energy*, replace Table 6.6.2.2 MPF values with those in Informative Table L5-5.

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Table L4.3.2-1 TSPR Reference Building Design HVAC Complex Systems

Building Type Parameter	Large Office (warm) [a]	Large Office (cold) [b]	School (warm) [a]	School (cold) [b]
System type	*VAV*/*reheat* water-cooled chiller/ electric *reheat* with parallel fan powered boxes	*VAV*/*reheat* water-cooled chiller/ gas *boiler*	*VAV*/*reheat* water-cooled chiller/ electric *reheat* with parallel fan powered boxes	*VAV*/*reheat* water-cooled chiller/ gas *boiler*
Fan control	VSD, no static pressure *reset*	VSD, no static pressure *reset*	VSD, no static pressure *reset*	VSD, no static pressure *reset*
Main fan power (W/cfm) proposed ≥MERV13	1.165	1.165	1.165	1.165
Main fan power (W/cfm) proposed <MERV13	1.066	1.066	1.066	1.066
Zonal fan power, W/cfm	0.35	NA	0.35	NA
Minimum zone airflow fraction	$1.5 \times V_{oz}$	$1.5 \times V_{oz}$	$1.2 \times V_{oz}$	$1.2 \times V_{oz}$
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Outdoor air economizer	No	Yes except 4A	No	Yes except 4A
Occupied *outdoor air* (= proposed)	Sum(V_{oz})/0.75	Sum(V_{oz})/0.75	Sum(V_{oz})/0.65	Sum(V_{oz})/0.65
Energy recovery ventilator *enthalpy recovery ratio* bypass; SAT set point	NA	NA	50%; no bypass	50%; 60°F except no bypass required in Climate Zone 4A
Demand control ventilation	No	No	No	No
Cooling source	2 water-cooled centrif. chillers	2 water-cooled centrif. chillers	2 water-cooled screw chillers	2 water-cooled screw chillers
Cooling *efficiency*	Table G3.5.3	Table G3.5.3	Table G3.5.3	Table G3.5.3
Heating source (*reheat*)	*Electric resistance*	Gas *boiler*	*Electric resistance*	Gas *boiler*
Furnace or *boiler efficiency*	1.0	75% E_t	1.0	80% E_t
Condenser heat rejection	Axial-fan open-circuit cooling tower			
Cooling-tower *efficiency*, gpm/hp (See Section G3.2.3.11)	38.2	38.2	38.2	38.2
Open-circuit cooling-tower turndown (>300 ton)	50%	50%	50%	50%
Pump (constant flow/variable flow)	Constant flow; 10°F range	Constant flow; 10°F range	Constant flow; 10°F range	Constant flow; 10°F range
Open-circuit cooling-tower approach	G3.1.3.11	G3.1.3.11	G3.1.3.11	G3.1.3.11
Cooling condenser *pump* power, W/gpm	19	19	19	19

a. "Warm" refers to Climate Zones 0 through 2 and 3A.
b. "Cold" refers to Climate Zones 3B, 3C, and 4 through 8.
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Table L4.3.2-1 TSPR Reference Building Design HVAC Complex Systems *(Continued)*

Building Type Parameter	Large Office (warm) [a]	Large Office (cold) [b]	School (warm) [a]	School (cold) [b]
Cooling primary *pump* power, W/gpm	9	9	9	9
Cooling secondary *pump* power, W/gpm	13	13	13	13
Cooling-coil CHW temperature difference, °F	12	12	12	12
Design CHWST, °F	44	44	44	44
CHWST *reset set point* vs. OAT, °F	CHWST/OAT: 44–54/80–60 (See Normative Appendix G.)	CHWST/OAT: 44–54/80–60 (See Normative Appendix G.)	CHWST/OAT: 44–54/80–60 (See Normative Appendix G.)	CHWST/OAT: 44–54/80–60 (See Normative Appendix G.)
CHW-loop pumping control	Two-way valves and *pump* VSD	Two-way valves and *pump* VSD	Two-way valves and *pump* VSD	Two-way valves and *pump* VSD
Heating-*pump* power, W/gpm	16.1	16.1	16.1	16.1
Heating-oil HW temperature difference, °F	50	50	50	50
Design HWST, °F	180	180	180	180
HWST *reset set point* vs. OAT, °F	HWST/OAT: 180–150/20–50	HWST/OAT: 180–150/20–50	HWST/OAT: 180–150/20–50	HWST/OAT: 180–150/20–50
HW-loop pumping control	Two-way valves and *pump* VSD	Two-way valves and *pump* VSD	Two-way valves and *pump* VSD	Two-way valves and *pump* VSD

a. "Warm" refers to Climate Zones 0 through 2 and 3A.
b. "Cold" refers to Climate Zones 3B, 3C, and 4 through 8.
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Table L4.3.2-2 TSPR Reference Building Design HVAC Simple Systems 1

Building Type Parameter	Medium Office (warm)[a]	Medium Office (cold)[b]	Small Office (warm)[a]	Small Office (cold)[b]	Retail (warm)[a]	Retail (cold)[b]
System type	Package *VAV*—electric *reheat*	Package *VAV*—hydronic *reheat*	PSZ-HP	PSZ-AC	PSZ-HP	PSZ-AC
Fan control	VSD, no static pressure reset	VSD, no static pressure reset	Constant volume	Constant volume	Constant volume	Constant volume
Main fan power (W/cfm) proposed ≥MERV13	1.285	1.285	0.916	0.916	0.899	0.899
Main fan power (W/cfm) proposed <MERV13	1.176	1.176	0.850	0.850	0.835	0.835
Zonal fan power (W/cfm)	0.35	NA	NA	NA	NA	NA
Minimum zone airflow fraction	30%	30%	NA	NA	NA	NA
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	NA	NA	<40°F OAT	NA	<40°F OAT	NA
Outdoor air economizer	No	Yes except 4A	No	Yes except 4A	No	Yes except 4A
Occupied *outdoor air* source	Packaged unit, occupied damper, all *building* use types					
Energy recovery ventilator	No	No	No	No	No	No
Demand control ventilation	No	No	No	No	No	No
Cooling source	DX, multistage	DX, multistage	DX, single stage (heat pump)	DX, single stage	DX, single stage (heat pump)	DX, single stage
Cooling *COP* (net of fan)	3.40	3.40	3.00	3.00	3.40	3.50
Heating source	*Electric resistance*	Gas *boiler*	Heat pump	Furnace	Heat pump	Furnace
Heating *COP* (net of fan)/furnace or *boiler efficiency*	1.0	75% E_t	3.40	80% E_t	3.40	80% E_t

a. "Warm" refers to Climate Zones 0 through 2 and 3A.
b. "Cold" refers to Climate Zones 3B, 3C, and 4 through 8.
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Table L4.3.2-3 TSPR Reference Building Design HVAC Simple Systems 2

Building Type Parameter	**Hotel (warm)** [a]	**Hotel (cold)** [b]	**Multifamily (warm)** [a]	**Multifamily (cold)** [b]
System type	*PTHP*	*PTAC*	*PTHP*	*PTAC*
Fan control	Constant volume	Constant volume	Constant volume	Constant volume
Main fan power, W/cfm	0.300	0.300	0.300	0.300
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	<40°F	NA	<40°F	NA
Outdoor air economizer	No	No	No	No
Occupied *outdoor air* source	Packaged unit, occupied damper	Packaged unit, occupied damper	Packaged unit, occupied damper	Packaged unit, occupied damper
Energy recovery ventilator	No	No	No	No
Demand control ventilation	No	No	No	No
Cooling source	DX, single stage (heat pump)	DX, single stage	DX, single stage (heat pump)	DX, single stage
Cooling *COP* (net of fan)	3.10	3.20	3.10	3.20
Heating source	*PTHP*	2 hydronic *boilers*	*PTHP*	2 hydronic *boilers*
Heating *COP* (net of fan)/furnace or *boiler efficiency*	3.10	75% E_t	3.10	75% E_t
Heating *pump* power, W/gpm	NA	19	NA	19
Heating-coil HW temperature difference, °F	NA	50	NA	50
Design HWST, °F	NA	180	NA	180
HWST reset *set point* vs. OAT, °F	NA	HWST/OAT: 180–150/20–50	NA	HWST/OAT: 180–150/20–50
HW-loop pumping control	NA	Two-way valves and ride *pump* curve	NA	Two-way valves and ride *pump* curve

a. "Warm" refers to Climate Zones 0 through 2 and 3A.
b. "Cold" refers to Climate Zones 3B, 3C, and 4 through 8.
Informative Note: See Section 3.3 for a full list of terms used in this table.

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Table L5-1 Energy Conversion Factors for HVAC Energy Input [a]

Building Project Energy Source	Units	Energy Cost, $/unit	Energy Cost, $/1000 site Btu
Electricity	kWh	$0.1099	$32.21
Natural gas	therm	$0.983	$9.83
Propane	therm	$0.983	$9.83
Distillate fuel oil	gal	$1.353	$9.83

a. *Energy* input conversion factors are based on U.S. averages. Nonelectric heating prices are based on blended heating prices adjusted for the U.S. average mix of heating fuels. These prices are applied to fuel output per unit.

Informative Table L5-2 Energy Conversion Factors for HVAC Energy Input [a]

Building Project Energy Source	Units	Carbon Emissions (CO_2e), lb/unit	Site Energy, Btu/unit	Source Energy, Btu/unit
Electricity	kWh	1.418	3412	9008
Natural gas	therm	19.960	100,000	109,000
Propane	therm	19.080	100,000	115,000
Distillate fuel oil	gal	28.830	137,600	163,744

a. *Energy* input conversion factors are based on ASHRAE Standard 189.1-2020. They represent average U.S. values and may be replaced with local values.

Informative Table L5-3 Mechanical Performance Factors (MPF), Carbon Emission Basis

Building Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium) [a]	0.72	0.72	0.70	0.71	0.69	0.65	0.71	0.67	0.63	0.73	0.66	0.69	0.76	0.70	0.71	0.79	0.75	0.80	0.82
Office (large) [a]	0.83	0.83	0.84	0.84	0.79	0.82	0.72	0.83	0.78	0.68	0.79	0.66	0.72	0.74	0.66	0.73	0.72	0.71	0.70
Retail	0.60	0.57	0.50	0.55	0.46	0.46	0.43	0.47	0.38	0.42	0.48	0.54	0.42	0.55	0.54	0.46	0.41	0.42	0.37
Hotel/motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.71	0.73	0.55	0.64	0.61	0.49	0.55	0.63	0.45	0.48	0.41	0.34
Apartment/dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.69	0.55	0.57	0.55	0.49	0.57	0.51	0.44	0.56	0.52	0.53	0.50
School/education	0.82	0.81	0.80	0.79	0.75	0.72	0.71	0.72	0.68	0.68	0.71	0.65	0.75	0.70	0.61	0.79	0.73	0.75	0.71

a. Office sizes defined in Section L1.1.1.1.

Informative Table L5-4 Mechanical Performance Factors (MPF), Site Energy Basis

Building Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium [a]	0.72	0.72	0.70	0.71	0.69	0.65	0.71	0.68	0.65	0.81	0.70	0.78	0.85	0.77	0.81	0.87	0.84	0.88	0.90
Office (large)[a]	0.83	0.83	0.84	0.84	0.79	0.82	0.72	0.81	0.77	0.67	0.76	0.63	0.71	0.72	0.63	0.73	0.71	0.71	0.71
Retail	0.60	0.57	0.50	0.55	0.46	0.46	0.43	0.51	0.40	0.45	0.57	0.68	0.46	0.68	0.67	0.50	0.45	0.44	0.38
Hotel/motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.71	0.73	0.45	0.59	0.52	0.38	0.47	0.51	0.35	0.38	0.31	0.26
Apartment/dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.72	0.55	0.53	0.50	0.44	0.54	0.47	0.38	0.55	0.50	0.51	0.47
School/education	0.82	0.81	0.80	0.79	0.75	0.72	0.71	0.72	0.67	0.73	0.72	0.68	0.82	0.73	0.61	0.89	0.80	0.83	0.77

a. Office sizes defined in Section L1.1.1.1.

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Informative Table L5-5 Mechanical Performance Factors (MPF), Source Energy Basis

Building Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Office (small and medium) [a]	0.72	0.72	0.70	0.71	0.69	0.65	0.71	0.67	0.63	0.71	0.66	0.68	0.75	0.69	0.69	0.77	0.73	0.78	0.81
Office (large) [a]	0.83	0.83	0.84	0.84	0.79	0.82	0.72	0.83	0.78	0.68	0.79	0.67	0.72	0.75	0.66	0.73	0.72	0.71	0.70
Retail	0.60	0.57	0.50	0.55	0.46	0.46	0.43	0.47	0.38	0.41	0.47	0.52	0.42	0.53	0.52	0.45	0.40	0.41	0.37
Hotel/motel	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.71	0.73	0.56	0.65	0.63	0.51	0.57	0.65	0.47	0.50	0.43	0.36
Apartment/dormitory	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.68	0.54	0.58	0.56	0.50	0.57	0.51	0.46	0.56	0.52	0.54	0.51
School/education	0.82	0.81	0.80	0.79	0.75	0.72	0.71	0.72	0.68	0.68	0.71	0.65	0.74	0.69	0.61	0.78	0.71	0.74	0.70

a. Office sizes defined in Section L1.1.1.1.

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INFORMATIVE APPENDIX M
ADDENDA DESCRIPTION

ANSI/ASHRAE/IES Standard 90.1-2022 incorporates all addenda to ANSI/ASHRAE/IES Standard 90.1-2019. Table M-1 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 M-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2019

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	Cosponsor Approval (IES)	ASHRAE BOD/Tech Council Approval	ANSI Approval
af	G3.1, G3.6	Modifies lighting modeling requirements in Appendix G with more specific guidance on determining lighting power in the baseline vs. proposed building.	6/30/2020	5/29/2020	N/A	6/30/2020
bc	6.5.4.8	Requires condensing boilers for new construction to achieve condensing-level efficiency (i.e., 90% E_t) for large boiler systems (i.e., between 1 and 10 million Btuh) and, to ensure condensing occurs, requires boiler entering water to be in the prescribed limits for temperature or flow rate.	6/30/2020	5/29/2020	N/A	6/30/2020
cd	6.5.6.1.2	Establishes a minimum enthalpy recovery ratio for energy recovery systems and specifies how bypass or control of the energy recovery system must operate to ensure proper economizer performance.	6/30/2020	5/29/2020	N/A	6/30/2020
db	G3.1, G3.4-9	Clarifies how to establish the Normative Appendix G baseline space conditioning categories that must be used in conjunction with Tables G3.4-1 through G3.4-8 so that the baseline envelope will remain consistent should Section 3 undergo changes.	6/30/2020	5/29/2020	N/A	6/30/2020
by	3.2, 10.2.1, 10.5.1	Adds a minimum prescriptive requirement for on-site renewable energy.	6/26/2020	5/19/2020	7/1/2020	7/31/2020
ck	12.4.1, 12.4.3, Table 12.5.1	Explains Section 12 modeling requirements for proposed designs that utilize a trade-off for the renewable energy requirements in Section 10.5.1.	6/26/2020	5/19/2020	7/1/2020	7/31/2020
cp	4.2.1.1, G2.2, Table G3.1	Explains Appendix G modeling requirements for proposed designs that utilize a trade-off for the renewable energy requirements in Section 10.5.1.	6/26/2020	5/19/2020	7/1/2020	7/31/2020
a	6.5.3.7, 6.5.3.8, 13	Establishes minimum fan efficacy requirements for low-power ventilation fans and references Standard 62.2 for determining the minimum ventilation rates for nontransient dwelling units.	10/30/2020	10/7/2020	N/A	10/30/2020
b	6.4.3.8	Revises demand control ventilation parameters to be based on climate zone and Standard 62.1 airflow requirements.	10/30/2020	10/7/2020	N/A	10/30/2020
c	6.3.2, 6.4.3.3	Requires residential HVAC systems greater than 2.1 kW to be equipped with start/stop and setback controls.	10/30/2020	10/6/2020	N/A	10/30/2020
d	3.2, 6.4.3.4.5	Adds new term to define parking garage section so that fan requirements can be refined for different configurations. Requires fans with the ability to modulate airflow and power as specified.	12/30/2020	12/16/2020	N/A	12/30/2020
f	Table 6.5.1-2	Clarifies the efficiency improvement required in order to eliminate an economizer.	2/26/2021	2/18/2021	N/A	2/26/2021
g	6.5.1.1.5	Adds more specific language about relieving excess outdoor air during air economizer operation through the use of fans or dampers.	12/30/2020	12/16/2020	N/A	12/30/2020

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Table M-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2019 *(Continued)*

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	Cosponsor Approval (IES)	ASHRAE BOD/Tech Council Approval	ANSI Approval
h	4.2.1.1	Clarifies that the gross floor area should be used when calculating the area-weighted building performance factor (BPF.)	10/30/2020	10/6/2020	N/A	10/30/2020
i	G3.1.2.10	Reinstates exception to Appendix G exhaust air energy recovery requirements for laboratory HVAC systems.	10/30/2020	10/6/2020	N/A	10/30/2020
k	12.5.2	Adjusts Section 12 budget building fan requirements to avoid creating a fan power credit for energy recovery.	10/30/2020	10/6/2020	N/A	10/30/2020
l	G3.1	Revises Appendix G language describing how to calculate and assign vertical fenestration in the baseline design.	10/30/2020	10/6/2020	N/A	10/30/2020
m	6.4.3.4.1	Clarifies requirements for motorized dampers on vents for elevator shafts and stairwells; adds exception to allow nonmotorized dampers in mild climates and low-rise buildings.	10/30/2020	10/6/2020	N/A	10/30/2020
n	6.5.2.6	Adds an exception to Section 6.5.2.6 allowing units to heat the ventilation airstream above 60°Fif exclusively using series energy recovery.	10/30/2020	10/6/2020	N/A	10/30/2020
o	9.4.1.1	Reduces the minimum connected load that triggers daylighting responsive control requirements for sidelighting and toplighting.	7/30/2021	6/9/2021	N/A	7/30/2021
p	9.1.2, 9.1.4	Modifies portions of Section 9 pertaining to alterations to ensure that such projects meet all applicable lighting requirements.	2/26/2021	2/18/2021	N/A	2/26/2021
q	Table G3.7	Corrects Table G3.7 to maintain equivalent space type requirements per the established 2004 baseline.	2/26/2021	2/18/2021	N/A	2/26/2021
r	6.4.3.3.3	Clarifies that residential spaces are not required to have optimal start controls.	2/26/2021	2/18/2021	N/A	2/26/2021
s	3.2, 5.5.3.1.1, 5.5.3.2, 5.5.4.5, Table 12.5.1, C3.6, Table G3.1	Replaces the term *solar reflectance index (SRI)* with *solar reflectance* (for walls only) and establishes a minimum solar reflectance requirement for east-, south-, and west-oriented walls in Climate Zone 0.	2/26/2021	2/18/2021	N/A	2/26/2021
t	3.2, 4.2.5, 5.1.3, 5.4.3, 5.7.2, 5.7.3.1, 5.8, 5.9.1.2, 6.4.4.2.1, 6.4.5, 6.5.1, Table 12.5.1 (5), 12.5.3, 13, C1.5, C3.5.5.3, C3.6, C3.1.1.4, Table G3.1 (5), Table H-3	Adds requirement to perform whole-building air leakage testing and measurement on buildings less than 25,000 ft^2, specifies performance requirements for compliance, references the applicable ASTM standard, and modifies relevant Section 3 terminology.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
u	12.5.2	Specifies the use of air economizers for budget building systems and clarifies method for determining prescriptive HVAC requirements based on the budget system type and capacity.	7/30/2021	6/9/2021	N/A	7/30/2021
v	12.7.2, G1.3.2	Clarifies the documentation that must be submitted to the rating authority or jurisdiction by projects following Section 12 and Appendix G, including simulation files upon request.	7/30/2021	6/9/2021	N/A	7/30/2021
w	G3.1.3.7	Indicates that chillers (type and number) shall be modeled in the baseline building design based on the total peak coincident cooling load of the baseline HVAC system using chilled water.	2/26/2021	2/18/2021	N/A	2/26/2021
x	6.4.1.2, Table 6.8.1-3	Updates the cooling efficiency adjustment for centrifugal chillers and the requirements for chillers utilizing freeze-protection. Replaces "fluid" and "water" with "liquid" throughout.	12/9/2021	12/8/2021	N/A	12/9/2021
y	Table 6.8.1-16	Modifies the minimum efficiency requirements for air-source heat pumps, updates the related AHRI rating standards, introduces a new metric (COP_{HR}) for units that perform heat recovery during chiller operation.	12/9/2021	12/8/2021	N/A	12/9/2021

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Table M-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2019 *(Continued)*

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	Cosponsor Approval (IES)	ASHRAE BOD/Tech Council Approval	ANSI Approval
z	9.1.4	Lowers the wattage assigned for track lighting to reflect the predominate use of higher-efficiency LED technology.	2/28/2022	2/25/2022	N/A	2/28/2022
aa	G3.1.2.9, Table G3.1	Corrects the SI fan power values in Appendix G to make them consistent with the rest of the standard.	5/28/2021	5/4/2021	N/A	5/28/2021
ab	3.2, 3.3, G3	Clarifies the process for selecting baseline HVAC systems when using the Appendix G Performance Rating Method (PRM); includes new acronyms to describe HVAC systems and a new definition for “residential associated HVAC zone.”	6/30/2021	6/9/2021	N/A	6/30/2021
ac	3.2, 9.4.1.2, Table 9.2.3.1, Table 9.6.1, Appendix E	Updates interior lighting power and minimum control requirements: adds a power exception for the germicidal function in luminaires and sources, removes exceptions for casinos and parking garage daylight transition zone lighting, and provides a definition for the latter item.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
ad	9	Reorganizes Section 9, “Lighting,” to better parallel the structure of the other main sections.	8/31/2021	8/26/2021	N/A	8/31/2021
ae	8.4.4	Updates exceptions and footnotes associated with Section 8.4.4 requirements for the minimum efficiency of low-voltage dry-type transformers in commercial buildings.	8/31/2021	8/26/2021	N/A	8/31/2021
ag	3.2, 3.3, 6.2.26.6, Appendix K	Introduces an optional Mechanical System Performance Path that allows HVAC system efficiency trade-offs based on a new metric—total system performance ratio (TSPR)—to ensure that equivalent energy savings are maintained compared to the prescriptive approach.	7/20/2022	9/8/2022	8/15/2022	9/9/2022
ah	7.5.3	Increases the thermal efficiency required for high-capacity gas-fired service water-heating equipment and provides the U.S. DOE criteria for defining high-capacity water heaters.	8/31/2021	8/26/2021	N/A	8/31/2021
aj	Table G-1	Updates Appendix G to align with Addendum ae clarifications related to baseline transformer performance.	9/30/2021	9/27/2021	N/A	9/30/2021
ak	G3.1.1	Provides criteria for determining when an HVAC zone should be isolated from a multizone system in the baseline building model.	9/30/2021	9/27/2021	N/A	9/30/2021
am	9.2.3.2, Table 9.2.3.2, 9.4.1.4, 9.4.2, Table 9.4.2-1, Table 9.4.2-2	Modifies exterior lighting power and control requirements based on improvements in technology and revised lighting practices; restructures portions of Section 9 to better communicate exceptions to those requirements.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
an	Table G3.1	Clarifies baseline HVAC fan schedule requirements for projects that rely on ventilation via operable windows that are manually opened by the occupants.	9/30/2021	9/27/2021	N/A	9/30/2021
ao	5.4.3.3.3, 6.4.3.9, 10.4.5, Table H-3	Revises the requirements for air curtain units and controls and indicates that installation is to be performed in accordance with the manufacturer’s instructions.	9/30/2021	9/27/2021	N/A	9/30/2021
ap	3.2, 3.3, 4.2.1, 4.2.2, 9.9.1, 12.2, 13, Section 11	Introduces a new section to Standard 90.1 for the use of energy credits to enable an approximately 4% to 5% energy cost savings. There are a total of 33 individual measures from which users can earn the required number of credits for their building type and climate zone.	7/20/2022	9/8/2022	8/15/2022	9/9/2022
aq	6.8.3, Table 6.8.3-1, Table 6.8.3-2, 7.4.3, Table 7-4	Introduces requirements for service water heating pipe insulation based on typical operating conditions.	7/29/2022	7/26/2022	N/A	7/29/2022
ar	3.2, Table 9.2.3.1, 9.4.4, Appendix E	Adds requirements for indoor horticultural lighting based on a new metric, photosynthetic photon efficacy (PPE), developed in ANSI/ASABE S640.	7/20/2022	9/8/2022	8/15/2022	9/9/2022
as	4.2.4, 5.9, 6.9, 7.9, 8.9, 9.9, 10.9	Rearranges envelope inspection requirements and improves commissioning language throughout.	1/27/2022	1/18/2022	N/A	1/27/2022

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Table M-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2019 *(Continued)*

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	Cosponsor Approval (IES)	ASHRAE BOD/Tech Council Approval	ANSI Approval
at	3.2, 4, 5, 6, 7, 8, 10	Establishes a consistent numbering system for each section of the standard and revises the definition for alteration.	1/27/2022	1/18/2022	N/A	1/27/2022
au	6.2, 6.3.2	Requires that heating and cooling equipment under the simplified compliance approach meet the requirements of Section 6.4.1.5.	1/21/2022	1/18/2022	N/A	1/21/2022
av	3.2, 3.3, 5.5.3.2, 5.5.5, 5.6.1.1, 5.7.2, 5.8.2.3, Table 12.5.1 (5), 13, A1, A10, C1.2.7, C2.9, C3.5.5.4, C3.6, Appendix E, Table G3.1 (5), Appendix J	Adds requirements to address the impacts of thermal bridges in the building envelope.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
aw	3.2, 3.3, 6.4.1.1, Table 6.8.1-21, Table F-6, 13	Adds the minimum energy efficiency requirements (and new CFEI metric) for large-diameter ceiling fans from 10 CFR 430.	1/21/2022	1/18/2022	N/A	1/21/2022
ay		Modifies Tables 6.8.1-8 and 6.8.1-9 for variable refrigerant flow (VRF) equipment based on the new AHRI 1230-2021 test procedure which required an adjustment to EER and IEER values.	7/20/2022	9/8/2022	8/15/2022	9/9/2022
az	3.2, 10.4.6	Introduces compressed air system requirements with measures for reducing common sources of energy waste.	1/21/2022	1/18/2022	N/A	1/21/2022
bb	9.5.1	Updates the lighting power density values for the Building Area Method compliance path based on manufacturer-reported improvements in lighting performance.	7/29/2022	7/26/2022	N/A	7/29/2022
bd	12.5.2, Table 12.5.1, G3.1.2, Table G3.1, Table G3.5.3, Appendix L	Provides performance curves for modeling chillers in budget (Section 12) and baseline designs (Appendix G) as well as default performance curves that can be used for chillers in proposed designs.	5/31/2022	5/19/2022	N/A	5/31/2022
be	12.4.1.4, 12, C3.1.4, G2.2.4	Updates references to the latest ANSI/ASHRAE Standard 140-2020 and specifies which simulation program tests are required for compliance with Appendix C and G of Standard 90.1.	1/21/2022	1/18/2022	N/A	1/21/2022
bf	9.5.2.2	Updates the decorative and retail lighting power allowances, adds an additional allowance for videoconferencing, and moves the additional power allowances and required controls to a table for easy reference.	5/31/2022	5/19/2022	N/A	5/31/2022
bg	3.2, 8.1, 8.7.3.2, 9.1.1, 9.4.1, 9.6.3, 10.1.1, Table 12.5.1 (12), G1.2.2, Table G3.1	Updates Sections 8, 9, 10, 12 and Appendix G to reflect the new purpose and scope (Addendum cb), utilizing the new definition of site.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
bh	Table 12.5.1	Revises the default PV system in the budget building design so that the temperature coefficient of power is aligned with the PV Watts input for a 19% panel efficiency as required by Addendum ck.	1/21/2022	1/18/2022	N/A	1/21/2022
bi	3.2, 5.1.3, 5.5.3.1	Creates specific provisions to distinguish roof replacements from other types of alterations.	7/29/2022	7/26/2022	N/A	7/29/2022
bj	5.5.3, A1, A9, Appendix E	Reformats and clarifies Normative Appendix A requirements for thermal performance calculations to demonstrate compliance with Section 5.5	6/25/2022	6/17/2022	6/29/2022	7/29/2022

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Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	Cosponsor Approval (IES)	ASHRAE BOD/Tech Council Approval	ANSI Approval
bk	6.3.2, 6.4.3.3.2, 6.4.3.3.5, 6.4.5, 6.4.6, 12.4.1.1, 12.5.2, G2.2.1	Updates humidity control requirements in accordance with the latest Standard 62.1-2019.	1/21/2022	1/18/2022	N/A	1/21/2022
bm	6.5.3.8	Modifies occupied-standby controls from multiple-zone systems to explicitly require an outdoor air reset when ventilation is reduced to zero.	1/21/2022	1/18/2022	N/A	1/21/2022
bp	9.4.1.3	Removes the exception for captive card key controls in hotel guestrooms	9/30/2022	9/8/2022	N/A	9/30/2022
bq	8.4.3	Adds a requirement to perform electrical energy monitoring with separate metering for refrigeration systems where refrigeration accounts for 10% or more of the building load.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
br	9.4.3	Increases the efficacy threshold for lamps and luminaires in dwelling units and specifies requirements for interior and exterior lighting controls.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
bs	9.3.1, 9.3.2	Updates the lighting power allowances (LPA) in the Simplified Building Method Compliance Path to maintain alignment with the established method (0.9x the Building Area Method LPA values.). Removes an exception for alterations that had incentivized the use of LEDs before they became commonplace.	7/29/2022	7/26/2022	N/A	7/29/2022
bt	G3.1.3.5, G3.1.3.10, G3.1.3.19	Indicates that baseline system pumps are to be modeled based on the presence of a load and preheat coil temperature is to be modeled compared to the zone with the highest set point.	6/30/2022	6/10/2022	N/A	6/30/2022
bv	Table 4.2.1.1	Updates the building performance factors (BPFs) used to determine compliance with Normative Appendix G based on energy-efficiency improvements in the 2022 standard.	6/30/2022	6/10/2022	N/A	6/30/2022
bw	6.5.3.1.3	Clarifies that the fan efficiency metric is to be applied at the highest design airflow rate.	4/29/2022	4/27/2022	N/A	4/29/2022
bx	Table 6.8.1-5	Modifies Table 6.8.1-5 for warm air furnace efficiency requirements to more accurately distinguish between different products and test procedures based on locations in which they are used and their status as DOE or non-DOE covered products.	7/29/2022	7/26/2022	N/A	7/29/2022
bz	6.5.6	Adds language to specify the sensible energy recovery ratio requirement for systems that require only sensible heating energy recovery.	4/29/2022	4/27/2022	N/A	4/29/2022
cb	1.1, 2.1, 2.2, 2.3, 3.2, 4.1.1.6, 4.2.1.4, 4.1.2.5, 10.4.6, Table G3.1	Revises the 90.1 Purpose and Scope to apply to areas outside of the physical building that qualify under the new definition for "site."	2/2/2022	1/28/2022	2/2/2022	3/1/2022
ce	A2.5, A3.3, A9.2, 13	Adds new reference and requirements for steel-framed walls aligned with ANSI/AISI S250, which provides additional options for wall framing and insulation placement.	4/29/2022	4/27/2022	N/A	4/29/2022
cf	10.4.3, 10.9.3	Introduces provisions that improve elevator fan, lighting, and movement efficiency.	4/29/2022	4/27/2022	N/A	4/29/2022
cg	5.5.3, A9.4.7	Adds a definition for insulated metal panels (IMPs) and a new section to explain how the U-factor of a given IMP is determined.	4/29/2022	4/27/2022	N/A	4/29/2022
ci	Table 6.5.1-1	Requires fan cooling-units outside of the building to have an economizer at the indicated capacity range.	4/29/2022	4/27/2022	N/A	4/29/2022
cj	Table 6.8.1-16	Corrects numerical errors that were present in the centrifugal chiller category when it was updated in Addendum y.	4/29/2022	4/27/2022	N/A	4/29/2022
cm	13	Updates the normative references used in the standard to the latest applicable versions.	7/29/2022	7/26/2022	N/A	7/29/2022

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Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	Cosponsor Approval (IES)	ASHRAE BOD/Tech Council Approval	ANSI Approval
co	4.2.1.1, 4.2.1.3, G3.1, G3.2, G3.3	Adds new performance requirements for alterations, allowing larger retrofit projects a 5% increase in Building Performance Factor (BPF) relative to new construction vs. smaller retrofit projects which are subject to a new Section G3.3.	6/25/2022	6/17/2022	6/29/2022	7/29/2022
cq	G3.1.2.1, Table G3.1 (10), Table G3.1.3.7, Table G3.5.3	Modifies Appendix G to align with Section 6 updates (e.g., removes outdated references, corrects instructions for determining equipment efficiency, converts “water” to “liquid” in the descriptions for chiller equipment.)	6/25/2022	6/27/2022	6/29/2022	7/29/2022
cr	12.2, G1.2.1	Adds language to limit the extent that envelope trade-offs can be used for compliance with Section 12 and Appendix G based on the amount that a proposed envelope performance factor is permitted to exceed the base value (i.e., envelope “backstop”).	11/4/2020	10/7/2020	11/18/2020	12/16/2020
cs	12.5.2	Clarifies efficiency requirements for HVAC and service water-heating equipment in the Section 12 budget building design.	6/30/2022	6/10/2022	N/A	6/30/2022
ct	Table G3.1 (5)	Provides additional details about the envelope modeling requirements for Appendix G baseline buildings.	6/30/2022	6/10/2022	N/A	6/30/2022
cu	6.5.6.3	Specifies that the heat source for performing heat recovery, as required for most acute inpatient hospitals, is the return water from a heat-pump chiller.	6/30/2022	6/10/2022	N/A	6/30/2022
cy	Section 12	Updates the normative references to include the latest published addenda to 90.4-2019	9/30/2022	9/8/2022	N/A	9/30/2022
da	G1.3.2, G2.2, G2.3, G2.4.2, G2.5, Table G3.1	Aligns Appendix G requirements for documentation, simulation programs, climactic data, and exceptions with the corresponding portions of Section 12.	12/30/2020	12/16/2020	N/A	12/30/2020

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ANNEX 1
REFERENCE STANDARD REPRODUCTION—ASHRAE STANDARD 169

Annex 1 contains extractions of the following material from ASHRAE Standard 169 in the following order:

ASHRAE Standard 169 Material
Table Annex1-1: Table B-1, U.S. Climate Zones by State and County
Figure Annex1-1: Figure B-1, Climate zones for United States counties.
Table Annex1-2: Table A-5, Canada Stations and Climate Zones
Figure Annex1-3: Table A-6, International Stations and Climate Zones
Section Annex1-1: Section A3, Climate Zone Definitions
Table Annex1-4: Table A-3, Thermal Climate Zone Definitions
Figure Annex1-2: Figure A-1, Thermal climate zones as a function of heating and cooling degree-days.
Figure Annex1-3: Figure C-2, World climate zones map.
Section Annex1-2: Section 4, Climatic Design Data and Climate Zones

Informative Note: Section references that appear in this annex are references to sections or appendices in ANSI/ASHRAE Standard 169.

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County

State/County	Zone	State/County	Zone
Alabama (AL)		**Arkansas (AR)**	
Zone 3A except...		*Zone 3A except...*	
Baldwin	2A	Baxter	4A
Coffee	2A	Benton	4A
Covington	2A	Boone	4A
Dale	2A	Carroll	4A
Escambia	2A	Fulton	4A
Geneva	2A	Izard	4A
Henry	2A	Madison	4A
Houston	2A	Marion	4A
Mobile	2A	Newton	4A
Alaska (AK)		Searcy	4A
Zone 7 except...		Stone	4A
Ketchikan Gateway	5C	Washington	4A
Prince of Wales-Outer Ketchikan	5C	**California (CA)**	
Sitka	5C	*Zone 3B except...*	
Haines	6A	Imperial	2B
Juneau	6A	Alameda	3C
Kodiak Island	6A	Marin	3C
Skagway-Hoonah-Angoon	6A	Mendocino	3C
Wrangell-Petersburg	6A	Monterey	3C
Denali	8	Napa	3C
Fairbanks North Star	8	San Benito	3C
Nome	8	San Francisco	3C
North Slope	8	San Luis Obispo	3C
Northwest Arctic	8	San Mateo	3C
Southeast Fairbanks	8	Santa Barbara	3C
Wade Hampton	8	Santa Clara	3C
Yukon-Koyukuk	8	Santa Cruz	3C
Arizona (AZ)		Sonoma	3C
Zone 3B except...		Ventura	3C
La Paz	2B	Amador	4B
Maricopa	2B	Calaveras	4B
Pima	2B	El Dorado	4B
Pinal	2B	Inyo	4B
Yuma	2B	Lake	4B
Gila	4B	Mariposa	4B
Yavapai	4B	Trinity	4B

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Apache	5B	Tuolumne	4B
Coconino	5B	Del Norte	4C
Navajo	5B	Humboldt	4C
Lassen	5B	**Connecticut (CT)**	
Modoc	5B	Zone 5A	
Nevada	5B	Delaware (DE)	
Plumas	5B	Zone 4A	
Sierra	5B	District of Columbia (DC)	
Siskiyou	5B	Zone 4A	
Alpine	6B	Florida (FL)	
Mono	6B	Zone 2A except...	
Colorado (CO)		Broward	1A
Zone 5B except...		Miami-Dade	1A
Baca	4B	Monroe	1A
Bent	4B	Palm Beach	1A
Las Animas	4B	**Georgia (GA)**	
Otero	4B	*Zone 3A except...*	
Prowers	4B	Appling	2A
Alamosa	6B	Atkinson	2A
Archuleta	6B	Bacon	2A
Chaffee	6B	Baker	2A
Conejos	6B	Berrien	2A
Costilla	6B	Brantley	2A
Dolores	6B	Brooks	2A
Eagle	6B	Bryan	2A
Moffat	6B	Calhoun	2A
Ouray	6B	Camden	2A
Rio Blanco	6B	Charlton	2A
Saguache	6B	Chatham	2A
San Miguel	6B	Clinch	2A
Clear Creek	7	Coffee	2A
Grand	7	Colquitt	2A
Gunnison	7	Cook	2A
Hinsdale	7	Decatur	2A
Jackson	7	Dougherty	2A
Lake	7	Early	2A
Mineral	7	Echols	2A
Park	7	Effingham	2A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone
Pitkin	7
Rio Grande	7
Routt	7
San Juan	7
Summit	7
Lanier	2A
Liberty	2A
Long	2A
Lowndes	2A
McIntosh	2A
Miller	2A
Mitchell	2A
Pierce	2A
Seminole	2A
Tattnall	2A
Thomas	2A
Tift	2A
Toombs	2A
Ware	2A
Wayne	2A
Worth	2A
Hawaii (HI)	
Zone 1A	
Idaho (ID)	
Zone 6B except...	
Ada	5B
Benewah	5B
Canyon	5B
Cassia	5B
Clearwater	5B
Elmore	5B
Gem	5B
Gooding	5B
Idaho	5B
Jerome	5B
Kootenai	5B
Latah	5B
Lewis	5B
Evans	2A
Glynn	2A
Grady	2A
Irwin	2A
Jeff Davis	2A
Illinois (IL)	
Zone 5A except...	
Alexander	4A
Bond	4A
Calhoun	4A
Christian	4A
Clark	4A
Clay	4A
Clinton	4A
Coles	4A
Crawford	4A
Cumberland	4A
Edwards	4A
Effingham	4A
Fayette	4A
Franklin	4A
Gallatin	4A
Greene	4A
Hamilton	4A
Hardin	4A
Jackson	4A
Jasper	4A
Jefferson	4A
Jersey	4A
Johnson	4A
Lawrence	4A
Macoupin	4A
Madison	4A
Marion	4A
Massac	4A
Monroe	4A
Montgomery	4A
Perry	4A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Lincoln	5B	Pope	4A
Minidoka	5B	Pulaski	4A
Nez Perce	5B	Randolph	4A
Owyhee	5B	Richland	4A
Payette	5B	Saline	4A
Power	5B	Shelby	4A
Shoshone	5B	St. Clair	4A
Twin Falls	5B	Union	4A
Washington	5B	Wabash	4A
Washington	4A	Scott	4A
Wayne	4A	Shelby	4A
White	4A	Spencer	4A
Williamson	4A	Sullivan	4A
Indiana (IN)		Switzerland	4A
Zone 5A except...		Union	4A
Bartholomew	4A	Vanderburgh	4A
Brown	4A	Vigo	4A
Clark	4A	Warrick	4A
Clay	4A	Washington	4A
Crawford	4A	**Iowa (IA)**	
Daviess	4A	*Zone 5A except...*	
Dearborn	4A	Cerro Gordo	6A
Decatur	4A	Clay	6A
Dubois	4A	Dickinson	6A
Fayette	4A	Emmet	6A
Floyd	4A	Hancock	6A
Franklin	4A	Kossuth	6A
Gibson	4A	Lyon	6A
Greene	4A	Mitchell	6A
Harrison	4A	O'Brien	6A
Hendricks	4A	Osceola	6A
Jackson	4A	Palo Alto	6A
Jefferson	4A	Sioux	6A
Jennings	4A	Winnebago	6A
Johnson	4A	Worth	6A
Knox	4A	**Kansas (KS)**	
Lawrence	4A	*Zone 4A except...*	
Marion	4A	Cheyenne	5A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Martin	4A	Decatur	5A
Monroe	4A	Gove	5A
Morgan	4A	Greeley	5A
Ohio	4A	Jewell	5A
Orange	4A	Logan	5A
Owen	4A	Norton	5A
Perry	4A	Phillips	5A
Pike	4A	Rawlins	5A
Posey	4A	Republic	5A
Putnam	4A	Scott	5A
Ripley	4A	Sheridan	5A
Rush	4A	Sherman	5A
Smith	5A	**Massachusetts (MA)**	
Thomas	5A	Zone 5A	
Wallace	5A	**Michigan (MI)**	
Wichita	5A	*Zone 5A except...*	
Kentucky (KY)		Alcona	6A
Zone 4A		Alger	6A
Louisiana (LA)		Alpena	6A
Zone 2A except...		Antrim	6A
Bienville Parish	3A	Arenac	6A
Bossier Parish	3A	Baraga	6A
Caddo Parish	3A	Benzie	6A
Caldwell Parish	3A	Charlevoix	6A
Catahoula Parish	3A	Cheboygan	6A
Claiborne Parish	3A	Chippewa	6A
Concordia Parish	3A	Clare	6A
De Soto Parish	3A	Crawford	6A
East Carroll Parish	3A	Delta	6A
Franklin Parish	3A	Dickinson	6A
Grant Parish	3A	Emmet	6A
Jackson Parish	3A	Gladwin	6A
La Salle Parish	3A	Gogebic	6A
Lincoln Parish	3A	Grand Traverse	6A
Madison Parish	3A	Houghton	6A
Morehouse Parish	3A	Iosco	6A
Natchitoches Parish	3A	Iron	6A
Ouachita Parish	3A	Isabella	6A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Red River Parish	3A	Kalkaska	6A
Richland Parish	3A	Lake	6A
Sabine Parish	3A	Leelanau	6A
Tensas Parish	3A	Luce	6A
Union Parish	3A	Mackinac	6A
Vernon Parish	3A	Manistee	6A
Webster Parish	3A	Mason	6A
West Carroll Parish	3A	Mecosta	6A
Winn Parish	3A	Menominee	6A
Maine (ME)		Missaukee	6A
Zone 6A except...		Montmorency	6A
Aroostook	7	Newaygo	6A
Maryland (MD)		Oceana	6A
Zone 4A except...		Ogemaw	6A
Allegany	5A	Ontonagon	6A
Garrett	5A	Osceola	6A
Oscoda	6A	Jackson	2A
Otsego	6A	Pearl River	2A
Presque Isle	6A	Stone	2A
Roscommon	6A	**Missouri (MO)**	
Schoolcraft	6A	*Zone 4A except...*	
Wexford	6A	Dunklin	3A
Keweenaw	7	Pemiscot	3A
Marquette	7	Adair	5A
Minnesota (MN)		Andrew	5A
Zone 6A except...		Atchison	5A
Fillmore	5A	Clark	5A
Houston	5A	Daviess	5A
Winona	5A	DeKalb	5A
Aitkin	7	Gentry	5A
Beltrami	7	Grundy	5A
Carlton	7	Harrison	5A
Cass	7	Holt	5A
Clearwater	7	Knox	5A
Cook	7	Lewis	5A
Crow Wing	7	Linn	5A
Hubbard	7	Livingston	5A
Itasca	7	Macon	5A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone
Kittson	7
Koochiching	7
Lake	7
Lake of the Woods	7
Mahnomen	7
Marshall	7
Norman	7
Pennington	7
Pine	7
Polk	7
Red Lake	7
Roseau	7
St. Louis	7
Wadena	7
Mississippi (MS)	
Zone 3A except...	
George	2A
Hancock	2A
Harrison	2A
Douglas	4B
Esmeralda	4B
Lincoln	4B
Lyon	4B
Mineral	4B
Nye	4B
New Hampshire (NH)	
Zone 6A except...	
Hillsborough	5A
Merrimack	5A
Rockingham	5A
Strafford	5A
New Jersey (NJ)	
Zone 4A except...	
Bergen	5A
Hunterdon	5A
Morris	5A
Passaic	5A
Somerset	5A
Marion	5A
Mercer	5A
Nodaway	5A
Pike	5A
Putnam	5A
Ralls	5A
Schuyler	5A
Scotland	5A
Shelby	5A
Sullivan	5A
Worth	5A
Montana (MT)	
Zone 6B	
Nebraska (NE)	
Zone 5A	
Nevada (NV)	
Zone 5B except...	
Clark	3B
Carson City	4B
Union	4B
Valencia	4B
New York (NY)	
Zone 5A except...	
Bronx	4A
Kings	4A
Nassau	4A
New York	4A
Queens	4A
Richmond	4A
Suffolk	4A
Chenango	6A
Clinton	6A
Delaware	6A
Essex	6A
Franklin	6A
Fulton	6A
Hamilton	6A
Herkimer	6A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Sussex	5A	Jefferson	6A
Warren	5A	Lewis	6A
New Mexico (NM)		Madison	6A
Zone 5B except...		Montgomery	6A
Chaves	3B	Oneida	6A
Dona Ana	3B	Otsego	6A
Eddy	3B	St. Lawrence	6A
Hidalgo	3B	Sullivan	6A
Lea	3B	Ulster	6A
Luna	3B	Warren	6A
Otero	3B	**North Carolina (NC)**	
Sierra	3B	*Zone 3A except...*	
Bernalillo	4B	Alleghany	5A
Catron	4B	Ashe	5A
Curry	4B	Avery	5A
DeBaca	4B	Buncombe	4A
Grant	4B	Burke	4A
Guadalupe	4B	Caldwell	4A
Lincoln	4B	Graham	4A
Quay	4B	Haywood	4A
Roosevelt	4B	Henderson	4A
Socorro	4B	Jackson	4A
Macon	4A	Greene	4A
Madison	4A	Hamilton	4A
McDowell	4A	Highland	4A
Mitchell	4A	Hocking	4A
Stokes	4A	Jackson	4A
Surry	4A	Lawrence	4A
Swain	4A	Madison	4A
Transylvania	4A	Meigs	4A
Watauga	5A	Pickaway	4A
Wilkes	5A	Pike	4A
Yadkin	4A	Ross	4A
Yancy	5A	Scioto	4A
North Dakota (ND)		Vinton	4A
Zone 6A except...		Warren	4A
Benson	7	Washington	4A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Bottineau	7	**Oklahoma (OK)**	
Burke	7	*Zone 3A except...*	
Cavalier	7	Alfalfa	4A
Divide	7	Craig	4A
Grand Forks	7	Delaware	4A
McHenry	7	Ellis	4A
Nelson	7	Garfield	4A
Pembina	7	Grant	4A
Pierce	7	Harper	4A
Ramsey	7	Kay	4A
Renville	7	Major	4A
Rolette	7	Nowata	4A
Towner	7	Osage	4A
Walsh	7	Ottawa	4A
Ward	7	Washington	4A
Ohio (OH)		Woods	4A
Zone 5A except...		Woodward	4A
Adams	4A	Beaver	4B
Athens	4A	Cimarron	4B
Brown	4A	Texas	4B
Butler	4A	**Oregon (OR)**	
Clermont	4A	*Zone 4C except...*	
Clinton	4A	Baker	5B
Fayette	4A	Crook	5B
Franklin	4A	Deschutes	5B
Gallia	4A	Gilliam	5B
Grant	5B	Charles Mix	5A
Harney	5B	Clay	5A
Hood River	5B	Douglas	5A
Jefferson	5B	Gregory	5A
Klamath	5B	Haakon	5A
Lake	5B	Hutchinson	5A
Malheur	5B	Jackson	5A
Morrow	5B	Jones	5A
Sherman	5B	Lyman	5A
Umatilla	5B	Mellette	5A
Union	5B	Stanley	5A
Wallowa	5B	Todd	5A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Wasco	5B	Tripp	5A
Wheeler	5B	Union	5A
Pennsylvania (PA)		Yankton	5A
Zone 5A except...		**Tennessee (TN)**	
Adams	4A	*Zone 4A except...*	
Berks	4A	Bedford	3A
Bucks	4A	Chester	3A
Chester	4A	Coffee	3A
Cumberland	4A	Crockett	3A
Dauphin	4A	Davidson	3A
Delaware	4A	Decatur	3A
Franklin	4A	Dyer	3A
Lancaster	4A	Fayette	3A
Lebanon	4A	Franklin	3A
Montgomery	4A	Gibson	3A
Perry	4A	Giles	3A
Philadelphia	4A	Grundy	3A
York	4A	Hamilton	3A
Rhode Island (RH)		Hardeman	3A
Zone 5A		Hardin	3A
South Carolina (SC)		Haywood	3A
Zone 3A except...		Henderson	3A
Beaufort	2A	Hickman	3A
Jasper	2A	Lauderdale	3A
South Dakota (SD)		Lawrence	3A
Zone 6A except...		Lewis	3A
Bennett	5A	Lincoln	3A
Bon Homme	5A	Madison	3A
Brule	5A	Marion	3A
Marshall	3A	Fayette	2A
Maury	3A	Fort Bend	2A
McNairy	3A	Freestone	2A
Moore	3A	Galveston	2A
Perry	3A	Goliad	2A
Rutherford	3A	Gonzales	2A
Shelby	3A	Grimes	2A
Tipton	3A	Guadalupe	2A
Wayne	3A	Hardin	2A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Williamson	3A	Harris	2A
Texas (TX)		Hays	2A
Zone 3A except...		Hill	2A
Cameron	1A	Houston	2A
Hidalgo	1A	Jackson	2A
Willacy	1A	Jasper	2A
Anderson	2A	Jefferson	2A
Angelina	2A	Jim Hogg	2A
Aransas	2A	Jim Wells	2A
Atascosa	2A	Johnson	2A
Austin	2A	Karnes	2A
Bastrop	2A	Kenedy	2A
Bee	2A	Kleberg	2A
Bell	2A	Lavaca	2A
Bexar	2A	Lee	2A
Bosque	2A	Leon	2A
Brazoria	2A	Liberty	2A
Brazos	2A	Limestone	2A
Brooks	2A	Live Oak	2A
Burleson	2A	Madison	2A
Caldwell	2A	Matagorda	2A
Calhoun	2A	McLennan	2A
Chambers	2A	McMullen	2A
Cherokee	2A	Milam	2A
Colorado	2A	Montgomery	2A
Comal	2A	Navarro	2A
Coryell	2A	Newton	2A
Dallas	2A	Nueces	2A
DeWitt	2A	Orange	2A
Duval	2A	Polk	2A
Ellis	2A	Refugio	2A
Falls	2A	Robertson	2A
San Jacinto	2A	Crosby	3B
San Patricio	2A	Culberson	3B
Starr	2A	Dawson	3B
Tarrant	2A	Dickens	3B
Travis	2A	Ector	3B
Trinity	2A	El Paso	3B

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Tyler	2A	Fisher	3B
Victoria	2A	Foard	3B
Walker	2A	Gaines	3B
Waller	2A	Garza	3B
Washington	2A	Glasscock	3B
Wharton	2A	Hall	3B
Williamson	2A	Hardeman	3B
Wilson	2A	Haskell	3B
Bandera	2B	Hemphill	3B
Dimmit	2B	Howard	3B
Edwards	2B	Hudspeth	3B
Frio	2B	Irion	3B
Kinney	2B	Jeff Davis	3B
La Salle	2B	Jones	3B
Maverick	2B	Kent	3B
Medina	2B	Kerr	3B
Real	2B	Kimble	3B
Uvalde	2B	King	3B
Val Verde	2B	Knox	3B
Webb	2B	Loving	3B
Zapata	2B	Lubbock	3B
Zavala	2B	Lynn	3B
Andrews	3B	Martin	3B
Baylor	3B	Mason	3B
Borden	3B	McCulloch	3B
Brewster	3B	Menard	3B
Callahan	3B	Midland	3B
Childress	3B	Mitchell	3B
Coke	3B	Motley	3B
Coleman	3B	Nolan	3B
Collingsworth	3B	Pecos	3B
Concho	3B	Presidio	3B
Cottle	3B	Reagan	3B
Crane	3B	Reeves	3B
Crockett	3B	Runnels	3B
Schleicher	3B	Sherman	4B
Scurry	3B	Swisher	4B
Shackelford	3B	Yoakum	4B

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Sterling	3B	**Utah (UT)**	
Stonewall	3B	*Zone 5B except...*	
Sutton	3B	Washington	3B
Taylor	3B	Daggett	6B
Terrell	3B	Duchesne	6B
Terry	3B	Morgan	6B
Throckmorton	3B	Rich	6B
Tom Green	3B	Summit	6B
Upton	3B	Uintah	6B
Ward	3B	Wasatch	6B
Wheeler	3B	**Vermont (VT)**	
Wilbarger	3B	Zone 6A	
Winkler	3B	**Virginia (VA)**	
Armstrong	4B	*Zone 4A except...*	
Bailey	4B	Alleghany	5A
Briscoe	4B	Bath	5A
Carson	4B	Brunswick	3A
Castro	4B	Chesapeake city	3A
Cochran	4B	Clifton Forge city	5A
Dallam	4B	Covington city	5A
Deaf Smith	4B	Emporia city	3A
Donley	4B	Franklin city	3A
Floyd	4B	Greensville	3A
Gray	4B	Halifax	3A
Hale	4B	Hampton city	3A
Hansford	4B	Highland	5A
Hartley	4B	Isle of Wight	3A
Hockley	4B	Mecklenburg	3A
Hutchinson	4B	Newport News city	3A
Lamb	4B	Norfolk city	3A
Lipscomb	4B	Pittsylvania	3A
Moore	4B	Portsmouth city	3A
Ochiltree	4B	South Boston	3A
Oldham	4B	Southampton	3A
Parmer	4B	Suffolk city	3A
Potter	4B	Surry	3A
Randall	4B	Sussex	3A
Roberts	4B	Virginia Beach city	3A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Washington (WA)		Mason	4A
Zone 5B except...		McDowell	4A
Clark	4C	Mercer	4A
Cowlitz	4C	Mingo	4A
Grays Harbor	4C	Monroe	4A
Jefferson	4C	Morgan	4A
King	4C	Nicholas	4A
Lewis	4C	Pleasants	4A
Mason	4C	Putnam	4A
Pacific	4C	Raleigh	4A
Pierce	4C	Ritchie	4A
Skagit	4C	Roane	4A
Snohomish	4C	Summers	4A
Thurston	4C	Tyler	4A
Wahkiakum	4C	Upshur	4A
Whatcom	4C	Wayne	4A
Clallam	5C	Webster	4A
Island	5C	Wirt	4A
Kitsap	5C	Wood	4A
San Juan	5C	Wyoming	4A
Ferry	6B	**Wisconsin (WI)**	
Pend Oreille	6B	*Zone 6A except...*	
Stevens	6B	Adams	5A
West Virginia (WV)		Calumet	5A
Zone 5A except...		Columbia	5A
Berkeley	4A	Crawford	5A
Boone	4A	Dane	5A
Braxton	4A	Dodge	5A
Cabell	4A	Fond du Lac	5A
Calhoun	4A	Grant	5A
Clay	4A	Green	5A
Doddridge	4A	Green Lake	5A
Fayette	4A	Iowa	5A
Gilmer	4A	Jefferson	5A
Greenbrier	4A	Juneau	5A
Jackson	4A	Kenosha	5A
Jefferson	4A	La Crosse	5A
Kanawha	4A	Lafayette	5A

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Table Annex1-1 ASHRAE Standard 169-2013, Table B-1: U.S. Climate Zones by State and County *(Continued)*

State/County	Zone	State/County	Zone
Lewis	4A	Milwaukee	5A
Lincoln	4A	Monroe	5A
Logan	4A	Outagamie	5A
Ozaukee	5A	Platte	5B
Racine	5A	Lincoln	7
Richland	5A	Sublette	7
Rock	5A	Teton	7
Sauk	5A	**Commonwealth/Municipality**	**Zone**
Vernon	5A	**Puerto Rico (PR)**	
Walworth	5A	*Zone 1A except...*	
Washington	5A	Barraquitas	2B
Waukesha	5A	Cayey	2B
Waushara	5A	Other	Zone
Winnebago	5A	**Pacific Islands (PI)**	
Wyoming (WY)		*Zone 1A except...*	
Zone 6B except...		Midway Sand Island	2A
Goshen	5B	**Virgin Islands (VI)**	
Laramie	5B	Zone 1A	

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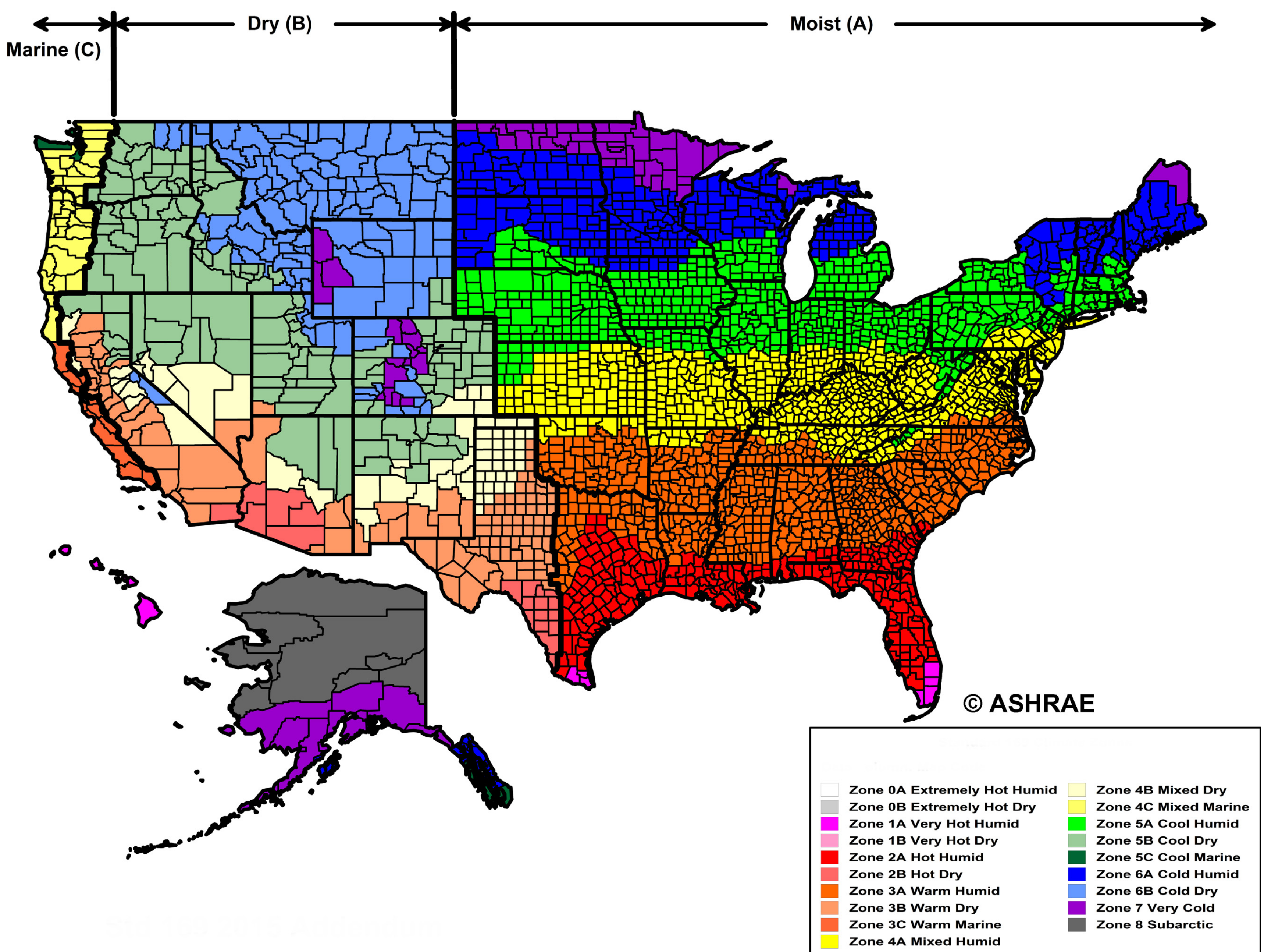

Figure Annex1-1 ASHRAE Standard 169-2013, Figure B-1: Climate zones for United States counties.

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Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones

					Precipitation							Precipitation	
Province/LOCATION	**WMO#**	**Lat**	**Long**	**CZ**	**mm**	**in.**	**Province/LOCATION**	**WMO#**	**Lat**	**Long**	**CZ**	**mm**	**in.**
Alberta (AB)							**British Columbia (BC)**						
BANFF CS	711220	51.19	–115.55	7	487	19	ABBOTSFORD A	711080	49.03	–122.36	4C	1168	46
BOW ISLAND	712310	49.73	–111.45	6A	374	15	AGASSIZ CS	711130	49.25	–121.77	4C	1769	70
BOW VALLEY	712320	51.08	–115.07	7	584	23	ALERT BAY	711100	50.58	–126.93	5C	1668	66
BRETON PLOTS	712330	53.09	–114.44	7	460	18	AMPHITRITE POINT	711120	48.92	–125.54	5C	3212	126
BROOKS	714570	50.55	–111.85	6B	318	13	BALLENAS ISLAND	717690	49.35	–124.16	4C	981	39
CALGARY INT'L A	718770	51.11	–114.02	7	425	17	BLUE RIVER CS	718830	52.13	–119.29	6A	1032	41
CAMROSE	712540	53.03	–112.81	7	499	20	BONILLA ISLAND (AUT)	714840	53.50	–130.63	5C	2169	85
CARDSTON	711530	49.20	–113.29	6A	505	20	BURNS LAKE DECKER LAKE	719520	54.38	–125.96	7	503	20
CLARESHOLM	712340	50.00	–113.64	6A	433	17	CAPE SCOTT	711110	50.78	–128.43	5C	2296	90
COLD LAKE A	711200	54.42	–110.28	7	464	18	CAPE ST JAMES CS	711070	51.94	–131.02	5C	1599	63
COP UPPER	712350	51.08	–114.22	7	451	18	CATHEDRAL POINT (AUT)	714820	52.19	–127.47	5C	3439	135
CORONATION (AUT)	718730	52.08	–111.45	7	405	16	CLINTON (AUT)	714740	51.14	–121.50	7	392	15
CROWSNEST	712360	49.63	–114.48	7	664	26	COMOX A	718930	49.72	–124.90	5C	1340	53
DRUMHELLER EAST	712370	51.43	–112.67	7	390	15	CRANBROOK A	718800	49.61	–115.78	6A	408	16
EDMONTON CITY CENTRE A	718790	53.57	–113.52	7	481	19	CRESTON CAMPBELL SCIENTIFIC	717700	49.08	–116.50	5A	511	20
EDMONTON INT'L A	711230	53.32	–113.58	7	493	19	CUMSHEWA ISLAND	717710	53.03	–131.60	5C	2374	93
EDMONTON NAMAO A	711210	53.67	–113.47	7	457	18	DEASE LAKE	719580	58.43	–130.01	7	452	18
EDSON A	718810	53.60	–116.48	7	597	24	DISCOVERY ISLAND	710310	48.42	–123.23	4C	646	25
ELK ISLAND NAT PARK	712380	53.68	–112.87	7	442	17	ENTRANCE ISLAND CS	717720	49.22	–123.80	4C	1135	45
ESTHER 1	712400	51.67	–110.21	7	323	13	ESQUIMALT HARBOUR	717980	48.43	–123.44	4C	646	25
FORT CHIPEWYAN A	719330	58.77	–111.12	8	417	16	ESTEVAN POINT CS	718940	49.38	–126.54	5C	3276	129
FORT MCMURRAY A	719320	56.65	–111.22	7	476	19	FORT NELSON A	719450	58.84	–122.60	7	469	18
GARDEN RIVER	712530	58.71	–113.87	7	385	15	FORT ST JOHN A	719430	56.24	–120.74	7	477	19
GRANDE PRAIRIE A	719400	55.18	–118.88	7	477	19	GREY ISLET (AUT)	714760	54.58	–130.70	5A	2302	91
HIGH LEVEL A	710660	58.62	–117.16	8	441	17	HERBERT ISLAND (AUT)	714850	50.94	–127.64	5C	2155	85
HIGHVALE	712410	53.45	–114.47	7	458	18	HOLLAND ROCK	712190	54.17	–130.36	5C	2353	93
JASPER	718880	52.88	–118.07	7	415	16	HOPE	711140	49.37	–121.48	5C	1760	69
JASPER WARDEN	714860	52.93	–118.03	7	415	16	HOWE SOUND - PAM ROCKS	712110	49.49	–123.30	4C	1535	60
LAC LA BICHE (AUT)	729310	54.77	–112.02	7	457	18	KAMLOOPS A	718870	50.70	–120.44	5B	286	11
LACOMBE CDA 2	712420	52.45	–113.76	7	454	18	KELOWNA A	712030	49.96	–119.38	5A	471	19
LETHBRIDGE A	718740	49.63	–112.80	6A	425	17	KINDAKUN ROCKS (AUT)	714720	53.32	–132.77	5C	1981	78
LETHBRIDGE CDA	712430	49.70	–112.78	6A	425	17	LANGARA	718990	54.26	–133.06	5C	1952	77
LLOYDMINSTER A	718710	53.31	–110.07	7	426	17	LILLOOET	719990	50.68	–121.93	5A	392	15
MEDICINE HAT A	718720	50.02	–110.72	6B	347	14	LUCY ISLAND LIGHTSTATION	712200	54.30	–130.61	5C	2317	91
MILDRED LAKE	712550	57.04	–111.56	7	345	14	LYTTON	718910	50.22	–121.58	5C	455	18
MILK RIVER	712440	49.13	–112.05	6B	364	14	MACKENZIE A	719440	55.31	–123.14	7	687	27
NAKISKA RIDGETOP	712450	50.94	–115.19	8	605	24	MALAHAT	717740	48.57	–123.53	5C	1095	43
ONEFOUR CDA	711160	49.12	–110.47	6A	347	14	NAKUSP CS	712160	50.27	–117.81	5A	832	33
PEACE RIVER A	710680	56.23	–117.45	7	412	16	NELSON CS	717760	49.49	–117.31	5A	741	29
PINCHER CREEK (AUT)	718750	49.52	–113.98	6A	484	19	OSOYOOS CS	712150	49.03	–119.44	5B	319	13
RED DEER A	718780	52.18	–113.89	7	473	19	PEMBERTON AIRPORT CS	717770	50.30	–122.74	5C	850	33
RED EARTH	712460	56.55	–115.28	7	430	17	PENTICTON A	718890	49.46	–119.60	5B	303	12
ROCKY MTN HOUSE (AUT)	719280	52.42	–114.91	7	522	21	PITT MEADOWS CS	717750	49.21	–122.69	4C	1483	58
SLAVE LAKE A	710690	55.28	–114.78	7	525	21	POINT ATKINSON	710370	49.33	–123.26	4C	1535	60
SPRINGBANK A	718600	51.10	–114.37	7	491	19	PORT ALBERNI (AUT)	714750	49.32	–124.93	5C	1636	64
STAVELY AAFC	715550	50.18	–113.88	6A	472	19	PORT HARDY A	711090	50.68	–127.37	5C	1917	75
SUNDRE A	712480	51.78	–114.68	7	464	18	PRINCE GEORGE A	718960	53.89	–122.68	7	658	26
THREE HILLS	712490	51.83	–113.21	7	407	16	PRINCE RUPERT A	718980	54.29	–130.44	5C	2690	106
VAUXHALL CDA CS	712510	50.05	–112.13	6B	351	14	PRINCETON CS	710320	49.47	–120.51	6A	369	15
VEGREVILLE	714580	53.51	–112.10	7	375	15	PUNTZI MOUNTAIN (AUT)	710500	52.11	–124.14	7	394	16
WAINWRIGHT CFB AIRFIELD 21	711180	52.83	–111.10	7	431	17	QUESNEL A	711030	53.03	–122.51	6A	554	22
WATERTON PARK GATE	711540	49.13	–113.81	6A	551	22	REVELSTOKE A	718820	50.96	–118.18	6A	1018	40
WHITECOURT A	719300	54.14	–115.79	7	594	23	ROSE SPIT (AUT)	714770	54.16	–131.66	5A	1434	56

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Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones *(Continued)*

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
SALMON ARM CS	712180	50.70	–119.29	5A	458	18
SANDHEADS CS	712090	49.11	–123.30	4C	1082	43
SANDSPIT A	711010	53.25	–131.81	5C	1323	52
SARTINE ISLAND (AUT)	714780	50.82	–128.91	5C	1920	76
SHERINGHAM POINT	717800	48.38	–123.92	5C	1497	59
SISTERS ISLAND	717810	49.49	–124.43	4C	1103	43
SMITHERS A	719500	54.82	–127.18	7	539	21
SOLANDER ISLAND (AUT)	714790	50.11	–127.94	5C	2375	94
SPARWOOD CS	717820	49.75	–114.89	7	1021	40
SQUAMISH	712070	49.78	–123.16	5C	2294	90
SUMMERLAND CS	717680	49.56	–119.64	5B	321	13
TERRACE A	719510	54.47	–128.58	6A	1378	54
VANCOUVER HARBOUR CS	712010	49.30	–123.12	4C	1517	60
VANCOUVER INT'L A	718920	49.20	–123.18	4C	1209	48
VERNON CS	711150	50.22	–119.19	5A	453	18
VICTORIA GONZALES CS	712000	48.41	–123.33	4C	646	25
VICTORIA HARTLAND CS	710380	48.53	–123.46	4C	948	37
VICTORIA INT'L A	717990	48.65	–123.43	5C	948	37
VICTORIA MARINE	712020	48.37	–123.75	5C	1265	50
VICTORIA UNIVERSITY CS	717830	48.46	–123.30	4C	646	25
WEST VANCOUVER AUT	717840	49.35	–123.19	4C	1517	60
WHITE ROCK CAMPBELL SCIENTIFI	717850	49.02	–122.78	4C	1049	41
WILLIAMS LAKE A	711040	52.18	–122.05	7	451	18
YOHO PARK	717860	51.44	–116.34	7	541	21
Manitoba (MB)						
BERENS RIVER CS	711580	52.36	–97.02	7	475	19
BRANDON A	711400	49.91	–99.95	7	471	19
CARBERRY CS	711700	49.91	–99.36	7	523	21
CARMAN U OF M CS	711470	49.50	–98.03	7	527	21
CHURCHILL A	719130	58.74	–94.06	8	449	18
DAUPHIN A	718550	51.10	–100.05	7	513	20
DELTA MARSH CS	715630	50.18	–98.38	7	530	21
EMERSON AUT	715600	49.00	–97.24	7	488	19
FISHER BRANCH (AUT)	714420	51.08	–97.55	7	562	22
GEORGE ISLAND (AUT)	714450	52.82	–97.62	7	449	18
GILLAM A	719120	56.36	–94.71	8	518	20
GIMLI INDUSTRIAL PARK	718560	50.63	–97.05	7	500	20
GRAND RAPIDS (AUT)	718580	53.19	–99.27	7	485	19
GRETNA (AUT)	714410	49.03	–97.56	7	512	20
HUNTERS POINT MARINE	711420	53.03	–100.93	7	462	18
ISLAND LAKE A	711450	53.85	–94.65	7	581	23
LYNN LAKE A	710780	56.86	–101.08	8	535	21
MELITA	714470	49.28	–100.99	7	446	18
NORWAY HOUSE A	711410	53.95	–97.85	7	530	21
OAKPOINT MARINE	711440	50.50	–98.04	7	532	21
PILOT MOUND (AUT)	711480	49.19	–98.90	7	487	19
PINAWA	714480	50.18	–96.06	7	435	17
PORTAGE SOUTHPORT A	718510	49.90	–98.27	7	515	20
ROBLIN	715530	51.18	–101.36	7	466	18
SHOAL LAKE CS	711500	50.45	–100.60	7	504	20
SPRAGUE	714490	49.02	–95.60	7	622	24
SWAN RIVER RCS	714430	52.12	–101.23	7	468	18
THE PAS A	718670	53.97	–101.10	7	470	18
THOMPSON A	710790	55.80	–97.86	8	520	20

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
VICTORIA BEACH (AUT)	715520	50.70	–96.57	7	489	19
WASAGAMING	714440	50.66	–99.94	7	528	21
WILSON CREEK WEIR CS	711490	50.71	–99.53	7	536	21
WINNIPEG RICHARDSON INT'L A	718520	49.92	–97.23	7	523	21
New Brunswick (NB)						
BAS CARAQUET	715980	47.80	–64.83	6A	1049	41
CHARLO A	717110	47.98	–66.33	7	1112	44
FREDERICTON A	717000	45.87	–66.53	6A	1151	45
MIRAMICHI A	717170	47.01	–65.47	7	1090	43
MIRAMICHI RCS	717440	47.01	–65.46	6A	1090	43
MISCOU ISLAND (AUT)	717190	48.01	–64.49	7	1037	41
MONCTON A	717050	46.10	–64.69	6A	1290	51
POINT ESCUMINAC (AUT)	714140	47.07	–64.80	6A	1133	45
POINT LEPREAU CS	716990	45.07	–66.45	6A	1253	49
SAINT JOHN A	716090	45.32	–65.89	6A	1317	52
ST LEONARD CS	710190	47.16	–67.83	7	997	39
ST STEPHEN (AUT)	716070	45.22	–67.25	6A	1149	45
Newfoundland And Labrador (NL)						
ARGENTIA (AUT)	718070	47.29	–53.99	6A	1304	51
BADGER (AUT)	714000	48.97	–56.07	7	1072	42
BONAVISTA	711960	48.67	–53.11	6A	1068	42
BURGEO 2	711940	47.62	–57.62	6A	1818	72
CAPE KAKKIVIAK	711760	59.98	–64.16	8	376	15
CAPE RACE (AUT)	718000	46.66	–53.08	6A	1378	54
CARTWRIGHT	718180	53.71	–57.04	7	1060	42
CHURCHILL FALLS	711820	53.56	–64.09	8	999	39
COMFORT COVE	711930	49.27	–54.88	7	1213	48
CORNER BROOK	719730	48.93	–57.92	6A	1222	48
DANIELS HARBOUR	711850	50.24	–57.58	7	1164	46
DEER LAKE A	718090	49.22	–57.40	7	1105	44
ENGLEE (AUT)	714170	50.72	–56.11	7	1022	40
FEROLLE POINT (AUT)	714060	51.02	–57.10	7	1185	47
GANDER INT'L A	718030	48.95	–54.58	7	1255	49
GOOSE A	718160	53.32	–60.42	7	996	39
GRATES COVE	713360	48.17	–52.94	6A	1408	55
HOPEDALE (AUT)	719000	55.45	–60.22	8	884	35
LA SCIE	713370	49.92	–55.67	7	1293	51
MARTICOT ISLAND	716920	47.33	–54.59	6A	1395	55
POOLS ISLAND	719310	49.11	–53.58	6A	1015	40
PORT AUX BASQUES	711970	47.57	–59.15	7	1563	62
SAGLEK	713350	58.33	–62.59	8	836	33
SAGONA ISLAND	714080	47.37	–55.79	6A	1574	62
ST ANTHONY	715580	51.38	–56.10	7	1183	47
ST JOHN'S A	718010	47.62	–52.74	6A	1547	61
ST LAWRENCE	718020	46.92	–55.38	6A	1603	63
STEPHENVILLE A	718150	48.53	–58.55	6A	1364	54
TWILLINGATE (AUT)	714020	49.68	–54.80	7	1015	40
WABUSH LAKE A	718250	52.93	–66.87	8	936	37
Nova Scotia (NS)						
AMHERST (AUT)	714100	45.85	–64.27	6A	1212	48
BACCARO POINT	716910	43.45	–65.47	6A	1258	50
BEAVER ISLAND (AUT)	714030	44.82	–62.33	6A	1472	58
BRIER ISLAND	719880	44.29	–66.35	6A	1202	47
CARIBOU POINT (AUT)	714150	45.77	–62.68	6A	1063	42

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Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones *(Continued)*

					Precipitation	
Province/LOCATION	WMO#	Lat	Long	CZ	mm	in.
GRAND ETANG	715970	46.55	–61.05	6A	1202	47
GREENWOOD A	713970	44.98	–64.92	6A	1253	49
HALIFAX STANFIELD INT'L A	713950	44.88	–63.52	6A	1532	60
HART ISLAND (AUT)	714190	45.35	–60.98	6A	1464	58
KEJIMKUJIK 1	715990	44.43	–65.20	6A	1438	57
SABLE ISLAND	716000	43.93	–60.01	5A	1392	55
SHEARWATER A	716010	44.63	–63.50	6A	1414	56
SHEARWATER JETTY	CAN35X	44.63	–63.52	5A	1414	56
ST PAUL ISLAND (AUT)	714180	47.23	–60.14	6A	1391	55
SYDNEY A	717070	46.17	–60.05	6A	1523	60
WESTERN HEAD	714110	43.99	–64.66	6A	1405	55
YARMOUTH A	716030	43.83	–66.09	6A	1305	51
Northwest Territories (NT)						
AULAVIK NATIONAL PARK	719740	74.14	–119.99	8	116	5
CAPE PARRY A	719480	70.17	–124.72	8	154	6
COLVILLE LAKE	710550	67.04	–126.08	8	317	12
FORT GOOD HOPE CS	714910	66.24	–128.64	8	317	12
FORT LIARD	714970	60.23	–123.47	8	435	17
FORT PROVIDENCE	710870	61.32	–117.60	8	266	10
FORT RELIANCE	710730	62.72	–109.17	8	283	11
FORT SIMPSON A	719460	61.76	–121.24	8	376	15
FORT SMITH A	719340	60.02	–111.96	8	373	15
HANBURY RIVER	719630	63.60	–105.13	8	275	11
HAY RIVER A	719350	60.84	–115.78	8	373	15
INNER WHALEBACKS	711620	61.92	–113.73	8	283	11
INUVIK A	719570	68.30	–133.48	8	267	11
LAC LA MARTRE	711630	63.13	–117.25	8	265	10
LINDBURG LANDING	716820	61.12	–122.85	8	399	16
LITTLE CHICAGO	711640	67.18	–130.23	8	310	12
LIVERPOOL BAY	719600	69.60	–130.91	8	130	5
MOULD BAY A	710720	76.23	–119.33	8	114	4
NICHOLSON PENINSULA	719560	69.93	–128.97	8	107	4
NORMAN WELLS A	710430	65.28	–126.80	8	336	13
PELLY ISLAND	715020	69.63	–135.44	8	194	8
RAE LAKES	711650	64.11	–117.33	8	260	10
SACHS HARBOUR CLIMATE	714670	71.99	–125.25	8	134	5
TROUT LAKE	711660	60.44	–121.24	8	405	16
TUKTOYAKTUK	719850	69.43	–133.02	8	136	5
YELLOWKNIFE A	719360	62.46	–114.44	8	287	11
YOHIN	710200	61.24	–123.74	8	413	16
Nunavut (NU)						
ALERT	710820	82.52	–62.28	8	172	7
BAKER LAKE A	719260	64.30	–96.08	8	272	11
BREVOORT ISLAND	710970	63.34	–64.15	8	624	25
BYRON BAY A	719290	68.75	–109.07	8	121	5
CAMBRIDGE BAY A	719250	69.11	–105.14	8	149	6
CAPE DORSET A	719100	64.23	–76.53	8	402	16
CAPE DYER	710940	66.65	–61.38	8	627	25
CAPE HOOPER	710930	68.47	–66.82	8	265	10
CAPE MERCY	719750	64.96	–63.58	8	467	18
CAPE PEEL WEST	710640	69.04	–107.82	8	133	5
CLINTON POINT	710530	69.58	–120.80	8	161	6
CLYDE A	710900	70.49	–68.52	8	239	9
CORAL HARBOUR A	719150	64.19	–83.36	8	299	12
CROKER RIVER	710590	69.28	–119.22	8	183	7
DEWAR LAKES	710920	68.65	–71.17	8	248	10
ENNADAI LAKE (AUT)	719230	61.13	–100.88	8	326	13
EUREKA	719170	79.98	–85.93	8	76	3
FOX FIVE	710960	67.54	–63.79	8	289	11
GLADMAN POINT A	719270	68.67	–97.80	8	125	5
HALL BEACH A	710810	68.78	–81.24	8	235	9
HAT ISLAND	710840	68.32	–100.09	8	204	8
IQALUIT A	719090	63.75	–68.55	8	422	17
JENNY LIND ISLAND A	710710	68.65	–101.73	8	116	5
KUGLUKTUK A	719380	67.82	–115.14	8	263	10
LADY FRANKLIN POINT A	719370	68.50	–113.22	8	121	5
LONGSTAFF BLUFF	710910	68.90	–75.14	8	212	8
MACKAR INLET	710800	68.30	–85.67	8	187	7
PANGNIRTUNG	718260	66.15	–65.72	8	427	17
PELLY BAY	719190	68.43	–89.72	8	240	9
POND INLET A	710950	72.68	–77.98	8	196	8
RANKIN INLET A	710830	62.82	–92.12	8	324	13
RESOLUTE CARS	719240	74.72	–94.99	8	152	6
RESOLUTION ISLAND	719720	61.60	–64.63	8	364	14
ROBERTSON LAKE (AUT)	714900	65.10	–102.43	8	256	10
SHEPHERD BAY A	719110	68.82	–93.43	8	155	6
Ontario (ON)						
ARMSTRONG (AUT)	718410	50.29	–88.91	7	737	29
ATIKOKAN (AUT)	717470	48.76	–91.63	7	798	31
BANCROFT AUTO	712940	45.07	–77.88	7	873	34
BEAUSOLEIL	712720	44.85	–79.87	6A	934	37
BELLE RIVER	712730	42.30	–82.70	5A	804	32
BIG TROUT LAKE	718480	53.83	–89.87	8	582	23
BIG TROUT LAKE READAC	718440	53.82	–89.90	8	582	23
BURLINGTON PIERS (AUT)	714370	43.30	–79.80	5A	827	33
COBOURG (AUT)	714310	43.95	–78.17	6A	808	32
COLLINGWOOD	712700	44.50	–80.22	6A	766	30
COVE ISLAND (AUT)	714390	45.33	–81.73	6A	869	34
EARLTON A	717350	47.70	–79.85	7	801	32
ERIEAU (AUT)	714650	42.25	–81.90	5A	797	31
GERALDTON A	718340	49.78	–86.93	7	774	30
GODERICH	712610	43.77	–81.72	5A	981	39
GORE BAY A	717330	45.88	–82.57	6A	834	33
GREAT DUCK ISLAND (AUT)	714620	45.63	–82.95	6A	809	32
GRENADIER ISLAND	712810	44.42	–75.85	6A	947	37
KAPUSKASING A	718310	49.41	–82.47	7	891	35
KENORA A	718500	49.79	–94.37	7	674	27
KILLARNEY (AUT)	714600	45.97	–81.48	6A	839	33
LAGOON CITY	712820	44.55	–79.22	6A	929	37
LANSDOWNE HOUSE (AUT)	718460	52.20	–87.94	7	719	28
LONDON INT'L AIRPORT	716230	43.03	–81.15	5A	981	39
LONG POINT (AUT)	714640	42.57	–80.05	5A	948	37
MOOSONEE A	718360	51.29	–80.61	7	722	28
MOUNT FOREST (AUT)	716310	43.98	–80.75	6A	969	38
NAGAGAMI (AUT)	718320	49.75	–84.16	7	793	31
NORTH BAY A	717310	46.36	–79.42	7	1012	40
OTTAWA MACDONALD-CARTIER INT'	716280	45.32	–75.67	6A	922	36
PEAWANUCK (AUT)	714340	54.98	–85.43	8	602	24

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Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones *(Continued)*

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
PETAWAWA A	716250	45.95	–77.32	7	851	34
PETERBOROUGH A	716290	44.23	–78.37	6A	843	33
PICKLE LAKE (AUT)	718350	51.45	–90.22	7	726	29
POINT PETRE (AUT)	714300	43.83	–77.15	6A	965	38
PORT COLBORNE (AUT)	714630	42.87	–79.25	5A	986	39
PORT WELLER (AUT)	714320	43.25	–79.22	5A	890	35
PUKASKWA (AUT)	717500	48.59	–86.29	7	865	34
RED LAKE A	718540	51.07	–93.79	7	668	26
ROYAL ISLAND (AUT)	CAN21X	49.47	–94.76	7	613	24
SAULT STE MARIE A	712600	46.48	–84.51	6A	932	37
SIOUX LOOKOUT A	718420	50.12	–91.90	7	739	29
SUDBURY A	717300	46.62	–80.80	7	917	36
THUNDER BAY A	717490	48.37	–89.33	7	731	29
TIMMINS VICTOR POWER A	717390	48.57	–81.38	7	921	36
TORONTO BUTTONVILLE A	716390	43.86	–79.37	6A	781	31
TORONTO ISLAND A	712650	43.63	–79.40	5A	848	33
TORONTO LESTER B. PEARSON INT	716240	43.68	–79.63	5A	785	31
TRENTON A	716210	44.12	–77.53	6A	858	34
UPSALA (AUT)	714350	49.03	–90.47	7	715	28
WAWA (AUT)	717380	47.97	–84.78	7	906	36
WELCOME ISLAND (AUT)	717510	48.37	–89.12	7	659	26
WIARTON A	716330	44.75	–81.11	6A	1049	41
WINDSOR A	715380	42.28	–82.96	5A	920	36
Prince Edward Island (PE)						
CHARLOTTETOWN A	717060	46.29	–63.13	6A	1217	48
EAST POINT (AUT)	714120	46.46	–61.99	6A	1285	51
NORTH CAPE	719870	47.06	–64.00	6A	1103	43
SUMMERSIDE	717020	46.44	–63.84	6A	1077	42
Quebec (QC)						
AMQUI	713860	48.47	–67.43	7	1028	40
BAGOTVILLE A	717270	48.33	–71.00	7	966	38
BAIE-COMEAU	718290	49.26	–68.15	7	981	39
BAIE-COMEAU A	711870	49.13	–68.20	7	1045	41
BARRAGE TEMISCAMINGUE	717320	46.71	–79.10	6A	956	38
BEAUCEVILLE	713230	46.20	–70.78	7	1127	44
BLANC-SABLON A	718080	51.45	–57.18	7	1091	43
BONNARD 1	713830	50.73	–71.01	7	1006	40
CAP-CHAT	714280	49.11	–66.65	7	928	37
CAP-D'ESPOIR	714290	48.42	–64.32	7	1089	43
CAP-MADELEINE	714250	49.25	–65.32	7	897	35
CAP-ROUGE	711860	48.37	–70.54	7	944	37
CAP-TOURMENTE	713840	47.08	–70.78	6A	1104	43
CHARLEVOIX (MRC)	713190	47.28	–70.64	7	1103	43
CHEVERY	718140	50.46	–59.64	7	1161	46
CHIBOUGAMAU CHAPAIS A	718220	49.77	–74.53	7	969	38
CHUTE-DES-PASSES	715220	49.84	–71.17	7	1091	43
DESCHAMBAULT	713890	46.69	–71.97	7	1134	45
FRELIGHSBURG	713730	45.05	–72.86	6A	1180	46
GASPE A	711880	48.78	–64.48	7	1048	41
HAVRE-SAINT-PIERRE A	713130	50.28	–63.60	7	1094	43
HEATH POINT	714230	49.09	–61.70	7	1030	41
ILE AUX PERROQUETS	713750	50.22	–64.21	7	1099	43
ILE ROUGE	714260	48.07	–69.56	7	998	39
ILES DE LA MADELEINE	717100	47.43	–61.77	6A	1049	41
INUKJUAK A	719070	58.47	–78.08	8	457	18
JONQUIERE	716170	48.42	–71.15	7	948	37
KUUJJUAQ A	719060	58.10	–68.42	8	520	20
KUUJJUARAPIK A	719050	55.28	–77.75	8	667	26
LA BAIE	713880	48.30	–70.92	7	966	38
LA GRANDE IV A	718230	53.76	–73.68	8	773	30
LA GRANDE RIVIERE A	718270	53.63	–77.70	8	683	27
LA POCATIERE	717130	47.36	–70.03	6A	963	38
LA TUQUE	713780	47.41	–72.79	7	959	38
LAC BENOIT	715200	51.53	–71.11	8	925	36
LAC EON	714210	51.87	–63.28	8	1058	42
LAC SAINT-PIERRE	711980	46.18	–72.92	6A	993	39
L'ACADIE	713720	45.29	–73.35	6A	1021	40
L'ASSOMPTION	715240	45.81	–73.43	6A	999	39
LENNOXVILLE	716110	45.37	–71.82	6A	1095	43
L'ETAPE	713820	47.56	–71.23	7	1261	50
LONGUE-POINTE-DE-MINGAN	715120	50.27	–64.23	7	1108	44
MANIWAKI AIRPORT	717210	46.27	–75.99	7	966	38
MANIWAKI UA	717220	46.30	–76.01	7	928	37
MANOUANE EST	715210	50.66	–70.53	8	908	36
MATAGAMI A	718210	49.77	–77.80	7	838	33
MCTAVISH	716120	45.50	–73.58	6A	1096	43
MISTOOK	713810	48.60	–71.72	7	942	37
MONT-JOLI A	717180	48.60	–68.22	7	969	38
MONT-ORFORD	716180	45.31	–72.24	7	1082	43
MONTREAL/MIRABEL INT'L A	716260	45.67	–74.03	6A	1024	40
MONTREAL/PIERRE ELLIOTT TRUDE	716270	45.47	–73.75	6A	988	39
MONTREAL/ST-HUBERT A	713710	45.52	–73.42	6A	1027	40
MONTREAL-EST	716750	45.63	–73.55	6A	1013	40
NATASHQUAN A	718130	50.18	–61.82	7	1182	47
NEW CARLISLE 1	716190	48.01	–65.33	7	1015	40
NICOLET	717230	46.23	–72.66	6A	1026	40
NORMANDIN	713790	48.84	–72.55	7	913	36
ONATCHIWAY	713870	48.89	–71.03	7	937	37
PARENT	717260	47.92	–74.62	7	1015	40
POINTE CLAVEAU	711890	48.26	–70.11	7	995	39
POINTE NOIRE CS	713900	50.16	–66.43	7	1119	44
POINTE-AU-PERE (INRS)	715540	48.51	–68.47	7	888	35
POINTE-DES-MONTS	714270	49.32	–67.38	7	982	39
PORT-MENIER	718100	49.84	–64.29	7	1047	41
QUEBEC/JEAN LESAGE INTL A	717080	46.80	–71.38	7	1266	50
RIVIERE-DU-LOUP	717150	47.81	–69.55	7	981	39
ROBERVAL A	717280	48.52	–72.27	7	872	34
ROUYN	717340	48.25	–79.03	7	865	34
ROUYN A	717400	48.22	–78.83	7	882	35
SCHEFFERVILLE A	718280	54.80	–66.82	8	784	31
SEPT-ILES A	718110	50.22	–66.27	7	1173	46
SHERBROOKE A	716100	45.43	–71.68	7	1162	46
ST-ANICET 1	717120	45.12	–74.29	6A	968	38
STE AGATHE DES MONTS	717200	46.05	–74.28	7	1236	49
STE-ANNE-DE-BELLEVUE 1	713770	45.43	–73.93	6A	958	38
STE-CLOTHILDE	716140	45.17	–73.68	6A	925	36
STE-FOY (U. LAVAL)	713920	46.78	–71.29	6A	1266	50
ST-JOVITE	713760	46.08	–74.56	7	1130	44

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Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones *(Continued)*

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
TROIS-RIVIERES	717240	46.35	–72.52	6A	1024	40
VAL-D'OR A	717250	48.06	–77.79	7	981	39
VARENNES	711840	45.72	–73.38	6A	1027	40
Saskatchewan (SK)						
ASSINIBOIA AIRPORT	714870	49.73	–105.93	7	400	16
BROADVIEW	718610	50.37	–102.57	7	416	16
COLLINS BAY	710750	58.18	–103.70	8	546	21
CORONACH SPC	715160	49.05	–105.48	7	338	13
CREE LAKE	719200	57.35	–107.13	8	476	19
CYPRESS HILLS PARK	711390	49.65	–109.52	7	346	14
EASTEND CYPRESS (AUT)	711310	49.43	–108.98	7	386	15
ELBOW CS	714500	51.13	–106.58	7	325	13
ESTEVAN A	718620	49.22	–102.97	7	434	17
HUDSON BAY	718680	52.82	–102.32	7	479	19
INDIAN HEAD CDA	715150	50.55	–103.65	7	444	17
KEY LAKE A	714880	57.25	–105.60	8	493	19
KINDERSLEY A	711290	51.52	–109.18	7	324	13
LA RONGE A	719220	55.15	–105.27	7	501	20
LAST MOUNTAIN CS	715560	51.42	–105.25	7	384	15
LEADER AIRPORT	714590	50.90	–109.50	7	365	14
LUCKY LAKE	714550	50.95	–107.15	7	342	13
MAPLE CREEK	714530	49.90	–109.47	6A	371	15
MEADOW LAKE A	711250	54.13	–108.52	7	431	17
MELFORT	714560	52.82	–104.60	7	416	16
MOOSE JAW A	718640	50.33	–105.55	7	375	15
MOOSE JAW CS	715390	50.33	–105.56	7	375	15
NIPAWIN A	711300	53.33	–104.00	7	453	18
NORTH BATTLEFORD A	718760	52.77	–108.26	7	391	15
OUTLOOK PFRA	715510	51.48	–107.05	7	350	14
PRINCE ALBERT A	718690	53.22	–105.67	7	426	17
REGINA A	718630	50.43	–104.67	7	395	16
ROCKGLEN (AUT)	711350	49.17	–105.98	7	335	13
ROSETOWN EAST	715100	51.57	–107.92	7	347	14
SASKATOON DIEFENBAKER INT'L A	718660	52.17	–106.72	7	364	14
SASKATOON KERNEN FARM	715130	52.15	–106.55	7	364	14
SCOTT CDA	714890	52.36	–108.83	7	388	15
SOUTHEND	714510	56.33	–103.28	8	535	21
SPIRITWOOD WEST	711330	53.37	–107.55	7	417	16
STONY RAPIDS A	711320	59.25	–105.83	8	429	17
SWIFT CURRENT A	718700	50.30	–107.68	7	389	15
SWIFT CURRENT CDA	714460	50.27	–107.73	7	389	15
URANIUM CITY (AUT)	710760	59.57	–108.48	8	379	15
VAL MARIE SOUTHEAST	711370	49.07	–107.58	7	295	12
WASKESIU LAKE	714540	53.92	–106.07	7	414	16
WATROUS EAST	715110	51.67	–105.40	7	379	15
WEYBURN	714520	49.70	–103.80	7	391	15
WYNYARD (AUT)	718650	51.77	–104.20	7	429	17
YORKTON A	711380	51.27	–102.47	7	457	18
Yukon (YT)						
BURWASH A	719670	61.37	–139.05	8	302	12
FARO (AUT)	719490	62.23	–133.35	8	275	11
HAINES JUNCTION	715050	60.77	–137.58	8	334	13
HERSCHEL ISLAND	715010	69.57	–138.91	8	188	7
IVVAVIK NAT. PARK	719780	69.16	–140.15	8	176	7
KOMAKUK BEACH	710460	69.61	–140.20	8	168	7
MAYO A	719650	63.62	–135.87	8	329	13
ROCK RIVER	715060	66.98	–136.22	8	337	13
SHINGLE POINT A	719680	68.95	–137.22	8	260	10
TESLIN (AUT)	710450	60.17	–132.73	8	340	13
WATSON LAKE A	719530	60.12	–128.82	8	436	17
WHITEHORSE A	719640	60.71	–135.07	7	281	11

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
Albania (ALB)						
TIRANA	136150	41.33	19.78	3A	1234	49
Algeria (DZA)						
ADRAR	606200	27.88	–0.18	1B	14	1
ANNABA	603600	36.83	7.82	3A	630	25
BATNA	604680	35.75	6.32	3B	362	14
BECHAR	605710	31.50	–2.25	2B	87	3
BEJAIA-AEROPORT	604020	36.72	5.07	3A	776	31
BISKRA	605250	34.80	5.73	2B	110	4
BORDJ-BOU-ARRERIDJ	604440	36.07	4.77	3B	420	17
CONSTANTINE	604190	36.28	6.62	3A	516	20
DAR-EL-BEIDA	603900	36.68	3.22	3A	701	28
DJANET	606700	24.27	9.47	2B	21	1
EL-BAYADH	605500	33.67	1.00	4B	269	11
EL-GOLEA	605900	30.57	2.87	2B	37	1
EL-OUED	605590	33.50	6.78	2B	71	3
GHARDAIA	605660	32.40	3.80	2B	65	3
HASSI-MESSAOUD	605810	31.67	6.15	2B	40	2
ILLIZI	606400	26.50	8.42	1B	18	1
IN-AMENAS	606110	28.05	9.63	2B	25	1
IN-SALAH	606300	27.23	2.50	0B	12	0
JIJEL-ACHOUAT	603510	36.80	5.88	3A	943	37
MASCARA-MATEMORE	605060	35.60	0.30	3A	443	17
MECHERIA	605490	33.58	–0.28	3B	231	9
ORAN-SENIA	604900	35.63	–0.60	3A	368	15
OUARGLA	605800	31.93	5.40	2B	50	2
SETIF	604450	36.18	5.25	4A	492	19
SKIKDA	603550	36.88	6.90	3A	734	29
TAMANRASSET	606800	22.80	5.43	2B	40	2
TAMANRASSET	606805	22.80	5.45	2B	40	2
TEBESSA	604750	35.42	8.12	3B	369	15
TIARET	605110	35.35	1.47	3B	355	14
TINDOUF	606560	27.70	–8.17	1B	51	2
TLEMCEN-ZENATA	605310	35.02	–1.47	3A	468	18
TOUGGOURT	605550	33.12	6.13	2B	58	2
American Samoa (ASM)						
PAGO PAGO WSO AP	917650	–14.33	–170.71	0A	2990	118
Antarctica (ATA)						
BASE ARTURO PRAT	890570	–62.50	–59.68	8	902	35
BASE ESPERANZA	889630	–63.40	–56.98	8	840	33
BASE JUBANY	890530	–62.23	–58.63	8	905	36
BASE MARAMBIO	890550	–64.23	–56.72	8	792	31
BASE ORCADAS	889680	–60.73	–44.73	8	902	35
BASE SAN MARTIN	890660	–68.12	–67.13	8	624	25
BELLINGSHAUSEN AWS	890500	–62.20	–58.93	8	905	36
BERNARDO O`HIGGINS	890590	–63.32	–57.90	8	858	34
BUTLER ISLAND	892660	–72.21	–60.17	8	610	24
CASEY	896110	–66.28	110.52	8	398	16
DAVIS	895710	–68.58	77.95	8	281	11
DINAMET-URUGUAY	890540	–62.18	–58.83	8	905	36
DUMONT DURVILLE	896420	–66.67	140.02	8	431	17
FREI CHI-BASE	890560	–62.18	–58.98	8	905	36
GREAT *WALL*	890580	–62.22	–58.97	8	905	36
HALLEY	890220	–75.50	–26.65	8	307	12
MANUELA	898640	–74.95	163.69	8	350	14
MARBLE POINT	898660	–77.43	163.75	8	190	7
MAWSON	895640	–67.60	62.87	8	307	12
MIRNYJ	895920	–66.55	93.02	8	745	29
MOLODEZNAJA	895420	–67.67	45.85	8	529	21
MOUNT SIPLE	893270	–73.20	–127.05	8	504	20
NEUMAYER	890020	–70.67	–8.25	8	394	16
NOVOLAZAREVSKAJA	895120	–70.77	11.83	8	354	14
POSSESSION ISLAND	898790	–71.89	171.21	8	453	18
SIPLE DOME	893450	–81.65	–148.77	8	285	11
SYOWA	895320	–69.00	39.58	8	449	18
Antigua and Barbuda (ATG)						
VC BIRD INTL AIRPOR	788620	17.12	–61.78	0A	883	35
Argentina (ARG)						
AEROPARQUE BS. AS.	875820	–34.57	–58.42	3A	1049	41
BAHIA BLANCA AERO	877500	–38.73	–62.17	3A	632	25
BARILOCHE AERO	877650	–41.15	–71.17	5C	801	32
CATAMARCA AERO.	872220	–28.60	–65.77	2B	383	15
CERES AERO	872570	–29.88	–61.95	3A	936	37
COMODORO RIVADAVIA	878600	–45.78	–67.50	4C	238	9
CONCORDIA AERO	873950	–31.30	–58.02	3A	1298	51
CORDOBA AERO	873440	–31.32	–64.22	3A	827	33
CORRIENTES AERO.	871660	–27.45	–58.77	2A	1460	57
ESQUEL AERO	878030	–42.93	–71.15	5C	488	19
EZEIZA AERO	875760	–34.82	–58.53	3A	967	38
FORMOSA AERO	871620	–26.20	–58.23	2A	1411	56
GUALEGUAYCHU AERO	874970	–33.00	–58.62	3A	1038	41
IGUAZU AERO	870970	–25.73	–54.47	2A	1826	72
JUJUY AERO	870460	–24.38	–65.08	3A	818	32
JUNIN AERO	875480	–34.55	–60.92	3A	983	39
LA RIOJA AERO.	872170	–29.38	–66.82	2B	361	14
LAGO ARGENTINO ARPT	879030	–50.33	–72.30	5C	200	8
MALARGUE AERO	875060	–35.50	–69.58	4B	285	11
MAR DEL PLATA AERO	876920	–37.93	–57.58	3A	879	35
MARCOS JUAREZ AERO	874670	–32.70	–62.15	3A	884	35
MENDOZA AERO	874180	–32.83	–68.78	3B	196	8
MONTE CASEROS AERO	873930	–30.27	–57.65	2A	1466	58
NEUQUEN AERO	877150	–38.95	–68.13	3B	194	8
PARANA AERO	873740	–31.78	–60.48	3A	1025	40
PASO DE LOS LIBRES	872890	–29.68	–57.15	2A	1492	59
POSADAS AERO.	871780	–27.37	–55.97	2A	1686	66
PRESIDENCIA ROQUE S	871490	–26.82	–60.45	2A	1054	41
RECONQUISTA AERO	872700	–29.18	–59.70	2A	1206	47
RESISTENCIA AERO	871550	–27.45	–59.05	2A	1335	53
RIO CUARTO AERO	874530	–33.12	–64.23	3A	827	33
RIO GALLEGOS AERO	879250	–51.62	–69.28	5B	253	10
RIO GRANDE B.A.	879340	–53.80	–67.75	6A	325	13
ROSARIO AERO	874800	–32.92	–60.78	3A	977	38
SALTA AERO	870470	–24.85	–65.48	3A	740	29
SAN ANTONIO OESTE A	877840	–40.78	–65.10	3B	242	10
SAN JUAN AERO	873110	–31.40	–68.42	3B	92	4
SAN JULIAN AERO	879090	–49.32	–67.75	5B	243	10

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
SAN LUIS AERO	874360	–33.27	–66.35	3B	617	24
SAN MARTIN	874160	–33.08	–68.42	3B	169	7
SAN RAFAEL AERO	875090	–34.58	–68.40	3B	336	13
SANTA ROSA AERO	876230	–36.57	–64.27	3A	695	27
SANTIAGO DEL ESTERO	871290	–27.77	–64.30	2B	577	23
SAUCE VIEJO AERO	873710	–31.70	–60.82	3A	991	39
TANDIL AERO	876450	–37.23	–59.25	3A	969	38
TARTAGAL AERO	870220	–22.65	–63.82	2A	1008	40
TRELEW AERO	878280	–43.20	–65.27	3B	183	7
TUCUMAN AERO	871210	–26.85	–65.10	2A	1078	42
USHUAIA AERO	879380	–54.80	–68.32	6A	525	21
VIEDMA AERO	877910	–40.85	–63.02	3B	353	14
VILLA REYNOLDS AERO	874480	–33.73	–65.38	3A	700	28
Armenia (ARM)						
AMASIA	376820	40.78	43.83	6A	599	24
SEVAN	377090	40.55	44.93	6A	498	20
YEREVAN/YEREVAN-ARA	377890	40.13	44.47	4B	342	13
Aruba (ABW)						
QUEEN BEATRIX AIRPO	789820	12.50	–70.02	0B	417	16
Australia (AUS)						
ADELAIDE AIRPORT	946720	–34.95	138.53	3B	446	18
ADELAIDE REGIONAL O	946750	–34.92	138.62	3A	552	22
ADELE ISLAND	942100	–15.52	123.15	0A	847	33
AIREYS INLET	948460	–38.45	144.10	3A	679	27
ALBANY AIRPORT	948020	–34.93	117.80	3C	806	32
ALBURY AEROPORT	958960	–36.07	146.95	3A	722	28
ALICE SPRINGS AIRPO	943260	–23.80	133.88	2B	296	12
AMBERLEY AMO	945680	–27.63	152.72	2A	859	34
APPLETHORPE GBHRS A	945530	–28.62	151.95	3A	784	31
ARARAT PRISON	948340	–37.28	142.98	4A	594	23
ARCHERFIELD AIRPORT	945750	–27.57	153.00	2A	1178	46
ARGYLE AERODROME	942170	–16.63	128.45	0B	725	29
AVALON AIRPORT	948540	–38.03	144.47	3A	564	22
BALLARAT AERODROME	948520	–37.52	143.78	4A	681	27
BANKSTOWN AIRPORT A	947650	–33.92	150.98	3A	911	36
BATCHELOR AERO	941250	–13.05	131.02	0A	1389	55
BATHURST AIRPORT AW	947290	–33.42	149.65	4A	654	26
BEGA AWS	959310	–36.67	149.82	3A	839	33
BENDIGO AIRPORT AWS	948550	–36.73	144.32	3A	582	23
BILOELA THANGOOL AI	943760	–24.48	150.57	2B	661	26
BIRDSVILLE POLICE S	944820	–25.90	139.35	2B	172	7
BOMBALA AWS	949290	–37.00	149.23	4A	660	26
BORROLOOLA	941520	–16.08	136.30	1A	935	37
BOULIA AIRPORT	943330	–22.92	139.90	1B	259	10
BOURKE AIRPORT AWS	947030	–30.03	145.95	2B	366	14
BOWEN AIRPORT	943660	–20.02	148.20	1A	974	38
BRAIDWOOD RACECOURS	949270	–35.43	149.78	4A	773	30
BRISBANE AERO	945780	–27.38	153.13	2A	1130	44
BROKEN HILL AIRPORT	946910	–32.00	141.47	3B	266	10
BROOME AIRPORT	942030	–17.95	122.23	0B	660	26
BUNDABERG AERO	943870	–24.90	152.32	2A	1015	40
BURKETOWN POST OFFI	942590	–17.75	139.55	1B	753	30
BUSSELTON AERO	956110	–33.68	115.40	3C	791	31
CAIRNS AERO	942870	–16.88	145.75	1A	2013	79
CAMDEN AIRPORT	947550	–34.03	150.68	3A	857	34
CANBERRA AIRPORT	949260	–35.30	149.20	4A	614	24
CANTERBURY RACECOUR	947660	–33.90	151.12	3A	1104	43
CAPE BORDA	948050	–35.75	136.58	3C	604	24
CAPE BRUNY LIGHTHOU	949670	–43.50	147.15	4A	1006	40
CAPE DON AWS	941290	–11.32	131.77	0A	1310	52
CAPE FOURCROY	941220	–11.78	130.02	0A	1845	73
CAPE GRIM B.A.P.S.	949540	–40.67	144.68	4A	946	37
CAPE JAFFA AWS	948130	–36.97	139.72	3C	569	22
CAPE LEEUWIN	946010	–34.37	115.13	3C	1017	40
CAPE MORETON LIGHTH	945940	–27.03	153.47	2A	1532	60
CAPE NATURALISTE	946000	–33.53	115.02	3C	834	33
CAPE NELSON LIGHTHO	948260	–38.43	141.55	3C	774	30
CAPE OTWAY LIGHTHOU	948420	–38.85	143.52	3A	954	38
CAPE SORELL	949740	–42.20	145.17	4A	1603	63
CAPE WESSEL AWS	941470	–11.02	136.75	0A	1365	54
CARNARVON AIRPORT	943000	–24.88	113.67	2B	211	8
CATO ISLAND	943940	–23.25	155.53	1A	814	32
CEDUNA AMO	946530	–32.13	133.70	3C	287	11
CENTRE ISLAND	942480	–15.75	136.80	0A	981	39
CERBERUS AWS	948980	–38.35	145.17	3A	807	32
CESSNOCK AIRPORT	957710	–32.78	151.33	3A	746	29
CHARLEVILLE AERO	945100	–26.42	146.27	2B	476	19
COBAR AIRPORT AWS	947100	–31.53	145.80	3B	405	16
COBAR MO	947110	–31.48	145.83	3B	405	16
COCONUT ISLAND	941820	–10.05	143.07	0A	1522	60
COFFS HARBOUR MO	947910	–30.32	153.12	3A	1649	65
COMBIENBAR	949140	–37.33	149.02	4A	971	38
CONDOBOLIN AIRPORT	957080	–33.07	147.22	3B	468	18
COOBER PEDY AIRPORT	954580	–29.03	134.72	2B	173	7
COOKTOWN MISSION	942830	–15.43	145.18	1A	1732	68
COOLANGATTA AIRPORT	945920	–28.17	153.50	2A	1710	67
COOMA AIRPORT AWS	949210	–36.30	148.97	4A	541	21
COONABARABRAN NAMOI	947280	–31.27	149.27	3A	826	33
CREAL REEF	943710	–20.53	150.38	1A	858	34
CUNDERDIN AIRFIELD	956250	–31.62	117.22	3A	371	15
CUNNAMULLA POST OFF	945000	–28.07	145.68	2B	384	15
CURTIN AERO	942040	–17.58	123.82	0B	752	30
DARWIN AIRPORT	941200	–12.42	130.88	0A	1730	68
DERBY AERO	952050	–17.37	123.67	0B	632	25
DEVONPORT AIRPORT	959600	–41.17	146.42	4A	792	31
DOUBLE ISLAND POINT	945840	–25.93	153.18	2A	1569	62
DUBBO AIRPORT AWS	957190	–32.22	148.57	3A	617	24
DUNNS HILL	948720	–37.88	145.33	4A	936	37
EAST SALE AIRPORT	949070	–38.10	147.13	3A	586	23
EDDYSTONE POINT	949830	–41.00	148.35	3A	804	32
EDITHBURGH AWS	948090	–35.12	137.73	3C	392	15
EILDON FIRE TOWER	948810	–37.22	145.83	4A	827	33
EMERALD AIRPORT	943630	–23.57	148.18	2B	646	25
ESPERANCE	946380	–33.83	121.88	3C	611	24
ESPERANCE AERO	956380	–33.68	121.83	3C	549	22
FALLS CREEK AWS	949030	–36.87	147.27	6A	1197	47

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
FLINDERS ISLAND AIR	949800	–40.10	148.00	3A	745	29
FLINDERS REEF	942900	–17.72	148.45	1A	945	37
FORBES AIRPORT	947150	–33.37	147.92	3A	558	22
FORREST	956460	–30.83	128.12	3B	199	8
FRANKSTON AWS	948710	–38.15	145.12	3A	773	30
GABO ISLAND	949330	–37.57	149.90	3A	958	38
GANNET CAY	943790	–21.97	152.47	1A	821	32
GAYNDAH POST OFFICE	945430	–25.63	151.62	2A	723	28
GEELONG AIRPORT	948570	–38.23	144.33	3A	564	22
GELANTIPY	949130	–37.22	148.27	4A	794	31
GEORGETOWN POST OFF	942750	–18.30	143.55	1A	812	32
GERALDTON AIRPORT	944030	–28.80	114.70	3A	443	17
GILES METEOROLOGICA	944610	–25.03	128.30	2B	271	11
GLADSTONE AIRPORT	943810	–23.87	151.22	2A	919	36
GLADSTONE RADAR	943800	–23.85	151.27	2A	919	36
GLEN INNES AIRPORT	945880	–29.68	151.70	4A	911	36
GOLD COAST SEAWAY	945800	–27.93	153.43	2A	1522	60
GOLDSTREAM	948640	–37.73	145.40	4A	889	35
GOONDIWINDI AIRPORT	945300	–28.52	150.32	2A	584	23
GOULBURN AIRPORT AW	957160	–34.82	149.73	4A	680	27
GOVE AIRPORT	941500	–12.28	136.82	1A	1437	57
GREEN ISLAND	952890	–16.77	145.97	1A	2315	91
GRIFFITH AWS	947050	–34.32	146.07	3B	407	16
HALLS CREEK AIRPORT	942120	–18.23	127.67	0B	586	23
HAMILTON AIRPORT	948290	–37.65	142.07	4A	667	26
HAY AWS	947010	–34.53	144.87	3B	398	16
HERON ISLAND RES ST	943860	–23.45	151.92	1A	876	34
HOBART AIRPORT	949750	–42.83	147.50	4A	495	19
HOBART ELLERSLIE RO	949700	–42.88	147.33	4A	589	23
HOLMES REEF	942890	–16.47	147.87	1A	1263	50
HOMEBUSH (OLYMPIC SITE)	957650	–33.85	151.07	3A	928	37
HUNTERS HILL	948780	–36.22	147.53	4A	934	37
JABIRU AIRPORT	941370	–12.67	132.90	0A	1450	57
JACUP	956360	–33.88	119.10	3B	429	17
JANDAKOT AERO	946090	–32.10	115.88	3A	838	33
KALGOORLIE-BOULDER	946370	–30.78	121.45	3B	275	11
KARRATHA AERO	953070	–20.72	116.77	1B	252	10
KARRATHA LEGENDRE I	943070	–20.37	116.85	1B	405	16
KATANNING	946290	–33.68	117.55	3A	480	19
KATOOMBA	947440	–33.72	150.28	4A	1390	55
KHANCOBAN	949190	–36.23	148.13	3A	961	38
KILMORE GAP	948600	–37.38	144.97	4A	699	28
KING ISLAND AIRPORT	948500	–39.88	143.88	4C	888	35
KING ISLAND CURRIE	948510	–39.93	143.85	3C	888	35
KUNUNURRA AERO	942160	–15.78	128.72	0B	779	31
KYANCUTTA	946570	–33.13	135.55	3B	300	12
LADY ELLIOT ISLAND	943880	–24.12	152.72	2A	1166	46
LAKE GRACE	946350	–33.12	118.47	3B	345	14
LANCELIN	956060	–31.02	115.32	3A	600	24
LATROBE VALLEY AIRP	948910	–38.22	146.47	3A	760	30
LAUNCESTON AIRPORT	949680	–41.53	147.20	4A	652	26
LAVERTON AERO	944490	–28.62	122.42	2B	246	10
LAVERTON AERODROME	948650	–37.87	144.75	3A	547	22
LEARMONTH AIRPORT	943020	–22.23	114.08	1B	235	9
LEINSTER AERO	954480	–27.85	120.70	2B	238	9
LEONORA POST OFFICE	944480	–28.88	121.33	2B	249	10
LIHOU REEF	942960	–17.12	152.00	1A	1026	40
LONGERENONG	958350	–36.67	142.30	3B	422	17
LONGREACH AERO	943460	–23.43	144.28	1B	418	16
LOOKOUT HILL	948350	–37.28	143.25	5A	675	27
LORD HOWE ISLAND AE	949950	–31.53	159.07	3A	1456	57
LOW ROCKY POINT (AWS)	959610	–42.98	145.50	4A	1922	76
LUCINDA POINT AWS	942950	–18.52	146.40	1A	2183	86
MAATSUYKER ISLAND L	949620	–43.65	146.27	4A	1377	54
MACKAY MO	943670	–21.12	149.22	2A	1563	62
MACQUARIE ISLAND	949980	–54.50	158.95	6A	947	37
MALLACOOTA	949350	–37.60	149.73	3A	1020	40
MANDURAH	946050	–32.52	115.72	3A	842	33
MANGALORE AWS COMPO	948740	–36.88	145.18	3A	574	23
MANGROVE MOUNTAIN A	957740	–33.28	151.22	3A	1059	42
MARION REEF	942980	–19.08	152.38	1A	858	34
MARLA POLICE STATIO	944770	–27.30	133.62	2B	229	9
MAROOCHYDORE AERO	945690	–26.60	153.10	2A	1687	66
MARYBOROUGH COMPOSI	945670	–25.52	152.72	2A	1070	42
MEEKATHARRA AIRPORT	944300	–26.62	118.55	2B	246	10
MELBOURNE	948680	–37.82	144.97	3A	635	25
MELBOURNE AIRPORT	948660	–37.67	144.85	3A	537	21
MILDURA AIRPORT	946930	–34.23	142.08	3B	280	11
MILINGIMBI	941400	–12.12	134.90	0A	1199	47
MOOMBA AIRPORT	954810	–28.10	140.20	2B	175	7
MOORABBIN AIRPORT	948700	–37.98	145.10	3A	724	29
MOREE	945270	–29.47	149.85	3A	588	23
MOREE AERO	955270	–29.48	149.83	3A	588	23
MORTLAKE AWS	948400	–38.07	142.77	4A	685	27
MORUYA HEADS PILOT	949370	–35.92	150.15	3A	1014	40
MOUNT BOYCE	947430	–33.62	150.27	4A	1184	47
MOUNT BULLER AWS	948940	–37.15	146.43	6A	1243	49
MOUNT GAMBIER AERO	948210	–37.73	140.78	3C	696	27
MOUNT ISA AERO	943320	–20.68	139.48	1B	446	18
MOUNT LAWLEY PERTH	946080	–31.92	115.87	3A	820	32
MT HOTHAM AWS	949060	–36.97	147.12	7	1336	53
MT LOFTY AWS	956780	–34.97	138.70	4C	651	26
MT MOORNAPA	959130	–37.75	147.13	4A	685	27
MT WELLINGTON	959790	–42.88	147.23	7	662	26
MUDGEE AIRPORT AWS	947270	–32.57	149.62	3A	709	28
NAMBOUR DPI	955720	–26.65	152.93	2A	1680	66
NEPTUNE ISLAND	948040	–35.33	136.12	3C	467	18
NEWCASTLE NOBBYS SI	947740	–32.92	151.78	3A	1130	44
NORAH HEAD LIGHTHOU	957700	–33.27	151.57	3A	1206	47
NORMANTON	942670	–17.67	141.08	0A	853	34
NORSEMAN	946390	–32.20	121.78	3B	305	12
NORTH EAST ISLAND	941510	–13.65	136.93	0A	963	38
NOWRA RAN AIR STATI	947500	–34.95	150.53	3A	1075	42
NULLARBOR ROADHOUSE	946510	–31.45	130.90	3B	265	10
NULLO MOUNTAIN AWS	947540	–32.73	150.23	4A	731	29
OAKEY AERO	945520	–27.42	151.73	3A	638	25

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
ONSLOW	943050	–21.63	115.12	1B	287	11	TUNNAK FIRE STATION	949600	–42.45	147.47	5A	611	24
OUSE FIRE STATION	949570	–42.48	146.72	4A	544	21	ULLADULLA AWS	949380	–35.35	150.48	3A	1254	49
PARABURDOO AERO	943160	–23.17	117.75	1B	267	10	URANDANGIE	943290	–21.60	138.30	1B	314	12
PARKES (MACARTHUR ST)	947170	–33.13	148.17	3A	634	25	VICTORIA RIVER DOWN	942320	–16.40	131.02	0B	743	29
PAYNES FIND	944040	–29.27	117.68	2B	279	11	WAGGA WAGGA AMO	949100	–35.17	147.45	3A	574	23
PEARCE RAAF	946120	–31.67	116.02	3A	660	26	WALGETT AIRPORT	957150	–30.03	148.12	2B	507	20
PENRITH	947630	–33.72	150.68	3A	883	35	WANGARATTA AERO	948890	–36.42	146.30	3A	679	27
PERTH AIRPORT	946100	–31.93	115.97	3A	763	30	WARBURTO POINT	946660	–34.00	137.53	3B	351	14
POINT WILSON	948470	–38.10	144.53	3A	561	22	WARRNAMBOOL AIRPORT	948320	–38.28	142.43	4C	775	30
PORT ARTHUR (PALM.)	949780	–43.17	147.83	4A	1165	46	WARWICK	945550	–28.20	152.10	3A	728	29
PORT FAIRY AWS	948300	–38.40	142.23	3A	801	32	WEIPA AERO	941700	–12.68	141.92	0A	1883	74
PORT HEDLAND AIRPOR	943120	–20.37	118.63	1B	277	11	WILLIAMTOWN RAAF	947760	–32.80	151.83	3A	1144	45
PORT KEATS AWS AUT	941110	–14.23	129.45	0A	1491	59	WILLIS ISLAND	942990	–16.30	149.97	1A	1029	41
PORT MACQUARIE AIRP	947860	–31.43	152.85	3A	1522	60	WILSONS PROMONTORY	948930	–39.12	146.42	3C	1088	43
PORTLAND CASHMORE A	948280	–38.32	141.47	4C	812	32	WINDORAH	944880	–25.42	142.65	2B	269	11
PROSERPINE AIRPORT	943650	–20.50	148.53	2A	1455	57	WINTON (POST OFFICE)	943390	–22.38	143.03	1B	397	16
QUILPIE AIRPORT	944940	–26.62	144.25	2B	365	14	WONTHAGGI COMPOSITE	958810	–38.60	145.58	3A	954	38
RAVENSTHORPE HOPETO	956350	–33.93	120.13	3C	519	20	WOOMERA AERODROME	946590	–31.15	136.82	3B	184	7
REDESDALE	948590	–37.02	144.53	4A	697	27	WYNDHAM	942140	–15.48	128.12	0B	759	30
RENMARK	946870	–34.17	140.75	3B	259	10	WYNYARD AIRPORT	959570	–41.00	145.73	4C	960	38
RHYLL (AWS)	948920	–38.45	145.30	3A	829	33	YEPPOON AWS	943730	–23.13	150.75	2A	1220	48
RICHMOND POST OFFIC	943400	–20.73	143.13	1B	489	19	YOUNG AIRPORT	947120	–34.25	148.25	3A	668	26
RICHMOND RAAF	957530	–33.60	150.78	3A	842	33	YULARA AERO	944620	–25.20	130.98	2B	333	13
ROCKHAMPTON AERO	943740	–23.38	150.48	2A	791	31	**Austria (AUT)**						
ROEBOURNE POST OFFI	943090	–20.78	117.15	0B	296	12	AIGEN IM ENNSTAL	111570	47.53	14.13	6A	1300	51
ROMA AIRPORT	945150	–26.55	148.78	2A	616	24	ALLENTSTEIG	110190	48.68	15.37	5A	629	25
ROTTNEST ISLAND	946020	–32.02	115.50	3A	629	25	ALPINZENTRUM RUDOLF	111380	47.13	12.63	7	1130	44
RUNDLE ISLAND	943780	–23.53	151.28	2A	863	34	AMSTETTEN	110180	48.10	14.90	5A	989	39
SCONE AIRPORT	957580	–32.03	150.83	3A	708	28	ARRIACH	112750	46.73	13.85	6A	1322	52
SCORESBY RESEARCH	958670	–37.87	145.25	3A	936	37	BAD RADKERSBURG	112480	46.68	15.98	5A	943	37
SHARK BAY (DENHAM)	944020	–25.92	113.52	2B	221	9	BISCHOFSHOFEN	111410	47.40	13.22	5A	1314	52
SHEOAKS AWS	948630	–37.90	144.12	4A	613	24	BREGENZ	111010	47.50	9.75	5A	1784	70
SHEPPARTON AIRPORT	948750	–36.43	145.40	3A	504	20	BRENNER	111280	47.00	11.52	6A	933	37
SMITHTON AERODROME	949530	–40.83	145.08	4C	1105	44	DELLACH IM DRAUTAL	112700	46.73	13.08	5A	1073	42
SOUTHERN CROSS	946340	–31.23	119.33	3B	323	13	DORNBIRN	113020	47.43	9.73	5A	1393	55
SOUTHERN CROSS AIRF	956340	–31.23	119.35	3B	323	13	EISENSTADT	111900	47.85	16.53	5A	610	24
ST LAWRENCE POST OF	943690	–22.35	149.53	2A	990	39	FELDKIRCH	111050	47.27	9.62	5A	1393	55
STRAHAN AERODROME	949560	–42.15	145.28	4A	2101	83	FEUERKOGEL	111550	47.82	13.72	7	1361	54
SWAN HILL AERODROME	948430	–35.38	143.53	3B	337	13	FREISTADT	110150	48.50	14.50	5A	779	31
SWANBOURNE	946140	–31.95	115.77	3A	820	32	GMUNDEN	111540	47.90	13.80	5A	1416	56
SYDNEY AIRPORT AMO	947670	–33.93	151.18	3A	1104	43	GRAZ-THALERHOF-FLUG	112400	47.00	15.43	5A	847	33
SYDNEY REGIONAL OFF	947680	–33.85	151.20	3A	1253	49	GUMPOLDSKIRCHEN	110820	48.03	16.28	5A	604	24
TAMWORTH AIRPORT AW	957620	–31.07	150.83	3A	676	27	HAHNENKAMM/EHRENBAC	111350	47.42	12.37	7	1242	49
TELFER AERO	943190	–21.72	122.22	1B	302	12	HOHE WAND/HOCHKOGEL	113850	47.82	16.03	6A	745	29
TENNANT CREEK MET O	942380	–19.63	134.18	1B	446	18	INNSBRUCK-FLUGHAFEN	111200	47.27	11.35	5A	914	36
TEWANTIN RSL PARK	945700	–26.38	153.03	2A	1678	66	ISCHGL/IDALPE	113100	46.98	10.32	7	789	31
THREDBO (CRACKENBACK)	959090	–36.50	148.28	7	975	38	JAUERLING	110240	48.33	15.33	6A	646	25
TINDAL RAAF	941310	–14.52	132.37	0A	1013	40	KLAGENFURT-FLUGHAFE	112310	46.65	14.33	5A	905	36
TOOWOOMBA AIRPORT	955510	–27.55	151.92	3A	937	37	KLEINZICKEN	111920	47.20	16.33	5A	741	29
TOWN OF 1770	943840	–24.15	151.88	2A	1104	43	KOETSCHACH-MAUTHEN	112550	46.68	13.00	5A	1427	56
TOWNSVILLE AERO	942940	–19.25	146.77	1A	1042	41	KREMSMUENSTER	110120	48.05	14.13	5A	955	38
TROUGHTON ISLAND	941020	–13.75	126.15	0A	955	38	KUFSTEIN	111300	47.58	12.17	5A	1440	57
TUGGERANONG ISABELL	949250	–35.42	149.10	4A	733	29	LANDECK	111120	47.13	10.57	5A	913	36

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation	
					mm	in.
LANGENLOIS	110750	48.47	15.70	5A	574	23
LASSNITZHOEHE	112920	47.07	15.58	5A	869	34
LIENZ	112040	46.83	12.82	5A	1207	48
LILIENFELD/TARSCHBE	110780	48.03	15.58	5A	838	33
LINZ/HOERSCHING-FLU	110100	48.23	14.18	5A	955	38
LINZ/STADT	110600	48.30	14.28	5A	840	33
LITSCHAU	110210	48.95	15.03	6A	691	27
LUNZ	111700	47.85	15.07	6A	1229	48
MARIAPFARR	113480	47.15	13.75	6A	980	39
MARIAZELL	111720	47.77	15.32	6A	1066	42
MATTSEE	111520	47.98	13.10	5A	1400	55
MOENICHKIRCHEN	111850	47.52	16.03	6A	855	34
MURAU	112800	47.12	14.18	6A	962	38
NEUSIEDL	111940	47.95	16.85	5A	605	24
OBERTAUERN	111490	47.25	13.57	7	976	38
POYSDORF	110320	48.67	16.63	5A	527	21
PUCHBERG	113820	47.78	15.90	5A	991	39
RAMSAU/DACHSTEIN	113510	47.43	13.63	6A	1349	53
RAX/SEILBAHN-BERGST	111800	47.72	15.78	7	1039	41
REICHENAU/RAX	113800	47.70	15.83	5A	1039	41
RETZ	110220	48.77	15.95	5A	512	20
SALZBURG-FLUGHAFEN	111500	47.80	13.00	5A	1174	46
SCHMITTENHOEHE	113400	47.33	12.73	7	1364	54
SCHOECKL	112410	47.20	15.47	7	917	36
ST. MICHAEL/LEOBEN	111740	47.33	15.00	5A	1027	40
ST. POELTEN	110280	48.18	15.62	5A	690	27
ST. WOLFGANG	113570	47.73	13.45	5A	1465	58
STIFT ZWETTL	110200	48.62	15.20	6A	744	29
TULLN	110300	48.32	16.12	5A	606	24
VILLACH	112130	46.62	13.88	5A	1322	52
VIRGEN	112520	47.00	12.45	6A	921	36
WARTH	113080	47.25	10.18	6A	1500	59
WIEN/CITY	110340	48.20	16.37	4A	604	24
WIEN/HOHE WARTE	110350	48.25	16.37	5A	628	25
WIEN/SCHWECHAT-FLUG	110360	48.12	16.57	5A	558	22
WIENER NEUSTADT	111820	47.83	16.22	5A	745	29
WINDISCHGARSTEN	113550	47.73	14.33	5A	1190	47
ZELL AM SEE	111440	47.33	12.80	5A	1409	55
ZELTWEG	111650	47.20	14.75	6A	847	33
Azerbaijan (AZE)						
LANKARAN	379850	38.73	48.83	4A	1167	46
ZAKATALA	375750	41.67	46.65	4A	975	38
Bahamas (BHS)						
NASSAU AIRPORT NEW	780730	25.05	–77.47	1A	1334	53
SETTLEMENT POINT	994390	26.68	–79.00	1A	1281	50
Bahrain (BHR)						
BAHRAIN (INT. AIRPORT)	411500	26.27	50.65	0B	57	2
Barbados (BRB)						
GRANTLEY ADAMS	789540	13.07	–59.48	0A	1155	45
Belarus (BLR)						
BARANOVICHI	269410	53.12	26.00	6A	610	24
BOBRUISK	269610	53.22	29.18	6A	622	24
BREST	330080	52.12	23.68	5A	601	24
GOMEL	330410	52.40	30.95	6A	591	23
GRODNO	268250	53.60	24.05	6A	608	24
KOSTUCKOVICHI	268870	53.35	32.07	6A	585	23
LEPEL	266590	54.88	28.70	6A	672	26
LIDA	268320	53.85	25.32	6A	655	26
LYNTUPY	266450	55.05	26.32	6A	678	27
MINSK	268500	53.93	27.63	6A	673	27
MOGILEV	268630	53.95	30.07	6A	623	25
MOZYR	330360	51.95	29.17	6A	615	24
ORSHA	267630	54.50	30.42	6A	617	24
PINSK	330190	52.12	26.12	6A	575	23
SLUTSK	269510	53.03	27.55	6A	599	24
VERHNEDVINSK	265540	55.82	27.95	6A	614	24
VITEBSK	266660	55.17	30.22	6A	662	26
ZHITCKOVICHI	330270	52.22	27.87	6A	663	26
Belgium (BEL)						
ANTWERPEN/DEURNE	064500	51.20	4.47	4A	792	31
BEAUVECHAIN	064580	50.75	4.77	5A	807	32
BIERSET	064780	50.65	5.45	5A	899	35
BRUXELLES NATIONAL	064510	50.90	4.53	4A	784	31
CHARLEROI/GOSSELIES	064490	50.47	4.45	5A	883	35
CHIEVRES	064320	50.57	3.83	5A	767	30
ELSENBORN	064960	50.47	6.18	6A	1092	43
FLORENNES	064560	50.23	4.65	5A	984	39
GENT/INDUSTRIE-ZONE	064310	51.18	3.82	4A	772	30
KLEINE BROGEL	064790	51.17	5.47	5A	829	33
KOKSIJDE	064000	51.08	2.65	4A	697	27
LIEGE	064324	50.63	5.45	5A	899	35
OOSTENDE (AIRPORT)	064070	51.20	2.87	5A	755	30
OOSTENDE (PIER)	064080	51.23	2.92	4A	755	30
SEMMERZAKE	064280	50.93	3.67	4A	810	32
ST. TRUIDEN (BAFB)	064700	50.80	5.20	5A	823	32
ST-HUBERT	064760	50.03	5.40	5A	998	39
UCCLE	064470	50.80	4.35	4A	829	33
Belize (BLZ)						
BELIZE/PHILLIP GOLD	785830	17.53	–88.30	0A	1944	77
Benin (BEN)						
BOHICON	653380	7.17	2.07	0A	1145	45
COTONOU	653440	6.35	2.38	0A	1297	51
KANDI	653060	11.13	2.93	0A	1011	40
NATITINGOU	653190	10.32	1.38	0A	1242	49
PARAKOU	653300	9.35	2.62	0A	1177	46
SAVE	653350	8.03	2.47	0A	1116	44
Bermuda (BMU)						
BERMUDA INTL	780160	32.37	–64.68	2A	1456	57
Bolivia (BOL)						
COCHABAMBA	852230	–17.42	–66.18	3B	472	19
LA PAZ/ALTO	852010	–16.52	–68.18	5A	535	21
VIRU-VIRU	852440	–17.63	–63.13	1A	1365	54
Bosnia and Herzegovina (BIH)						
BANJA LUKA	132420	44.78	17.22	4A	1056	42
BIHAC	132280	44.82	15.88	4A	1252	49
BJELASNICA	146520	43.72	18.27	7	1155	45

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
MOSTAR	133480	43.33	17.78	3A	1632	64
SARAJEVO/BUTMIR	133530	43.82	18.33	5A	993	39
SARAJEVO-BJELAVE	146540	43.87	18.43	5A	921	36
Botswana (BWA)						
SERETSE KHAMA INTER	682400	–24.55	25.92	2B	449	18
Brazil (BRA)						
ANAPOLIS (BRAZ-AFB)	834190	–16.23	–48.97	2A	1584	62
ARACAJU (AEROPORTO)	830950	–10.98	–37.07	0A	1489	59
BELEM (AEROPORTO)	821930	–1.38	–48.48	0A	2958	116
BELO HORIZONTE	835870	–19.93	–43.93	2A	1477	58
BELO HORIZONTE (AERO)	835830	–19.85	–43.95	2A	1477	58
BOA VISTA (AEROPORTO)	820220	2.83	–60.70	0A	1547	61
BRASILIA (AEROPORTO)	833780	–15.87	–47.93	2A	1515	60
CAMPINAS (AEROPORTO)	837210	–23.00	–47.13	2A	1354	53
CAMPO GRANDE (AERO)	836120	–20.47	–54.67	1A	1498	59
CARAVELAS (AEROPORTO)	834970	–17.63	–39.25	1A	1472	58
CUIABA (AEROPORTO)	833620	–15.65	–56.10	0A	1346	53
CURITIBA (AEROPORTO)	838400	–25.52	–49.17	3A	1604	63
EDUARDO GOMES INTL	821110	–3.03	–60.05	0A	2282	90
FERNANDO DE NORONHA	824000	–3.85	–32.42	0A	1029	41
FLORIANOPOLIS (AERO)	838990	–27.67	–48.55	2A	1578	62
FORTALEZA (AEROPORTO)	823980	–3.78	–38.53	0A	1628	64
FOZ DO IGUACU (AERO)	838270	–25.52	–54.58	2A	1788	70
GALEAO	837460	–22.82	–43.25	1A	1397	55
GOIANIA (AEROPORTO)	834240	–16.63	–49.22	1A	1628	64
GUARULHOS	837753	–23.43	–46.47	2A	1472	58
LONDRINA (AEROPORTO)	837680	–23.33	–51.13	2A	1551	61
MACAPA	820980	0.03	–51.05	0A	2733	108
MACEIO (AEROPORTO)	829930	–9.52	–35.78	1A	1627	64
MANAUS (AEROPORTO)	823320	–3.15	–59.98	0A	2282	90
NATAL AEROPORTO	825990	–5.92	–35.25	0A	1306	51
PORTO ALEGRE (AERO)	839710	–30.00	–51.18	2A	1353	53
PORTO VELHO (AERO)	828240	–8.77	–63.92	0A	2230	88
RECIFE (AEROPORTO)	828990	–8.07	–34.85	0A	2353	93
RIO BRANCO	829170	–10.00	–67.80	1A	1451	57
RIO DE JANEIRO (AERO)	837550	–22.90	–43.17	1A	1154	45
SALVADOR (AEROPORTO)	832480	–12.90	–38.33	0A	1804	71
SANTAREM-AEROPORTO	822440	–2.43	–54.72	0A	2312	91
SAO LUIZ (AEROPORTO)	822810	–2.60	–44.23	0A	1982	78
SAO PAULO (AEROPORTO)	837800	–23.62	–46.65	2A	1511	59
TERESINA (AEROPORTO)	825790	–5.05	–42.82	0A	1392	55
UBERABA	835760	–19.78	–47.97	2A	1631	64
VITORIA (AEROPORTO)	836490	–20.27	–40.28	1A	1289	51
British Indian Ocean Territory (IOT)						
DIEGO GARCIA NAF	619670	–7.30	72.40	0A	2026	80
Brunei (BRN)						
BRUNEI AIRPORT	963150	4.93	114.93	0A	2922	115
Bulgaria (BGR)						
BOTEV VRAH (TOP/SOMMET)	156270	42.67	24.83	7	884	35
BURGAS	156550	42.48	27.48	4A	588	23
CHERNI VRAH (TOP/SOMMET)	156130	42.58	23.27	7	775	30
CHIRPAN	156350	42.20	25.33	4A	589	23
ELHOVO	156420	42.18	26.57	4A	541	21
IVAILO	156280	42.22	24.33	4A	515	20
KALIAKPA	155620	43.37	28.47	4A	422	17
KURDJALI	157300	41.65	25.37	4A	633	25
KUSTENDIL	156010	42.27	22.77	4A	668	26
LOM	155110	43.82	23.25	4A	553	22
LOVETCH	155250	43.13	24.72	4A	663	26
MOURGASH	156000	42.83	23.67	7	714	28
MUSSALA (TOP/SOMMET)	156150	42.18	23.58	8	971	38
PLEVEN	155260	43.42	24.60	4A	584	23
PLOVDIV	156250	42.13	24.75	4A	518	20
RAZGRAD	155490	43.52	26.53	4A	582	23
ROUSSE	155350	43.85	25.95	4A	583	23
SANDANSKI	157120	41.52	23.27	4A	539	21
SHABLA	155610	43.53	28.53	4A	408	16
SHUMEN	155440	43.27	26.93	4A	559	22
SLIVEN	156400	42.67	26.32	4A	559	22
SOFIA (OBSERV.)	156140	42.65	23.38	5A	612	24
SVICHTOV	155330	43.62	25.35	4A	534	21
SVILENGRAD	157410	41.77	26.20	4A	577	23
VARNA	155520	43.20	27.92	4A	490	19
VELIKO TARNOVO	155300	43.08	25.65	4A	655	26
VIDIN	155020	43.82	22.88	4A	544	21
VRATZA	155050	43.20	23.53	4A	754	30
Burkina Faso (BFA)						
BOBO-DIOULASSO	655100	11.17	–4.32	0A	1033	41
BOROMO	655160	11.75	–2.93	0A	883	35
DORI	655010	14.03	–0.03	0B	451	18
OUAGADOUGOU	655030	12.35	–1.52	0B	768	30
OUAHIGOUYA	655020	13.57	–2.42	0B	618	24
Cape Verde (CPV)						
SAL	085940	16.73	–22.95	1B	219	9
Chad (TCD)						
NDJAMENA	647000	12.13	15.03	0B	507	20
Chile (CHL)						
ANTOFAGASTA	854420	–23.43	–70.45	3C	23	1
ARICA	854060	–18.47	–70.17	3B	24	1
BALMACEDA	858740	–45.92	–71.70	6A	600	24
CONCEPCION	856820	–36.77	–73.07	3C	1286	51
FARO EVANGELISTAS	859300	–52.40	–75.10	6A	1267	50
IQUIQUE	854180	–20.53	–70.18	3B	6	0
ISLA DIEGO RAMIREZ	859720	–56.50	–68.67	6A	1088	43
LA SERENA	854880	–29.92	–71.20	3C	80	3
PUDAHUEL	855740	–33.38	–70.78	3C	324	13
PUERTO MONTT	857990	–41.43	–73.10	4A	1742	69
PUNTA ARENAS	859340	–53.00	–70.97	6A	386	15
TEMUCO	857430	–38.75	–72.63	4C	1475	58
China (CHN)						
ABAG QI	531920	44.02	114.95	7	242	10
AIHUI	504680	50.25	127.45	7	559	22
AKQI	517110	40.93	78.45	6B	187	7
ALAR	517300	40.50	81.05	5B	44	2
ALTAY	510760	47.73	88.08	7	188	7
ANDA	508540	46.38	125.32	7	429	17

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
ANDIR	518480	37.93	83.65	5B	21	1	DATONG	534870	40.10	113.33	6B	376	15
ANKANG	572450	32.72	109.03	3A	834	33	DAWU	561670	30.98	101.12	5A	596	23
ANQING	584240	30.53	117.05	3A	1370	54	DEGE	561440	31.80	98.57	5A	613	24
ANYANG	538980	36.05	114.40	4B	569	22	DELINGHA	527370	37.37	97.37	6B	159	6
ARXAN	507270	47.17	119.93	8	451	18	DENGQEN	561160	31.42	95.60	7	636	25
BACHU	517160	39.80	78.57	4B	52	2	DEQEN	564440	28.45	98.88	6A	655	26
BAILING-MIAO	533520	41.70	110.43	7	249	10	DEZHOU	547140	37.43	116.32	4A	571	22
BAINGOIN	552790	31.37	90.02	7	304	12	DINGHAI	584770	30.03	122.12	3A	1321	52
BAISE	592110	23.90	106.60	2A	1090	43	DINGTAO	549090	35.07	115.57	4A	687	27
BALGUNTAY	514670	42.67	86.33	6B	193	8	DIWOPU	514635	43.90	87.47	6B	258	10
BAODING	546020	38.85	115.57	4B	536	21	DONGFANG	598380	19.10	108.62	1A	935	37
BAOJI	570160	34.35	107.13	4A	690	27	DONGSHENG	535430	39.83	109.98	6B	393	15
BAOQING	508880	46.32	132.18	7	521	21	DONGTAI	582510	32.85	120.28	4A	1036	41
BAOSHAN	567480	25.12	99.18	3A	961	38	DULAN	528360	36.30	98.10	7	201	8
BARKAM	561720	31.90	102.23	5A	770	30	DUNHUA	541860	43.37	128.20	7	634	25
BATANG	562470	30.00	99.10	4B	473	19	DUNHUANG	524180	40.15	94.68	5B	38	1
BAYAN MOD	524950	40.75	104.50	6B	89	3	DUOLUN	542080	42.18	116.47	7	366	14
BAYANBULAK	515420	43.03	84.15	8	265	10	DUSHAN	579220	25.83	107.55	3A	1329	52
BAYTIK SHAN	512880	45.37	90.53	7	165	6	EJIN QI	522670	41.95	101.07	5B	31	1
BEIHAI	596440	21.48	109.10	2A	1717	68	EMEI SHAN	563850	29.52	103.33	7	1863	73
BEIJING	545110	39.93	116.28	4A	553	22	ENSHI	574470	30.28	109.47	3A	1470	58
BENGBU	582210	32.95	117.37	3A	904	36	ERENHOT	530680	43.65	112.00	7	136	5
BENXI	543460	41.32	123.78	6A	812	32	FANGXIAN	572590	32.03	110.77	4A	854	34
BIJIE	577070	27.30	105.23	4A	882	35	FENGJIE	573480	31.02	109.53	3A	1142	45
BINHAI	545273	39.12	117.33	4A	556	22	FENGNING	543080	41.22	116.63	6A	463	18
BOXIAN	581020	33.88	115.77	4A	802	32	FEZXZAN	549290	35.25	117.95	4A	863	34
BUGT	506320	48.77	121.92	7	479	19	FOGANG	590870	23.87	113.53	2A	2198	87
BUGT	542260	42.33	120.70	6B	420	17	FUDING	587540	27.33	120.20	3A	1677	66
CANGZHOU	546160	38.33	116.83	4A	613	24	FUJIN	507880	47.23	131.98	7	513	20
CHANG DAO	547510	37.93	120.72	4A	586	23	FUYANG	582030	32.87	115.73	3A	876	34
CHANGBAI	543860	41.35	128.17	7	692	27	FUYUN	510870	46.98	89.52	7	167	7
CHANGCHUN	541610	43.90	125.22	6A	580	23	FUZHOU	588470	26.08	119.28	2A	1352	53
CHANGDE	576620	29.05	111.68	3A	1303	51	GANGCA	527540	37.33	100.13	7	380	15
CHANGLING	540490	44.25	123.97	6A	457	18	GANYU	580400	34.83	119.13	4A	941	37
CHANGSHA	576870	28.23	112.87	3A	1426	56	GANZHOU	579930	25.87	115.00	2A	1426	56
CHANGTING	589110	25.85	116.37	3A	1734	68	GAOYAO	592780	23.05	112.47	2A	1645	65
CHAOYANG	543240	41.55	120.45	5A	478	19	GARZE	561460	31.62	100.00	6A	635	25
CHENGDE	544230	40.98	117.95	5A	521	21	GENGMA	569460	23.55	99.40	2A	1362	54
CHENGDU	562940	30.67	104.02	3A	921	36	GOLMUD	528180	36.42	94.90	6B	41	2
CHENGSHANTOU	547760	37.40	122.68	4A	751	30	GUAIZIHU	523780	41.37	102.37	5B	34	1
CHENZHOU	579720	25.80	113.03	2A	1487	59	GUANGCHANG	588130	26.85	116.33	2A	1719	68
CHIFENG	542180	42.27	118.97	6B	354	14	GUANGHUA	572650	32.38	111.67	3A	846	33
CHONGQING	575160	29.58	106.47	3A	1101	43	GUANGNAN	590070	24.07	105.07	3A	1037	41
CHUXIONG	567680	25.02	101.52	3A	788	31	GUANGZHOU	592870	23.17	113.33	2A	1726	68
DA XIAN	573280	31.20	107.50	3A	1208	48	GUILIN	579570	25.33	110.30	2A	1830	72
DACHEN DAO	586660	28.45	121.88	3A	1325	52	GUIPING	592540	23.40	110.08	2A	1670	66
DALI	567510	25.70	100.18	3C	1055	42	GUIYANG	578160	26.58	106.73	3A	1166	46
DALIAN	546620	38.90	121.63	5A	633	25	GUSHI	582080	32.17	115.67	3A	1081	43
DANDONG	544970	40.05	124.33	5A	969	38	HAIKOU	597580	20.03	110.35	1A	1662	65
DANXIAN	598450	19.52	109.58	1A	1803	71	HAILAR	505270	49.22	119.75	7	346	14
DAOCHENG	563570	29.05	100.30	6A	623	25	HAILS	532310	41.45	106.38	6B	110	4
DA-QAIDAM	527130	37.85	95.37	7	86	3	HAILUN	507560	47.43	126.97	7	551	22
DARLAG	560460	33.75	99.65	7	546	22	HAIYANG	548630	36.77	121.17	4A	778	31

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
HAIYANG DAO	545870	39.05	123.22	4A	788	31	KORLA	516560	41.75	86.13	5B	53	2
HALIUT	533360	41.57	108.52	6B	200	8	KUANDIAN	544930	40.72	124.78	6A	1100	43
HAMI	522030	42.82	93.52	5B	36	1	KUNMING	567780	25.02	102.68	3C	1004	40
HANGZHOU	584570	30.23	120.17	3A	1380	54	KUOCANG SHAN	586530	28.82	120.92	5A	2097	83
HANZHONG	571270	33.07	107.03	4A	900	35	KUQA	516440	41.72	82.95	5B	62	2
HARBIN	509530	45.75	126.77	7	527	21	LANCANG	569540	22.57	99.93	2A	1639	65
HECHI	590230	24.70	108.05	2A	1471	58	LANGZHONG	573060	31.58	105.97	3A	1039	41
HEFEI	583210	31.87	117.23	3A	984	39	LANZHOU	528890	36.05	103.88	5B	317	12
HENAN	560650	34.73	101.60	7	597	24	LENGHU	526020	38.83	93.38	7	17	1
HEQU	535640	39.38	111.15	5B	418	16	LETING	545390	39.43	118.90	5A	638	25
HEYUAN	592930	23.80	114.73	2A	1922	76	LHASA	555910	29.67	91.13	5B	440	17
HEZE/CAOZHOU	549060	35.25	115.43	4A	646	25	LHUNZE	556960	28.42	92.47	6B	269	11
HEZUO	560800	35.00	102.90	7	549	22	LIAN XIAN	590720	24.78	112.38	2A	1578	62
HOBOKSAR	511560	46.78	85.72	7	136	5	LIANGPING	574260	30.68	107.80	3A	1301	51
HOHHOT	534630	40.82	111.68	6B	400	16	LIANPING	590960	24.37	114.48	2A	1781	70
HONG KONG INTERNATI	450070	22.32	113.92	1A	1894	75	LIJING	566510	26.83	100.47	3C	954	38
HONG KONG OBSERVATO	450050	22.30	114.17	2A	2225	88	LINCANG	569510	23.95	100.22	3A	1187	47
HOTAN	518280	37.13	79.93	4B	35	1	LINDONG	540270	43.98	119.40	6B	370	15
HUA SHAN	570460	34.48	110.08	6A	875	34	LINGLING	578660	26.23	111.62	3A	1352	53
HUADE	533910	41.90	114.00	7	319	13	LINGXIAN	547150	37.33	116.57	4B	522	21
HUADIAN	542730	42.98	126.75	7	743	29	LINHAI	586600	28.85	121.13	3A	1778	70
HUAILAI	544050	40.40	115.50	5B	387	15	LINHE	535130	40.77	107.40	5B	135	5
HUAJIALING	529960	35.38	105.00	7	513	20	LINJIANG	543740	41.72	126.92	6A	837	33
HUANG SHAN	584370	30.13	118.15	5A	2317	91	LINXI	541150	43.60	118.07	6B	368	14
HUILI	566710	26.65	102.25	3C	1134	45	LINYI	549380	35.05	118.35	4A	870	34
HUIMIN	547250	37.50	117.53	4A	585	23	LISHI	537640	37.50	111.10	5A	500	20
HUIZE	566840	26.42	103.28	3A	776	31	LISHUI	586460	28.45	119.92	3A	1371	54
HULIN	509830	45.77	132.97	7	556	22	LITANG	562570	30.00	100.27	7	712	28
HUMA	503530	51.72	126.65	7	467	18	LIUZHOU	590460	24.35	109.40	2A	1388	55
HUOSHAN	583140	31.40	116.33	3A	1339	53	LIYANG	583450	31.43	119.48	3A	1144	45
JARTAI	535020	39.78	105.75	5B	103	4	LONGKOU	547530	37.62	120.32	4A	618	24
JARUD QI	540260	44.57	120.90	6B	386	15	LONGYAN	589270	25.10	117.02	2A	1713	67
JIAN	543770	41.10	126.15	2A	942	37	LONGZHOU	594170	22.37	106.75	2A	1380	54
JIAN	577990	27.12	114.97	6A	1477	58	LU SHAN	585060	29.58	115.98	4A	1965	77
JIANGCHENG	569770	22.62	101.82	2A	2229	88	LUODIAN	579160	25.43	106.77	2A	1150	45
JIANGLING	574760	30.33	112.18	3A	1083	43	LUSHI	570670	34.05	111.03	4A	636	25
JIEXIU	538630	37.03	111.92	5B	498	20	LUSI	582650	32.07	121.60	3A	1037	41
JINAN	548230	36.60	117.05	4A	733	29	LUXI	568860	24.53	103.77	3A	957	38
JINGDEZHEN	585270	29.30	117.20	3A	1694	67	LUZHOU	576020	28.88	105.43	3A	1152	45
JINGHE	513340	44.62	82.90	6B	96	4	MACHENG	573990	31.18	114.97	3A	1216	48
JINGHONG	569590	22.00	100.78	1A	1173	46	MADOI	560330	34.92	98.22	8	309	12
JINING	534800	41.03	113.07	7	361	14	MANDAL	531490	42.53	110.13	6B	168	7
JINZHOU	543370	41.13	121.12	5A	581	23	MANGNAI	518860	38.25	90.85	7	49	2
JIULONG	564620	29.00	101.50	5A	907	36	MAZONG SHAN	523230	41.80	97.03	7	76	3
JIUQUAN	525330	39.77	98.48	5B	85	3	MEI XIAN	591170	24.30	116.12	2A	1509	59
JIUXIAN SHAN	589310	25.72	118.10	4A	1720	68	MENGDING	569450	23.57	99.08	2A	1519	60
JIXI	509780	45.28	130.95	7	546	21	MENGJIN	570710	34.82	112.43	4A	603	24
JURH	532760	42.40	112.90	6B	213	8	MENGLA	569690	21.50	101.58	2A	1522	60
KABA HE	510530	48.05	86.35	6B	176	7	MENGSHAN	590580	24.20	110.52	2A	1691	67
KANGDING	563740	30.05	101.97	5A	801	32	MENGZI	569850	23.38	103.38	2A	855	34
KARAMAY	512430	45.60	84.85	6B	104	4	MIANYANG	561960	31.45	104.73	3A	925	36
KASHI	517090	39.47	75.98	4B	62	2	MINFENG	518390	37.07	82.72	5B	41	2
KESHAN	506580	48.05	125.88	7	486	19	MINQIN	526810	38.63	103.08	5B	111	4

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
MOHE	501360	52.13	122.52	8	414	16	SHANWEI	595010	22.78	115.37	2A	1806	71
MUDANJIANG	540940	44.57	129.60	7	535	21	SHAOGUAN	590820	24.80	113.58	2A	1493	59
NAGQU	552990	31.48	92.07	7	424	17	SHAOWU	587250	27.33	117.47	3A	1793	71
NANCHANG	586060	28.60	115.92	3A	1523	60	SHAOYANG	577660	27.23	111.47	3A	1303	51
NANCHENG	587150	27.58	116.65	3A	1649	65	SHENG SHANG	584730	30.72	122.82	3A	1431	56
NANCHONG	574110	30.80	106.08	3A	1026	40	SHENGSI	584720	30.73	122.45	3A	987	39
NANJING	582380	32.00	118.80	3A	1031	41	SHENGXIAN	585560	29.60	120.82	3A	1282	50
NANNING	594310	22.82	108.35	2A	1294	51	SHENYANG	543420	41.73	123.52	6A	683	27
NANPING	588340	26.63	118.00	2A	1655	65	SHENZHEN	594930	22.55	114.10	2A	1837	72
NANYANG	571780	33.03	112.58	4A	788	31	SHEYANG	581500	33.77	120.25	4A	1030	41
NANYUE	577760	27.30	112.70	4A	2004	79	SHIJIAZHUANG	536980	38.03	114.42	4B	528	21
NAPO	592090	23.30	105.95	2A	1407	55	SHIPU	585690	29.20	121.95	3A	1423	56
NARAN BULAG	530830	44.62	114.15	7	222	9	SHIQUANHE	552280	32.50	80.08	7	67	3
NEIJIANG	575040	29.58	105.05	3A	1058	42	SHISANJIANFANG	514950	43.22	91.73	5B	27	1
NENJIANG	505570	49.17	125.23	7	481	19	SIMAO	569640	22.77	100.98	2A	1513	60
NYINGCHI	563120	29.57	94.47	5A	660	26	SINAN	577310	27.95	108.25	3A	1123	44
OTOG QI	535290	39.10	107.98	6B	262	10	SIPING	541570	43.18	124.33	6A	638	25
PAGRI	557730	27.73	89.08	7	415	16	SOG XIAN	561060	31.88	93.78	7	569	22
PINGLIANG	539150	35.55	106.67	5A	518	20	SONGPAN	561820	32.65	103.57	5A	718	28
PINGTAN	589440	25.52	119.78	2A	1192	47	SUIFENHE	540960	44.38	131.15	7	564	22
PINGWU	561930	32.42	104.52	3A	837	33	SUNWU	505640	49.43	127.35	7	547	22
PISHAN	518180	37.62	78.28	4B	50	2	TACHENG	511330	46.73	83.00	6B	281	11
POTOU	546180	38.08	116.55	4B	554	22	TAI SHAN	548260	36.25	117.10	6A	1086	43
PUCHENG	587310	27.92	118.53	3A	1687	66	TAILAI	508440	46.40	123.42	7	391	15
QAMDO	561370	31.15	97.17	5A	473	19	TAISHAN	588530	27.00	120.70	3A	1099	43
QIAN GORLOS	509490	45.08	124.87	6A	438	17	TAIYUAN	537720	37.78	112.55	5B	448	18
QIEMO/QARQAN	518550	38.15	85.55	5B	23	1	TANGSHAN	545340	39.67	118.15	4A	635	25
QINGDAO	548570	36.07	120.33	4A	730	29	TAOXIAN	543424	41.63	123.48	6A	729	29
QINGJIANG	581440	33.60	119.03	4A	919	36	TENGCHONG	567390	25.12	98.48	3A	1494	59
QINGLONG	544360	40.40	118.95	5A	715	28	TIANJIN	545270	39.10	117.17	4A	559	22
QINGYUAN	542590	42.10	124.95	6A	811	32	TIANMU SHAN (MTNS)	584450	30.35	119.42	5A	1690	67
QINZHOU	596320	21.95	108.62	2A	2136	84	TIANSHUI	570060	34.58	105.75	4A	539	21
QIONGHAI	598550	19.23	110.47	1A	1999	79	TIKANLIK	517650	40.63	87.70	5B	37	1
QIQIHAR	507450	47.38	123.92	7	430	17	TINGRI	556640	28.63	87.08	7	355	14
QITAI	513790	44.02	89.57	6B	175	7	TONGCHUAN	539470	35.17	109.05	5A	578	23
QIXIAN SHAN	587260	27.95	117.83	4A	2021	80	TONGDAO	578450	26.17	109.78	3A	1418	56
QU XIAN	586330	28.97	118.87	3A	1630	64	TONGDE	529570	35.27	100.65	7	427	17
QUMARLEB	560210	34.13	95.78	8	407	16	TONGHE	509630	45.97	128.73	7	596	23
RIZHAO	549450	35.43	119.53	4A	891	35	TONGLIAO	541350	43.60	122.27	6B	373	15
RONGJIANG	579320	25.97	108.53	3A	1177	46	TRUONG SA	489200	8.65	111.92	0A	1942	76
RUILI	568380	24.02	97.83	2A	1400	55	TULIHE	504340	50.45	121.70	8	457	18
RUOERGAI	560790	33.58	102.97	7	661	26	TUOTUOHE	560040	34.22	92.43	8	266	10
RUOQIANG	517770	39.03	88.17	5B	25	1	TURPAN	515730	42.93	89.20	4B	16	1
SANGZHI	575540	29.40	110.17	3A	1392	55	ULIASTAI	509150	45.52	116.97	7	249	10
SANHU DAO	599850	16.53	111.62	0A	1321	52	WANYUAN	572370	32.07	108.03	3A	1236	49
SANSUI	578320	26.97	108.67	3A	1112	44	WEICHANG	543110	41.93	117.75	6A	422	17
SERTAR	561520	32.28	100.33	7	649	26	WEIFANG	548430	36.77	119.18	4A	621	24
SHACHE	518110	38.43	77.27	4B	47	2	WEINING	566910	26.87	104.28	4A	928	37
SHANGCHUAN DAO	596730	21.73	112.77	2A	2159	85	WENZHOU	586590	28.02	120.67	3A	1698	67
SHANGHAI	583620	31.40	121.47	3A	1130	45	WU LU MU QI	514630	43.80	87.65	6B	257	10
SHANGHAI/HONGQIAO	583670	31.17	121.43	3A	1125	44	WUDAOLIANG	529080	35.22	93.08	8	264	10
SHANGZHI	509680	45.22	127.97	7	666	26	WUDU	560960	33.40	104.92	3B	485	19
SHANTOU	593160	23.40	116.68	2A	1579	62	WUGANG	578530	26.73	110.63	3A	1381	54

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
WUHAN	574940	30.62	114.13	3A	1218	48
WUHU	583380	31.33	118.35	3A	1161	46
WUSHAOLING	527870	37.20	102.87	7	390	15
WUTAI SHAN	535880	38.95	113.52	8	815	32
WUYISHAN	587300	27.77	118.03	3A	1905	75
WUZHOU	592650	23.48	111.30	2A	1487	59
XAINZA	554720	30.95	88.63	7	285	11
XI UJIMQIN QI	540120	44.58	117.60	7	333	13
XIAMEN	591340	24.48	118.08	2A	1185	47
XIAN	570360	34.30	108.93	4B	562	22
XIAOERGOU	505480	49.20	123.72	7	490	19
XICHANG	565710	27.90	102.27	3A	968	38
XIFENGZHEN	539230	35.73	107.63	5A	569	22
XIGAZE	555780	29.25	88.88	6C	432	17
XIHUA	571930	33.78	114.52	4A	745	29
XILIN HOT	541020	43.95	116.12	7	277	11
XIN BARAG YOUQI	506030	48.67	116.82	7	250	10
XINGREN	579020	25.43	105.18	3A	1332	52
XINGTAI	537980	37.07	114.50	4B	527	21
XINING	528660	36.62	101.77	6B	371	15
XINXIAN	548080	36.23	115.67	4A	579	23
XINYANG	572970	32.13	114.05	3A	1115	44
XINYI	594560	22.35	110.93	2A	1781	70
XISHA DAO	599810	16.83	112.33	0A	1496	59
XIUSHUI	575980	29.03	114.58	3A	1538	61
XUNWU	591020	24.95	115.65	2A	1651	65
XUZHOU	580270	34.28	117.15	4A	828	33
YAAN	562870	29.98	103.00	3A	1724	68
YAN AN	538450	36.60	109.50	5A	561	22
YANCHI	537230	37.80	107.38	5B	278	11
YANGCHENG	539750	35.48	112.40	4A	616	24
YANGJIANG	596630	21.87	111.97	2A	2276	90
YANJI	542920	42.87	129.50	6A	514	20
YANZHOU	549160	35.57	116.85	4A	689	27
YAXIAN	599480	18.23	109.52	0A	1248	49
YIBIN	564920	28.80	104.60	3A	1147	45
YICHANG	574610	30.70	111.30	3A	1178	46
YICHUN	507740	47.72	128.90	7	643	25
YICHUN	577930	27.80	114.38	3A	1602	63
YINCHUAN	536140	38.47	106.20	5B	196	8
YINGKOU	544710	40.67	122.20	5A	675	27
YINING	514310	43.95	81.33	5B	262	10
YIWU	521180	43.27	94.70	7	90	4
YIYUAN	548360	36.18	118.15	4A	701	28
YONGAN	589210	25.97	117.35	2A	1566	62
YOUYANG	576330	28.83	108.77	3A	1360	54
YU XIAN	535930	39.83	114.57	6B	408	16
YUANJIANG	569660	23.60	101.98	1A	782	31
YUANLING	576550	28.47	110.40	3A	1422	56
YUANMOU	567630	25.73	101.87	2B	619	24
YUANPING	536730	38.75	112.70	5B	424	17
YUEYANG	575840	29.38	113.08	3A	1264	50
YULIN	536460	38.23	109.70	5B	402	16
YUMENZHEN	524360	40.27	97.03	6B	59	2
YUNCHENG	539590	35.05	111.05	4B	545	21
YUSHE	537870	37.07	112.98	5A	587	23
YUSHU	560290	33.02	97.02	7	487	19
YUTIAN/KERIYA	519310	36.87	81.70	5B	50	2
ZADOI	560180	32.90	95.30	7	531	21
ZAOYANG	572790	32.15	112.67	3A	862	34
ZHANG PING	589260	25.30	117.40	2A	1537	61
ZHANGJIAKOU	544010	40.78	114.88	5B	399	16
ZHANGWU	542360	42.42	122.53	6A	512	20
ZHANGYE	526520	38.93	100.43	5B	128	5
ZHANJIANG	596580	21.22	110.40	1A	1634	64
ZHANYI	567860	25.58	103.83	3C	830	33
ZHAOTONG	565860	27.33	103.75	4A	725	29
ZHENGZHOU	570830	34.72	113.65	4A	641	25
ZHIJIANG	577450	27.45	109.68	3A	1239	49
ZHONGNING	537050	37.48	105.68	5B	216	9
ZHONGXIANG	573780	31.17	112.57	3A	962	38
ZHUMADIAN	572900	33.00	114.02	4A	978	38
ZUNYI	577130	27.70	106.88	3A	1067	42
Christmas Island (CRX)						
CHRISTMAS ISLAND AE	969950	–10.45	105.68	1A	1848	73
Cocos (Keeling) Islands (CCK)						
COCOS ISLAND AERO	969960	–12.18	96.83	0A	1865	73
Colombia (COL)						
BARRANQUILLA/ERNEST	800280	10.88	–74.78	0A	824	32
BOGOTA/ELDORADO	802220	4.70	–74.13	3A	900	35
CALI/ALFONSO BONILL	802590	3.55	–76.38	1A	967	38
CARTAGENA/RAFAEL NU	800220	10.45	–75.52	0A	1055	42
RIONEGRO/J.M.CORDOV	801120	6.13	–75.43	3A	1934	76
Congo (COG)						
BRAZZAVILLE/MAYA-M	644500	–4.25	15.25	1A	1375	54
Cook Islands (COK)						
AMURI/AITUTAKI ISL	918300	–18.83	–159.77	1A	1964	77
MANGAIA ISLAND	918470	–21.92	–157.95	1A	1969	78
MAUKE ISLAND	918400	–20.13	–157.35	1A	1653	65
PENRHYN ISLAND	918000	–9.02	–158.07	0A	1573	62
PUKAPUKA	918110	–10.88	–165.82	0A	2788	110
RAROTONGA	918430	–21.20	–159.82	1A	2176	86
Costa Rica (CRI)						
JUAN SANTAMARIA INT	787620	9.98	–84.22	2A	1946	77
Côte D'Ivoire (CIV)						
ABIDJAN	655780	5.25	–3.93	0A	1886	74
Croatia (HRV)						
DARUVAR	142580	45.60	17.23	4A	890	35
DUBROVNIK-CILIPI	134520	42.57	18.27	3A	1857	73
GOSPIC	143300	44.55	15.37	5A	1400	55
PULA AERODROME	143070	44.90	13.92	4A	907	36
SPLIT/MARJAN	144450	43.52	16.43	3A	829	33
SPLIT/RESNIK	144440	43.53	16.30	3A	970	38
ZADAR/ZEMUNIK	144310	44.10	15.35	3A	928	37
ZAGREB/MAKSIMIR	142400	45.82	16.03	4A	1001	39
ZAGREB/PLESO	142410	45.73	16.07	4A	873	34

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

					Precipitation	
Country/LOCATION	**WMO#**	**Lat**	**Long**	**CZ**	**mm**	**in.**
Cuba (CUB)						
AEROPUERTO JOSE MAR	782240	22.98	–82.40	1A	1536	60
CAMAGUEY AEROPUERTO	782550	21.42	–77.85	1A	1386	55
GUANTANAMO BAY NAS	783670	19.90	–75.22	0B	567	22
SANTIAGO DE CUBA	782640	19.97	–75.85	1A	1124	44
VARADERO/MT	782290	23.02	–81.43	1A	1428	56
Curaçao (CUW)						
HATO ARPT (CIV/MIL)	789880	12.20	–68.97	0B	551	22
Cyprus (CYP)						
AKROTIRI	176010	34.58	32.98	3A	591	23
LARNACA AIRPORT	176090	34.88	33.63	3B	330	13
PAPHOS AIRPORT	176000	34.72	32.48	3A	480	19
Czech Republic (CZE)						
BRNO/TURANY	117230	49.15	16.70	5A	497	20
CASLAV	116240	49.93	15.38	5A	578	23
CERVENA	117660	49.77	17.55	6A	685	27
CESKE BUDEJOVICE	115410	48.95	14.43	5A	648	26
CHEB	114060	50.08	12.40	5A	564	22
CHURANOV	114570	49.07	13.62	6A	983	39
DOKSANY	115090	50.47	14.17	5A	496	20
DUKOVANY	116930	49.10	16.13	5A	505	20
HOLESOV	117740	49.32	17.57	5A	649	26
HRADEC KRALOVE	116480	50.25	15.85	5A	609	24
KARLOVY VARY	114140	50.20	12.92	6A	641	25
KOCELOVICE	114870	49.47	13.83	5A	611	24
KOSTELNI MYSLOVA	116360	49.18	15.47	6A	639	25
KRESIN-KRAMOLIN	116280	49.58	15.08	5A	650	26
KUCHAROVICE	116980	48.88	16.08	5A	492	19
LIBEREC	116030	50.77	15.02	5A	917	36
LUKA	117100	49.65	16.95	5A	617	24
LYSA HORA	117870	49.55	18.45	7	1004	40
MARIANSKE LAZNE	114180	49.92	12.72	6A	706	28
MILESOVKA	114640	50.55	13.93	6A	686	27
NAMEST NAD OSLAV	116920	49.17	16.12	5A	505	20
OSTRAVA/MOSNOV	117820	49.68	18.12	5A	864	34
PARDUBICE	116520	50.02	15.73	5A	584	23
PEC POD SNEZKOU	116430	50.67	15.75	6A	897	35
PLZEN LINE	114480	49.68	13.27	5A	565	22
PRADED MOUNTAIN	117350	50.07	17.23	7	946	37
PRAHA/RUZYNE	115180	50.10	14.25	5A	482	19
PRAHA-KBELY	115670	50.12	14.53	5A	548	22
PRAHA-LIBUS	115200	50.02	14.45	5A	497	20
PREROV	117480	49.42	17.40	5A	605	24
PRIBYSLAV	116590	49.58	15.77	6A	701	28
PRIMDA	114230	49.67	12.67	6A	814	32
SVRATOUCH	116830	49.73	16.03	6A	722	28
TEMELIN	115380	49.20	14.33	5A	600	24
TUSIMICE	114380	50.38	13.33	5A	650	26
USTI NAD LABEM	115020	50.68	14.03	5A	603	24
USTI NAD ORLICI	116790	49.98	16.43	5A	734	29
Denmark (DNK)						
AALBORG	060300	57.10	9.85	5A	607	24
BILLUND	061040	55.73	9.17	5A	888	35
BLAAVANDSHUK	060810	55.55	8.08	5A	792	31
CHRISTIANSO (LGT-H)	061910	55.32	15.18	5A	608	24
DROGDEN	061830	55.53	12.72	5A	602	24
ESBJERG	060800	55.53	8.57	5A	843	33
FORNAES (CAPE)	060710	56.45	10.97	5A	585	23
FREDERIKSHAVN	060430	57.40	10.52	5A	674	27
GNIBEN	061690	56.02	11.28	5A	550	22
HAMMER ODDE	061930	55.30	14.78	5A	538	21
HOLBAEK	061560	55.73	11.60	5A	601	24
HVIDE SANDE	060580	56.00	8.13	5A	788	31
KARUP	060600	56.30	9.12	5A	767	30
KEGNAES	061190	54.85	9.98	5A	706	28
KOEBENHAVN/KASTRUP	061800	55.62	12.65	5A	602	24
LANGOE	061380	54.82	11.00	5A	585	23
MARIBO	061430	54.70	11.45	5A	615	24
MOEN	061790	54.95	12.53	5A	763	30
NAKKEHOVED	061680	56.12	12.35	5A	626	25
ODENSE/BELDRINGE	061200	55.48	10.33	5A	632	25
OMOE	061510	55.17	11.13	5A	574	23
ROEMOE/JUVRE	060960	55.18	8.57	5A	801	32
ROENNE	061900	55.07	14.75	5A	577	23
ROESNAES	061590	55.75	10.87	5A	552	22
ROSKILDE/TUNE	061700	55.58	12.13	5A	606	24
SAEDENSTRAND	060890	55.50	8.40	5A	782	31
SKAGEN	060410	57.73	10.63	5A	640	25
SKRYDSTRUP	061100	55.23	9.27	5A	828	33
THYBOROEN	060520	56.70	8.22	5A	811	32
TIRSTRUP	060700	56.32	10.63	5A	627	25
VAERLOESE	061600	55.77	12.33	5A	642	25
Dominican Republic (DOM)						
LAS AMERICAS	784850	18.43	–69.67	1A	1198	47
SANTO DOMINGO	784860	18.43	–69.88	0A	1338	53
Ecuador (ECU)						
GUAYAQUIL AEROPUERT	842030	–2.15	–79.88	1A	866	34
MANTA	841170	–0.95	–80.68	1B	404	16
QUITO AEROPUERTO	840710	–0.13	–78.48	3A	1083	43
Egypt (EGY)						
ALEXANDRIA/NOUZHA	623180	31.20	29.95	2B	182	7
ASSWAN	624140	23.97	32.78	0B	1	0
ASYUT	623930	27.05	31.02	2B	6	0
BALTIM	623250	31.55	31.10	2B	180	7
CAIRO AIRPORT	623660	30.13	31.40	2B	23	1
DAKHLA	624320	25.48	29.00	1B	1	0
EL ARISH	623370	31.08	33.82	2B	135	5
EL TOR	624590	28.23	33.62	2B	7	0
HURGUADA	624630	27.15	33.72	1B	6	0
ISMAILIA	624400	30.60	32.25	2B	30	1
KHARGA	624350	25.45	30.53	1B	1	0
KOSSEIR	624650	26.13	34.15	1B	4	0
LUXOR	624050	25.67	32.70	1B	2	0
MERSA MATRUH	623060	31.33	27.22	2B	123	5
MINYA	623870	28.08	30.73	2B	3	0
PORT SAID	623330	31.27	32.30	2B	67	3

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
PORT SAID/EL GAMIL	623320	31.28	32.23	2B	67	3
SIWA	624170	29.20	25.32	2B	12	0
Estonia (EST)						
KUNDA	260450	59.52	26.53	6A	564	22
KURESSAARE	262150	58.23	22.50	6A	621	24
NARVA	260580	59.37	28.12	6A	640	25
PJARNU	262310	58.37	24.50	6A	657	26
RISTNA	261150	58.92	22.07	6A	880	35
TALLINN	260380	59.47	24.82	6A	654	26
TARTU	262420	58.30	26.73	6A	586	23
TURI	261350	58.82	25.42	6A	717	28
VALKE-MAARJA	261410	59.13	26.23	6A	658	26
Falkland Islands (Malvinas) (FLK)						
MOUNT PLEASANT AIRP	888890	–51.82	–58.45	6A	601	24
Faroe Islands (FRO)						
AKRABERG	060090	61.40	–6.67	6A	1606	63
TORSHAVN	060110	62.02	–6.77	6A	1411	56
Fiji (FJI)						
LAKEBA AWS	916910	–18.23	–178.80	1A	1482	58
MATUKU AWS	916970	–19.13	179.75	1A	1639	65
NADI AIRPORT	916800	–17.75	177.45	1A	1850	73
NAUSORI	916830	–18.05	178.57	1A	2866	113
ONO-I-LAU AWS	916990	–20.67	–178.72	1A	1740	69
ROTUMA	916500	–12.50	177.05	0A	3504	138
UDU POINT AWS	916520	–16.13	–179.98	0A	2433	96
VIWA AWS	916700	–17.15	176.90	0A	1763	69
VUNISEA	916930	–19.05	178.17	1A	1712	67
YASAWA-I-RARA AWS	916600	–16.70	177.58	0A	1854	73
Finland (FIN)						
AHTARI	029240	62.53	24.02	7	627	25
BAGASKAR	029840	59.93	24.02	6A	547	22
HALLI	029450	61.85	24.80	7	657	26
HELSINKI-VANTAA	029740	60.32	24.97	6A	658	26
ILOMANTSI	029190	62.68	30.95	7	685	27
ISOSAARI	029880	60.10	25.07	6A	654	26
IVALO	028070	68.62	27.42	7	393	15
JOENSUU	029290	62.67	29.63	7	627	25
JOKIOINEN	029630	60.82	23.50	7	597	23
JOMALA	029710	60.15	19.87	6A	530	21
JYVASKYLA	029350	62.40	25.68	7	636	25
KAJAANI	028970	64.28	27.68	7	559	22
KAUHAVA	029130	63.10	23.03	7	540	21
KEMI	028640	65.78	24.58	7	563	22
KEVO	028050	69.75	27.03	8	416	16
KRUUNUPYY	029030	63.72	23.15	7	553	22
KUMLINGE ISLAND	029900	60.30	20.75	6A	792	31
KUOPIO	029170	63.02	27.80	7	677	27
KUUSAMO	028690	65.97	29.18	7	598	24
KUUSKAJASKARI	029610	61.13	21.37	6A	607	24
LAHTI	029650	60.97	25.63	7	636	25
LAPPEENRANTA	029580	61.05	28.20	7	645	25
MARIEHAMN/ALAND ISL	029700	60.12	19.90	6A	530	21
MASSKAR	029010	63.73	22.58	7	531	21
MIKKELI	029470	61.73	27.30	7	625	25
MOIKIPAA	029210	62.88	21.10	7	542	21
MUONIO	028230	67.97	23.68	8	531	21
NIINISALO	029420	61.85	22.47	7	628	25
NIVALA	029050	63.92	24.97	7	567	22
NYHAMN	029800	59.97	19.97	6A	715	28
OULU	028750	64.93	25.37	7	442	17
PELLO	028440	66.80	24.00	7	523	21
PORI	029520	61.47	21.80	6A	604	24
PUDASJARVI	028670	65.37	27.02	7	601	24
RANKKI	029760	60.37	26.97	6A	634	25
ROVANIEMI	028450	66.57	25.83	7	535	21
RUSSARO	029820	59.77	22.95	6A	695	27
SALLA KK	028490	66.83	28.68	7	561	22
SAVONLINNA	029480	61.95	28.95	7	611	24
SODANKYLA	028360	67.37	26.65	7	530	21
SUOMUSSALMI	028790	64.90	29.02	7	664	26
TAMPERE/PIRKKALA	029440	61.42	23.58	7	566	22
TURKU	029720	60.52	22.27	6A	723	28
UTO	029810	59.78	21.38	6A	847	33
UTTI	029660	60.90	26.93	7	641	25
VAASA AIRPORT	029110	63.05	21.77	7	506	20
VALASSAARET	029100	63.43	21.07	7	719	28
VIITASAARI	029150	63.08	25.87	7	616	24
France (FRA)						
ABBEVILLE	070050	50.13	1.83	4A	771	30
AGEN	075240	44.18	0.60	4A	755	30
AJACCIO	077610	41.92	8.80	3A	626	25
ALBI	076320	43.92	2.12	4A	882	35
ALENCON	071390	48.43	0.10	4A	736	29
AMBERIEU	074820	45.98	5.33	4A	1181	46
AUCH	076220	43.68	0.60	4A	756	30
AURILLAC	075490	44.88	2.42	5A	1322	52
AUXERRE	072650	47.80	3.55	4A	654	26
BALE-MULHOUSE	072990	47.60	7.52	4A	775	30
BASTIA	077900	42.55	9.48	3A	756	30
BEAUCOUZE	072300	47.48	–0.60	4A	620	24
BEAUVAIS	070550	49.47	2.12	4A	730	29
BELFORT	072950	47.63	6.88	5A	1316	52
BELLE IIE LE TALUT	072070	47.30	–3.17	4A	705	28
BERGERAC	075300	44.82	0.52	4A	812	32
BESANCON	072880	47.25	5.98	4A	1170	46
BIARRITZ	076020	43.47	–1.53	3A	1824	72
BISCAROSSE	075030	44.43	–1.25	3A	937	37
BORDEAUX MERIGNAC	075100	44.83	–0.68	4A	940	37
BOULOGNE	070020	50.73	1.60	4A	760	30
BOURG ST-MAURICE	074970	45.62	6.77	5A	1258	50
BOURGES	072550	47.07	2.37	4A	734	29
BREHAT ISLAND	071210	48.85	–3.00	4A	752	30
BREST	071100	48.45	–4.42	4A	1152	45
BRIGNOGAN	071070	48.68	–4.33	4A	965	38
BRIVE	074380	45.15	1.47	4A	931	37
CAEN CARPIQUET	070270	49.18	–0.45	4A	776	31

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
CALVI	077540	42.53	8.80	3A	672	26	MARTIN DE VIVIES (ILE AMST.)	619960	–37.80	77.50	3A	1101	43
CAP BEAR	077490	42.52	3.13	3A	595	23	MAUPERTUS	070240	49.65	–1.48	4A	845	33
CAP CEPET	076610	43.08	5.93	3A	727	29	MELUN	071530	48.62	2.68	4A	651	26
CAP CORSE	077850	43.00	9.35	3A	705	28	METZ/FRESCATY	070900	49.08	6.13	4A	768	30
CAP COURONNE	076530	43.33	5.05	3A	514	20	MEYENHEIM-COLMAR	071970	47.92	7.40	4A	746	29
CAP DE LA HEVE	070280	49.50	0.07	4A	796	31	MILLAU	075580	44.12	3.02	4A	921	36
CAP FERRET	075000	44.63	–1.25	3A	904	36	MONT AIGOUAL	075600	44.12	3.58	6A	1444	57
CAP PERTUSATO	077700	41.37	9.17	3A	616	24	MONT-DE-MARSAN	076070	43.92	–0.50	4A	945	37
CAP POMEGUES	076520	43.27	5.30	3A	566	22	MONTELIMAR	075770	44.58	4.73	4A	930	37
CAPE FERRAT	076950	43.68	7.33	3A	904	36	MONTPELLIER	076430	43.58	3.97	3A	869	34
CAPE SAGRO	077910	42.80	9.48	3A	705	28	NANCY-ESSEY	071800	48.68	6.22	5A	768	30
CARCASSONNE	076350	43.22	2.32	3A	728	29	NANCY-OCHEY	071810	48.58	5.97	5A	837	33
CARPENTRAS	075860	44.08	5.05	3A	749	30	NANTES	072220	47.15	–1.60	4A	778	31
CAZAUX	075020	44.53	–1.13	4A	904	36	NEVERS	072600	47.00	3.10	4A	786	31
CHAMBERY/AIX-LES-BA	074910	45.63	5.87	4A	1218	48	NICE	076900	43.65	7.20	3A	790	31
CHARLEVILLE	070750	49.78	4.63	5A	1013	40	NIMES/GARONS (NAVY)	076460	43.75	4.42	3A	714	28
CHARTRES	071430	48.47	1.50	4A	611	24	NIMES-COURBESSAC	076450	43.87	4.40	3A	775	31
CHASSIRON	073140	46.05	–1.42	3A	730	29	NIORT	073300	46.32	–0.40	4A	903	36
CHATEAUROUX/DEOLS	073540	46.85	1.72	4A	774	30	ORANGE	075790	44.13	4.83	3A	719	28
CLERMONT-FERRAND	074600	45.78	3.17	4A	595	23	ORLEANS	072490	47.98	1.78	4A	641	25
COGNAC	074120	45.67	–0.32	4A	852	34	OUESSANT	071000	48.48	–5.05	4A	869	34
DIEPPE	070400	49.93	1.10	4A	854	34	PARIS-AEROPORT CHAR	071570	49.02	2.53	4A	701	28
DIJON	072800	47.27	5.08	4A	747	29	PARIS-MONTSOURIS	071560	48.82	2.33	4A	647	25
DINARD	071250	48.58	–2.07	4A	685	27	PARIS-ORLY	071490	48.72	2.38	4A	634	25
DUNKERQUE	070100	51.05	2.33	4A	685	27	PAU	076100	43.38	–0.42	4A	1173	46
EMBRUN	075910	44.57	6.50	5A	844	33	PERPIGNAN	077470	42.73	2.87	3A	572	23
EVREUX/FAUVILLE FAF	070380	49.02	1.22	4A	685	27	POINTE DU RAZ	071030	48.03	–4.73	4A	797	31
FIGARI	077800	41.50	9.10	3A	616	24	POITIERS	073350	46.58	0.30	4A	712	28
GOURDON	075350	44.75	1.40	4A	871	34	PORQUEROLLES	076700	43.00	6.23	3A	681	27
GRENOBLE-ST-GEOIRS	074860	45.37	5.33	4A	991	39	PORT EN BESSIN	070290	49.35	–0.77	4A	796	31
GROUIN DE CANCALE	071270	48.72	–1.85	4A	688	27	PTE DE LA HAGUE	070200	49.72	–1.93	4A	809	32
HYERES	076670	43.10	6.15	3A	745	29	PTE DE PENMARCH	072000	47.80	–4.37	4A	875	34
ILE ROUSSE	077530	42.63	8.92	3A	672	26	QUIMPER	072010	47.97	–4.17	4A	919	36
ISTRES	076470	43.52	4.92	3A	623	25	REIMS	070700	49.30	4.03	4A	656	26
L IIE D YEU	073000	46.70	–2.33	4A	796	31	RENNES	071300	48.07	–1.73	4A	710	28
LA CHIAPPA	077680	41.60	9.37	3A	746	29	ROUEN	070370	49.38	1.18	4A	790	31
LA ROCHELLE	073150	46.15	–1.15	4A	758	30	SAINT GIRONS	076270	43.00	1.10	4A	1163	46
LA ROCHE-SUR-YON	073060	46.70	–1.38	4A	856	34	SAINT-DIZIER	071690	48.63	4.90	4A	891	35
LANGRES	072830	47.85	5.33	5A	849	33	SAINT-NAZAIRE-MONTO	072170	47.32	–2.17	4A	735	29
LE BOURGET	071500	48.97	2.43	4A	647	25	SAINT-QUENTIN	070610	49.82	3.20	5A	696	27
LE LUC	076750	43.38	6.38	3A	907	36	SAINT-YAN	073790	46.42	4.02	4A	884	35
LE MANS	072350	47.93	0.20	4A	682	27	SERGE-FROLOW (ILE TROMELIN)	619760	–15.80	54.50	1A	850	33
LE PUY	074710	45.08	3.77	5A	769	30	SETE	076410	43.40	3.68	3A	650	26
LE RAIZET/GUADELOUP	788970	16.27	–61.60	0A	1475	58	SOCOA	076000	43.40	–1.68	3A	1824	72
LILLE LESQUI	070150	50.57	3.10	4A	698	27	SOLENZARA	077650	41.92	9.40	3A	843	33
LIMOGES	074340	45.87	1.18	4A	1013	40	ST-AUBAN-SUR-DURANC	075880	44.07	6.00	4A	746	29
LONS-LE-SAUNIER	073900	46.68	5.52	4A	1368	54	ST-ETIENNE BOUTHEON	074750	45.53	4.30	4A	765	30
LORIENT LAN BIHOUE	072050	47.77	–3.45	4A	867	34	STRASBOURG-ENTZHEIM	071900	48.55	7.63	4A	623	25
LUXEUIL	072920	47.80	6.38	5A	1155	45	TARBES-OSSUN	076210	43.18	0.00	4A	1140	45
LYON-BRON	074800	45.72	4.93	4A	808	32	TOULON	076600	43.10	5.93	3A	674	27
LYON-SATOLAS	074810	45.73	5.08	4A	927	37	TOULOUSE BLAGNAC	076300	43.63	1.37	4A	669	26
MACON	073850	46.30	4.80	4A	847	33	TOURS	072400	47.45	0.73	4A	674	27
MARIGNANE	076500	43.45	5.23	3A	514	20	TRAPPES	071450	48.77	2.00	4A	672	26

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

					Precipitation	
Country/LOCATION	WMO#	Lat	Long	CZ	mm	in.
TREMUSON-ST-BRIEUC	071200	48.53	–2.85	4A	764	30
TROYES BARBEREY	071680	48.33	4.02	4A	695	27
VANNES/SENE	072100	47.60	–2.72	4A	840	33
VICHY	073740	46.17	3.40	4A	763	30
VILLACOUBLAY	071470	48.77	2.20	4A	644	25
French Guiana (GUF)						
ROCHAMBEAU	814050	4.83	–52.37	0A	3614	142
French Polynesia (PYF)						
ATUONA	919250	–9.80	–139.03	0A	1311	52
BORA-BORA	919290	–16.43	–151.75	0A	2036	80
HAO	919440	–18.07	–140.95	0A	1428	56
MURUROA	919520	–21.82	–138.80	1A	1610	63
RAPA	919580	–27.62	–144.33	2A	2672	105
RIKITEA	919480	–23.13	–134.97	2A	1783	70
TAHITI-FAAA	919380	–17.55	–149.62	0A	1685	66
TAKAROA	919430	–14.48	–145.03	0A	1529	60
TUBUAI	919540	–23.35	–149.48	2A	1880	74
French Southern Territories (ATF)						
PORT-AUX-FRANCAIS	619980	–49.30	70.20	6A	1132	45
Gabon (GAB)						
LIBREVILLE	645000	0.45	9.42	0A	2769	109
Gambia (GMB)						
BANJUL/YUNDUM	617010	13.20	–16.63	0A	1162	46
Georgia (GEO)						
BATUMI	374840	41.62	41.60	3A	2575	101
KUTAISI	373950	42.27	42.63	3A	1599	63
PASANAURI	374320	42.35	44.70	5A	1507	59
SUHUMI	372600	42.87	41.13	4A	1532	60
TBILISI	375490	41.68	44.95	4A	480	19
Germany (DEU)						
AACHEN	105010	50.78	6.10	5A	789	31
AHLHORN(GAFB)	102180	52.88	8.23	5A	744	29
ANGERMUENDE	102910	53.03	14.00	5A	522	21
ARKONA (CAPE)	090910	54.68	13.43	5A	529	21
ARTERN	104600	51.38	11.30	5A	546	21
AUGSBERG/MULHAUSEN	108520	48.43	10.93	5A	810	32
BERGEN	102380	52.82	9.93	5A	766	30
BERLIN/DAHLEM	103810	52.47	13.30	5A	581	23
BERLIN/SCHONEFELD	093850	52.38	13.52	5A	563	22
BERLIN/TEGEL (FAFB)	103820	52.57	13.32	5A	605	24
BERLIN/TEMPELHOF	103840	52.47	13.40	5A	581	23
BITBURG(US ARMY)	106100	49.95	6.57	5A	774	30
BOIZENBURG (AUT)	102490	53.40	10.68	5A	675	27
BOLTENHAGEN	101610	54.00	11.20	5A	607	24
BRAUNSCHWEIG	103480	52.30	10.45	5A	652	26
BREMEN	102240	53.05	8.80	5A	712	28
BREMERHAVEN	101290	53.53	8.58	5A	796	31
BREMGARTEN(GAFB)	109000	47.90	7.62	4A	941	37
BROCKEN (PEAK)	104530	51.80	10.62	7	1753	69
BRUGGEN (RAF)	104010	51.20	6.13	5A	747	29
BUECHEL	106130	50.17	7.07	5A	749	29
BUECKEBURG	103350	52.28	9.08	5A	732	29
CELLE	103430	52.60	10.02	5A	708	28
CHEMNITZ	105770	50.80	12.87	5A	781	31
COTTBUS (FLUGPLATZ)	104920	51.77	14.30	5A	567	22
CUXHAVEN	101310	53.87	8.70	5A	835	33
DIEPHOLZ	103210	52.58	8.35	5A	729	29
DOBERLUG/KIRCHHAIN	094900	51.65	13.58	5A	587	23
DRESDEN/KLOTZSCHE	094880	51.13	13.77	5A	648	26
DUSSELDORF	104000	51.28	6.78	4A	844	33
EGGEBEK	100340	54.63	9.35	5A	842	33
EMDEN-FLUGPLATZ	102000	53.38	7.23	5A	785	31
ERFURT/BINDERSLEBN	095540	50.98	10.97	5A	514	20
ESSEN/MULHEIM	104100	51.40	6.97	5A	933	37
FASSBERG	102460	52.92	10.18	5A	753	30
FICHTELBERG MTN	095780	50.43	12.95	7	1136	45
FRANKFURT MAIN ARPT	106370	50.05	8.60	5A	651	26
FREIBURG (CIV/FAFB)	108030	48.00	7.85	4A	962	38
FRITZLAR	104390	51.12	9.28	5A	668	26
FUERSTENFELDBRUCK	108580	48.20	11.27	5A	968	38
FUERSTENZELL	108950	48.55	13.35	5A	955	38
GARDELEGEN (AUT)	103590	52.52	11.40	5A	550	22
GEILENKIRCHEN	105000	50.97	6.05	4A	789	31
GERA/LEUMNITZ	105670	50.88	12.13	5A	620	24
GIESSEN	105320	50.58	8.70	5A	739	29
GLUECKSBURG/MEIERWI	100330	54.83	9.50	5A	763	30
GOERLITZ	104990	51.17	14.95	5A	660	26
GRAFENWOEHR	106870	49.70	11.95	5A	767	30
GREIFSWALD	091840	54.10	13.38	5A	574	23
GUETERSLOH	103200	51.93	8.32	5A	767	30
HAHN	106160	49.95	7.27	5A	727	29
HAMBURG/FUHLSBUTTEL	101470	53.63	10.00	5A	782	31
HANNOVER	103380	52.47	9.70	5A	647	25
HEIDELBERG (USA-AF)	107340	49.40	8.65	4A	796	31
HOF	106850	50.32	11.88	6A	765	30
HOHENPEISSENBERG	109620	47.80	11.02	6A	1190	47
HOHN	100380	54.32	9.53	5A	836	33
HOLZDORF	104760	51.77	13.17	5A	548	22
HOPSTEN	103140	52.33	7.53	5A	758	30
IDAR-OBERSTEIN	106180	49.70	7.33	5A	781	31
ITZEHOE	101420	53.98	9.57	5A	824	32
JEVER	101220	53.53	7.90	5A	810	32
KAHLER ASTEN(MOUNT)	104270	51.18	8.48	6A	1104	43
KALKAR	104040	51.73	6.27	4A	759	30
KARLSRUHE BADEN BAD	107275	48.77	8.07	5A	916	36
KASSEL	104380	51.30	9.45	5A	706	28
KIEL HOLTENAU	100465	54.37	10.13	5A	779	31
KOLN/BONN (CIV/MIL)	105130	50.87	7.17	5A	833	33
KONSTANZ	109290	47.68	9.18	5A	831	33
KUEMMERSBRUCK	107710	49.43	11.90	5A	737	29
LAAGE	101720	53.92	12.28	5A	598	24
LAHR	108050	48.37	7.83	4A	897	35
LANDSBERG	108570	48.07	10.90	5A	942	37
LAUPHEIM	108370	48.22	9.92	5A	849	33
LECHFELD	108560	48.18	10.85	5A	942	37
LECK	100220	54.80	8.95	5A	822	32

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
LEINEFELDE (AUT)	104490	51.40	10.32	5A	689	27
LEIPZIG	104710	51.32	12.42	5A	513	20
LEIPZIG/SCHKEUDITZ	104690	51.42	12.23	5A	527	21
LINDENBERG	093930	52.22	14.12	5A	548	22
LUEDENSCHEID	104180	51.25	7.65	5A	1219	48
MAGDEBURG	093610	52.10	11.58	5A	508	20
MARNITZ (AUT)	102640	53.32	11.93	5A	608	24
MEININGEN	105480	50.57	10.38	6A	662	26
MEMMINGEN (GER-AFB)	109470	47.98	10.23	5A	1179	46
MENDIG	105140	50.37	7.32	5A	719	28
MESSSTETTEN	108270	48.18	9.00	6A	869	34
MUNICH	108650	48.13	11.55	5A	991	39
MUNICH/RIEM	108660	48.13	11.70	5A	928	37
NEUBURG/DONAU	108530	48.72	11.22	5A	766	30
NEUHAUSEN OB ECK	109210	47.98	8.90	6A	850	33
NEURUPPIN	102700	52.90	12.82	5A	566	22
NIEDERSTETTEN	107430	49.38	9.97	5A	781	31
NOERVENICH	105020	50.83	6.67	5A	701	28
NORDHOLZ	101360	53.77	8.67	5A	835	33
NUERBURG-BARWEILER	105060	50.37	6.87	5A	744	29
NURNBERG	107630	49.50	11.08	5A	627	25
OLDENBURG	102150	53.18	8.17	5A	765	30
OSCHATZ	104800	51.30	13.10	5A	571	22
PASSAU	108930	48.58	13.47	5A	955	38
PFERDSFELD (GER-AF)	106260	49.85	7.60	5A	628	25
PLAUEN (AUT)	105690	50.48	12.13	5A	727	29
POTSDAM	093790	52.38	13.07	5A	580	23
QUICKBORN	101460	53.73	9.88	5A	750	30
RAMSTEIN	106140	49.43	7.60	5A	864	34
REGENSBURG/OBERHUB	107760	49.05	12.10	5A	636	25
RHEINE-BENTLAGE	103060	52.30	7.38	5A	761	30
ROTH	107650	49.22	11.10	5A	725	29
SAARBRUCKEN/ENSHEIM	107080	49.22	7.12	5A	852	34
SCHLESWIG-JAGEL	100370	54.47	9.52	5A	898	35
SCHMUECKE (RIDGE)	105520	50.65	10.77	6A	893	35
SCHWERIN	091620	53.63	11.42	5A	629	25
SEEHAUSEN/ALTMARK	092610	52.90	11.73	5A	557	22
SONNEBERG/NEUFANG	105580	50.38	11.18	6A	896	35
SPANGDAHLEM	106070	49.98	6.70	5A	774	30
STRAUBING	107880	48.83	12.57	5A	835	33
STUTTGART/ECHTERDI	107380	48.68	9.22	5A	718	28
STUTTGART/SCHNARREN	107390	48.83	9.20	5A	672	26
TETEROW	101770	53.77	12.62	5A	592	23
TRIER/PETRISBERG	106090	49.75	6.67	5A	764	30
TROLLENHAGEN	102810	53.60	13.32	5A	548	22
UECKERMUENDE (AUT)	091930	53.75	14.07	5A	546	21
WAREN	102680	53.52	12.67	5A	567	22
WARNEMUENDE	091700	54.18	12.08	5A	597	23
WASSERKUPPE (MOUNT)	105440	50.50	9.95	6A	883	35
WEIMAR	105550	50.98	11.32	5A	572	23
WERNIGERODE (AUT)	104540	51.85	10.77	5A	587	23
WESTERMARKELSDORF	100550	54.53	11.07	5A	585	23
WIESENBURG	103680	52.12	12.47	5A	578	23

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
WILDENRATH(GAFB)	104020	51.12	6.22	5A	747	29
WITTENBERG	104740	51.88	12.65	5A	576	23
WITTMUNDHAVEN	101260	53.55	7.67	5A	793	31
WUNSTORF	103340	52.47	9.43	5A	773	30
ZINNWALD/GEORGENFE	105820	50.73	13.75	6A	686	27
ZUGSPITZE MOUNTAIN	109610	47.42	10.98	8	2020	80
Gibraltar (GIB)						
GIBRALTAR	084950	36.15	–5.35	3A	750	30
Greece (GRC)						
AKTION (AIRPORT)	166430	38.95	20.77	3A	917	36
ALEXANDROUPOLI (AIR)	166270	40.85	25.92	4A	554	22
ANDRAVIDA (AIRPORT)	166820	37.92	21.28	3A	820	32
ARAXOS (AIRPORT)	166870	38.15	21.42	3A	659	26
ATHINAI (AIRPORT)	167160	37.90	23.73	3B	353	14
CHRYSOPOULI (AIRPORT)	166240	40.98	24.60	3A	456	18
ELEFSIS (AIRPORT)	167180	38.07	23.55	3A	438	17
HERAKLION (AIRPORT)	167540	35.33	25.18	3A	485	19
KALAMATA (AIRPORT)	167260	37.07	22.02	3A	783	31
KERKYRA (AIRPORT)	166410	39.62	19.92	3A	1057	42
KOS (AIRPORT)	167420	36.78	27.07	3A	687	27
LARISSA (AIRPORT)	166480	39.63	22.42	3B	420	17
LIMNOS (AIRPORT)	166500	39.92	25.23	3A	480	19
METHONI	167340	36.83	21.70	3A	688	27
MILOS	167380	36.72	24.45	3A	409	16
MYTILINI (AIRPORT)	166670	39.07	26.60	3A	662	26
NAXOS	167320	37.10	25.38	3A	602	24
RHODES (AIRPORT)	167490	36.40	28.08	3A	743	29
SAMOS (AIRPORT)	167230	37.70	26.92	3A	606	24
SKYROS (AIRPORT)	166840	38.97	24.48	3A	661	26
SOUDA (AIRPORT)	167460	35.48	24.12	3A	792	31
SOUDA BAY CRETE	167464	35.53	24.15	3A	555	22
THESSALONIKI (AIRPORT)	166220	40.52	22.97	3B	444	17
TRIPOLIS (AIRPORT)	167100	37.53	22.40	4A	802	32
Greenland (GRL)						
AASIAAT (EGEDESMINDE)	042200	68.70	–52.85	8	287	11
ANGISOQ	042850	59.98	–45.20	7	1524	60
APUTITEEQ	043510	67.78	–32.30	8	949	37
DANEBORG	043300	74.30	–20.22	8	236	9
DANMARKSHAVN	043200	76.77	–18.67	8	156	6
HALL LAND	042070	81.68	–59.93	8	153	6
HENRIK KROEYER HOLM	043130	80.65	–13.72	8	226	9
IKERMIIT	043730	64.78	–40.30	8	918	36
IKERMIUARSUK	043820	61.93	–42.07	7	1333	52
ILULISSAT (JAKOBSHAVN)	042210	69.23	–51.07	8	258	10
ITTOQQORTOORMIIT	043390	70.48	–21.95	8	411	16
KANGERLUSSUAQ (SDR.)	042310	67.02	–50.70	8	181	7
KAP MORRIS JESUP	043010	83.65	–33.37	8	202	8
KITSISSORSUIT	042080	74.03	–57.82	8	230	9
KITSISSUT (ATTU)	042280	67.78	–53.97	8	325	13
KITSISSUT (CAREY OEER)	042030	76.63	–73.00	8	212	8
NARSARSUAQ	042700	61.13	–45.43	7	615	24
NUNARSUIT	042660	60.77	–48.42	7	1008	40
NUUK (GODTHAAB)	042500	64.17	–51.75	8	735	29

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
NUUSSUAATAA	042140	70.68	–54.62	8	273	11
PAAMIUT (FREDERIKSHAAB)	042600	62.00	–49.67	8	885	35
PITUFFIK (THULE A.B.)	042020	76.53	–68.75	8	113	4
PRINS CHRISTIAN SUN	043900	60.05	–43.17	7	2102	83
QAQORTOQ (JULIANEHAAB)	042720	60.72	–46.05	7	851	33
SIORALIK	042420	65.02	–52.55	8	588	23
SISIMIUT (HOLSTEINS)	042300	66.92	–53.67	8	379	15
STATION NORD AWS	043120	81.60	–16.68	8	233	9
TASIILAQ (AMMASSALIK)	043600	65.60	–37.63	8	910	36
UKIIVIK (FREDERIKSHAAB)	042530	62.57	–50.42	7	858	34
Grenada (GRD)						
POINT SALINES AIRPO	789580	12.00	–61.78	0A	1197	47
Guam (GUM)						
ANDERSEN AFB	912180	13.57	144.92	0A	2354	93
GUAM WFO	912120	13.48	144.80	0A	2288	90
Guatemala (GTM)						
GUATEMALA (AEROPUERTO)	786410	14.58	–90.52	2A	1141	45
Guernsey (GGY)						
GUERNSEY AIRPORT	038940	49.43	–2.60	4A	872	34
Guyana (GUY)						
TIMEHRI\CHEDDI JAG	810020	6.50	–58.25	0A	2234	88
Honduras (HND)						
LA MESA (SAN PEDRO SULA)	787080	15.45	–87.93	0A	1192	47
TEGUCIGALPA	787200	14.05	–87.22	2A	1085	43
Hungary (HUN)						
BAJA	129600	46.18	19.02	5A	592	23
BEKESCSABA	129920	46.68	21.17	5A	551	22
BUDAORS	128380	47.45	18.97	5A	560	22
BUDAPEST/FERIHEGY I	128390	47.43	19.27	5A	533	21
BUDAPEST/PESTSZENTL	128430	47.43	19.18	5A	533	21
DEBRECEN	128820	47.48	21.60	5A	559	22
GYOR	128220	47.72	17.68	5A	573	23
KECSKEMET	129700	46.92	19.75	5A	521	20
KEKESTETO	128510	47.87	20.02	6A	614	24
KESZTHELY	129200	46.73	17.23	5A	667	26
MISKOLC	127720	48.10	20.77	5A	557	22
MOSONMAGYAROVAR	128150	47.88	17.28	5A	570	22
NAGYKANIZSA	129250	46.45	16.97	5A	767	30
NYIREGYHAZA/NAPKOR	128920	47.97	21.88	5A	541	21
PAKS	129500	46.58	18.85	5A	564	22
PAPA	128250	47.20	17.50	5A	646	25
PECS/POGANY	129420	46.00	18.23	4A	648	25
SIOFOK	129350	46.92	18.05	4A	612	24
SOPRON	128050	47.68	16.60	5A	663	26
SZEGED	129820	46.25	20.10	5A	507	20
SZENTGOTTHARD/FARKA	129100	46.92	16.32	5A	788	31
SZOLNOK	128600	47.12	20.23	5A	509	20
SZOMBATHELY	128120	47.27	16.63	5A	662	26
TASZAR	129320	46.40	17.92	4A	662	26
VESZPREM/SZENTKIRAL	128300	47.07	17.83	5A	617	24
ZALAEGERSZEG/ANDRAS	129150	46.87	16.80	5A	693	27
Iceland (ISL)						
AKUREYRI	040630	65.68	–18.08	7	500	20
AKURNES	040820	64.30	–15.22	7	1370	54
BERGSTADIR	040530	65.70	–19.62	7	504	20
BOLUNGAVIK	040050	66.15	–23.25	7	969	38
DALATANGI	040970	65.27	–13.58	7	1301	51
EGILSSTADIR	040890	65.28	–14.40	7	760	30
GUFUSKALAR	040040	64.90	–23.93	7	1067	42
HORNBJARGSVITI (LH)	040230	66.42	–22.38	7	1018	40
HVERAVELLIR	040560	64.87	–19.57	7	701	28
KEFLAVIK	040180	63.97	–22.60	6A	1109	44
KIRKJUBAEJARKLAUSTU	040640	63.78	–18.07	6A	1857	73
RAUFARHOFN	040770	66.45	–15.95	7	686	27
REYKJAVIK	040300	64.13	–21.90	6A	818	32
VESTMANNAEYJAR	040480	63.40	–20.28	6A	1572	62
India (IND)						
AGARTALA	427240	23.88	91.25	1A	2260	89
AHMADABAD	426470	23.07	72.63	0B	773	30
AKOLA	429340	20.70	77.07	0B	772	30
AURANGABAD CHIKALTH	430140	19.85	75.40	1A	799	31
BALASORE	428950	21.52	86.93	0A	1635	64
BANGALORE	432950	12.97	77.58	1A	997	39
BELGAUM/SAMBRA	431980	15.85	74.62	1A	1063	42
BHOPAL/BAIRAGARH	426670	23.28	77.35	1A	1207	48
BHUBANESWAR	429710	20.25	85.83	0A	1514	60
BHUJ-RUDRAMATA	426340	23.25	69.67	0B	362	14
BIKANER	421650	28.00	73.30	0B	285	11
BOMBAY/SANTACRUZ	430030	19.12	72.85	0A	2448	96
CALCUTTA/DUM DUM	428090	22.65	88.45	0A	1675	66
CHITRADURGA	432330	14.23	76.43	1B	608	24
COIMBATORE/PEELAMED	433210	11.03	77.05	0B	648	26
CUDDALORE	433290	11.77	79.77	0A	1384	54
CWC VISHAKHAPATNAM	431500	17.70	83.30	0A	996	39
GADAG	432010	15.42	75.63	1B	669	26
GAUHATI	424100	26.10	91.58	1A	1690	67
GOA/PANJIM	431920	15.48	73.82	0A	2840	112
GWALIOR	423610	26.23	78.25	1A	817	32
HISSAR	421310	29.17	75.73	1B	401	16
HYDERABAD AIRPORT	431280	17.45	78.47	0A	822	32
INDORE	427540	22.72	75.80	1A	956	38
JABALPUR	426750	23.20	79.95	1A	1336	53
JAGDALPUR	430410	19.08	82.03	1A	1435	56
JAIPUR/SANGANER	423480	26.82	75.80	1B	562	22
JAMSHEDPUR	427980	22.82	86.18	0A	1434	56
JODHPUR	423390	26.30	73.02	0B	342	13
KAKINADA	431890	16.95	82.23	0A	1048	41
KOZHIKODE	433140	11.25	75.78	0A	3163	125
KURNOOL	432130	15.80	78.07	0B	695	27
LUCKNOW/AMAUSI	423690	26.75	80.88	1A	1038	41
MACHILIPATNAM	431850	16.20	81.15	0A	1090	43
MADRAS/MINAMBAKKAM	432790	13.00	80.18	0A	1401	55
MANGALORE/BAJPE	432840	12.92	74.88	0A	3730	147
NAGPUR SONEGAON	428670	21.10	79.05	0A	1110	44
NELLORE	432450	14.45	79.98	0A	1046	41
NEW DELHI/PALAM	421810	28.57	77.12	1B	783	31

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
NEW DELHI/SAFDARJUN	421820	28.58	77.20	1B	783	31
PATIALA	421010	30.33	76.47	2B	728	29
PATNA	424920	25.60	85.10	1A	1169	46
PBO ANANTAPUR	432370	14.58	77.63	0B	533	21
POONA	430630	18.53	73.85	1B	733	29
RAJKOT	427370	22.30	70.78	0B	659	26
RATNAGIRI	431100	16.98	73.33	0A	2851	112
SHOLAPUR	431170	17.67	75.90	0B	716	28
SURAT	428400	21.20	72.83	0A	1252	49
THIRUVANANTHAPURAM	433710	8.48	76.95	0A	1795	71
TIRUCHCHIRAPALLI	433440	10.77	78.72	0A	915	36
VERAVAL	429090	20.90	70.37	0B	802	32
Indonesia (IDN)						
DENPASAR/NGURAH RAI	972300	–8.75	115.17	0A	1558	61
JAKARTA/SOEKARNO-HA	967490	–6.12	106.65	0A	1979	78
MEDAN/POLONIA	960350	3.57	98.68	0A	2465	97
MENADO/ SAM RATULAN	970140	1.53	124.92	0A	3143	124
PADANG/TABING	961630	–0.88	100.35	0A	3801	150
PEKAN BARU/SIMPANGT	961090	0.47	101.45	0A	2603	102
RENGAT/JAPURA	961710	–0.33	102.32	0A	2230	88
SIBOLGA/PINANGSORI	960730	1.55	98.88	0A	4076	160
SURABAYA/JUANDA	969350	–7.37	112.77	0A	1650	65
UJUNG PANDANG/HASAN	971800	–5.07	119.55	0A	3307	130
Iran, Islamic Republic of (IRN)						
ABADAN	408310	30.37	48.25	1B	160	6
AHWAZ	408110	31.33	48.67	1B	222	9
ANZALI	407180	37.47	49.47	3A	1427	56
ARAK	407690	34.10	49.77	4A	351	14
BABULSAR	407360	36.72	52.65	3A	799	31
BANDARABBASS	408750	27.22	56.37	0B	181	7
BIRJAND	408090	32.87	59.20	3B	190	7
ESFAHAN	408000	32.47	51.67	3B	143	6
HAMEDAN	407680	34.85	48.53	4A	351	14
KASHAN	407850	33.98	51.45	2B	141	6
KERMAN	408410	30.25	56.97	3B	157	6
KERMANSHAH	407660	34.27	47.12	4A	450	18
KHOY	407030	38.55	44.97	4B	359	14
MASHHAD	407450	36.27	59.63	4B	268	11
ORUMIEH	407120	37.53	45.08	4B	274	11
RAMSAR	407320	36.90	50.67	3A	1144	45
SABZEVAR	407430	36.22	57.67	3B	193	8
SHAHRUD	407390	36.42	54.95	4B	175	7
SHIRAZ	408480	29.53	52.53	3A	381	15
TABRIZ	407060	38.08	46.28	4B	270	11
TEHRAN-MEHRABAD	407540	35.68	51.32	3B	217	9
TORBAT-HEYDARIEH	407620	35.27	59.22	4B	282	11
ZAHEDAN	408560	29.47	60.88	2B	87	3
ZANJAN	407290	36.68	48.48	4B	314	12
Ireland (IRL)						
BELMULLET	039760	54.23	–10.00	4A	1185	47
BIRR	039650	53.08	–7.88	5A	825	32
CASEMENT AERODROME	039670	53.30	–6.43	5A	735	29
CLAREMORRIS	039700	53.72	–8.98	5A	1146	45
CLONES	039740	54.18	–7.23	5A	942	37
CONNAUGHT AIRPORT	039730	53.90	–8.82	5A	1264	50
CORK AIRPORT	039550	51.85	–8.48	5A	1221	48
DUBLIN AIRPORT	039690	53.43	–6.25	5A	743	29
KILKENNY	039600	52.67	–7.27	5A	842	33
MALIN HEAD	039800	55.37	–7.33	5A	1084	43
MULLINGAR	039710	53.53	–7.37	5A	945	37
ROCHES POINT	039520	51.80	–8.25	4A	945	37
ROSSLARE	039570	52.25	–6.33	4A	877	35
SHANNON AIRPORT	039620	52.70	–8.92	4A	960	38
VALENTIA OBSERVATOR	039530	51.93	–10.25	4A	1488	59
Isle of Man (IMN)						
ISLE OF MAN/RONALDS	032040	54.08	–4.63	5A	947	37
POINT OF AYRE (LH)	032080	54.42	–4.37	4A	838	33
Israel (ISR)						
BEER-SHEVA	401910	31.23	34.78	2B	193	8
BEN-GURION INT. AIR	401800	32.00	34.90	2A	563	22
EILAT	401990	29.55	34.95	1B	23	1
HAIFA	401550	32.80	35.03	2A	613	24
OVDA	401980	30.00	34.83	2B	25	1
SDE-DOV (TEL-AVIV)	401760	32.10	34.78	2A	564	22
Italy (ITA)						
ALGHERO	165200	40.63	8.28	3A	583	23
AMENDOLA	162610	41.53	15.72	3A	508	20
AVIANO (USAF)	160365	46.02	12.62	4A	1404	55
BARI/PALESE MACCHIE	162700	41.13	16.78	3A	549	22
BERGAMO/ORIO AL SER	160760	45.67	9.70	4A	1085	43
BOLOGNA/BORGO PANIG	161400	44.53	11.30	4A	725	29
BOLZANO	160200	46.47	11.33	4A	725	29
BRESCIA/GHEDI	160880	45.42	10.28	4A	896	35
BRINDISI	163200	40.65	17.95	3A	601	24
CAGLIARI/ELMAS	165600	39.25	9.07	3A	422	17
CAMPOBASSO	162520	41.57	14.65	4A	634	25
CAPO BELLAVISTA	165500	39.93	9.72	3A	604	24
CAPO CACCIA	165220	40.57	8.17	3A	521	21
CAPO FRASCA	165390	39.75	8.47	3A	541	21
CAPO MELE	161530	43.95	8.17	3A	786	31
CAPO PALINURO	163100	40.02	15.28	3A	766	30
CATANIA/FONTANAROSS	164600	37.47	15.05	3A	564	22
CATANIA/SIGONELLA	164590	37.40	14.92	3A	518	20
CERVIA	161480	44.22	12.30	4A	722	28
COZZO SPADARO	164800	36.68	15.13	3B	364	14
CROTONE	163500	39.00	17.07	3A	707	28
DOBBIACO	160330	46.73	12.22	6A	876	34
FALCONARA	161910	43.62	13.37	3A	809	32
FIRENZE/PERETOLA	161700	43.80	11.20	3A	847	33
FORLI	161470	44.20	12.07	4A	747	29
FUCINO	162270	41.88	13.58	4C	923	36
GELA	164530	37.08	14.22	3A	384	15
GENOVA/SESTRI	161200	44.42	8.85	3A	1110	44
GIOIA DEL COLLE	163120	40.77	16.93	3A	672	26
GRAZZANISE	162530	41.05	14.07	3A	930	37
GROSSETO	162060	42.75	11.07	3A	653	26

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

					Precipitation	
Country/LOCATION	**WMO#**	**Lat**	**Long**	**CZ**	**mm**	**in.**
ISOLA DI CARLOFORTE	165490	39.13	8.32	3A	571	22
LAMEZIA TERME	163620	38.90	16.25	3A	927	36
LAMPEDUSA	164900	35.50	12.60	2B	270	11
LATINA	162430	41.55	12.90	3A	969	38
LECCE	163320	40.23	18.15	3A	662	26
MARINA DI GINOSA	163250	40.43	16.88	3B	449	18
MESSINA	164200	38.20	15.55	3A	852	34
MILANO/LINATE	160800	45.43	9.28	4A	971	38
MILANO/MALPENSA	160660	45.62	8.73	4A	1087	43
MONTE ARGENTARIO	161680	42.38	11.17	4A	525	21
MONTE CIMONE	161340	44.20	10.70	7	778	31
MONTE SCURO	163440	39.33	16.40	5C	822	32
MONTE TERMINILLO	162190	42.47	12.98	6A	787	31
NAPLES	162894	40.90	14.30	3A	1019	40
NAPOLI/CAPODICHINO	162890	40.85	14.30	3A	1019	40
NOVARA/CAMERI	160640	45.52	8.67	4A	1087	43
NOVI LIGURE	161180	44.77	8.78	4A	812	32
OLBIA/COSTA SMERALD	165310	40.90	9.52	3A	535	21
PAGANELLA	160220	46.15	11.03	7	917	36
PALERMO/PUNTA RAISI	164050	38.18	13.10	3A	620	24
PANTELLERIA	164700	36.82	11.97	3B	442	17
PASSO ROLLE	160210	46.30	11.78	7	1044	41
PERUGIA	161810	43.08	12.50	4A	850	33
PESCARA	162300	42.43	14.20	3A	696	27
PIACENZA	160840	44.92	9.73	4A	911	36
PIAN ROSA	160520	45.93	7.70	8	513	20
PISA/S. GIUSTO	161580	43.68	10.38	3A	890	35
PONZA	162800	40.92	12.95	3A	631	25
PRATICA DI MARE	162450	41.65	12.45	3A	812	32
REGGIO CALABRIA	164220	38.07	15.65	3A	680	27
RESIA PASS	160083	46.83	10.50	6A	747	29
RIMINI	161490	44.03	12.62	4A	716	28
ROMA FIUMICINO	162420	41.80	12.23	3A	708	28
ROMA/CIAMPINO	162390	41.78	12.58	3A	800	32
RONCHI DEI LEGIONAR	161080	45.82	13.48	4A	1331	52
S. MARIA DI LEUCA	163600	39.82	18.35	3A	662	26
S. VALENTINO ALLA M	160080	46.75	10.53	6A	694	27
TORINO/BRIC DELLA C	160610	45.03	7.73	4A	816	32
TORINO/CASELLE	160590	45.22	7.65	4A	929	37
TRAPANI/BIRGI	164290	37.92	12.50	3A	470	18
TREVISO/ISTRANA	160980	45.68	12.10	4A	966	38
TREVISO/S. ANGELO	160990	45.65	12.18	4A	966	38
TRIESTE	161100	45.65	13.75	3A	1036	41
UDINE/RIVOLTO	160450	45.98	13.03	4A	1240	49
USTICA	164000	38.70	13.18	3A	400	16
VENEZIA/TESSERA	161050	45.50	12.33	4A	859	34
VERONA/VILLAFRANCA	160900	45.38	10.87	4A	769	30
Jamaica (JAM)						
KINGSTON/NORMAN MAN	783970	17.93	–76.78	0A	730	29
MONTEGO BAY/SANGSTE	783880	18.50	–77.92	0A	1184	47
Japan (JPN)						
ABASHIRI	474090	44.02	144.28	6A	819	32
ABURATSU	478350	31.58	131.40	3A	2593	102

					Precipitation	
Country/LOCATION	**WMO#**	**Lat**	**Long**	**CZ**	**mm**	**in.**
AIKAWA	476020	38.03	138.23	4A	1595	63
AJIRO	476680	35.05	139.10	3A	1832	72
AKITA	475820	39.72	140.10	4A	1727	68
AKUNE	478230	32.03	130.20	3A	2151	85
AOMORI	475750	40.82	140.77	5A	1325	52
ASAHIKAWA	474070	43.77	142.37	6A	1066	42
ASHIYA AB	478030	33.88	130.65	3A	1798	71
ASOSAN	478210	32.88	131.07	5A	2852	112
ATSUGI NAS	476790	35.45	139.45	3A	1556	61
CHIBA	476820	35.60	140.10	3A	1371	54
CHICHIBU	476410	35.98	139.07	4A	1382	54
CHICHIJIMA ISLAND	479710	27.08	142.18	2A	1321	52
CHITOSE (JASDF)	474340	42.82	141.68	6A	1212	48
CHITOSE AB	474250	42.80	141.67	6A	1212	48
CHOSHI	476480	35.73	140.85	3A	1641	65
ESASHI	474280	41.87	140.12	5A	1222	48
FUJISAN	476390	35.37	138.73	8	1624	64
FUKAURA	475740	40.65	139.93	5A	1508	59
FUKUE	478430	32.70	128.83	3A	1862	73
FUKUI	476160	36.05	136.22	4A	2381	94
FUKUOKA	478070	33.58	130.38	3A	1620	64
FUKUOKA AIRPORT	478080	33.58	130.45	3A	1620	64
FUKUSHIMA	475950	37.77	140.47	4A	1148	45
FUKUYAMA	477670	34.45	133.25	3A	1186	47
FUSHIKI	476060	36.80	137.05	4A	2302	91
FUTENMA	479330	26.27	127.75	2A	2078	82
GIFU	476320	35.40	136.77	3A	1820	72
GIFU AB	476340	35.38	136.87	3A	1820	72
HABORO	474040	44.37	141.70	6A	1322	52
HACHIJOJIMA	476780	33.12	139.78	3A	3153	124
HACHINOHE	475810	40.53	141.52	5A	1074	42
HACHINOHE AB	475150	40.55	141.47	5A	1114	44
HAGI	477540	34.42	131.40	3A	1773	70
HAKODATE	474300	41.82	140.75	5A	1172	46
HAMADA	477550	34.90	132.07	3A	1649	65
HAMAMATSU	476540	34.72	137.72	3A	1859	73
HAMAMATSU AB	476810	34.75	137.70	3A	1859	73
HIKONE	477610	35.28	136.25	4A	2007	79
HIMEJI	477690	34.83	134.67	3A	1352	53
HIRADO	478050	33.37	129.55	3A	2036	80
HIROO	474400	42.30	143.32	6A	1511	59
HIROSHIMA	477650	34.40	132.47	3A	1565	62
HITA	478140	33.32	130.93	3A	1883	74
HITOYOSHI	478240	32.22	130.75	3A	2414	95
HOFU AB	477880	34.03	131.55	3A	1829	72
HYAKURI AB	477150	36.18	140.42	4A	1308	52
IIDA	476370	35.52	137.82	4A	1537	61
IIZUKA	478090	33.65	130.70	3A	1780	70
IRAKO	476530	34.63	137.10	3A	1664	66
IROZAKI	476660	34.60	138.85	3A	2022	80
IRUMA AB	476430	35.83	139.42	4A	1432	56
ISHIGAKIJIMA	479180	24.33	124.17	1A	2064	81
ISHINOMAKI	475920	38.43	141.30	4A	1115	44

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
IWAKUNI	477640	34.15	132.23	3A	1693	67	NAHA AIRPORT	479300	26.20	127.65	2A	2026	80
IWAMIZAWA	474130	43.22	141.78	6A	1211	48	NARA	477800	34.70	135.83	3A	1504	59
IWOJIMA	479810	24.78	141.32	1A	1205	47	NAZE	479090	28.38	129.50	2A	2856	112
IZUHARA	478000	34.20	129.30	3A	2207	87	NEMURO	474200	43.33	145.58	6A	1040	41
KADENA (USAF\NAVY)	479310	26.35	127.77	2A	2078	82	NEW TOKYO INTERNATI	476860	35.77	140.38	4A	1353	53
KAGOSHIMA	478270	31.55	130.55	3A	2245	88	NIIGATA	476040	37.92	139.05	4A	1802	71
KANAZAWA	476050	36.58	136.63	4A	2465	97	NIKKO	476900	36.73	139.50	6A	1763	69
KANOYA AB	478500	31.37	130.83	3A	2421	95	NOBEOKA	478220	32.58	131.65	3A	2359	93
KANSAI INTERNATIONA	477740	34.43	135.25	3A	1412	56	NYUTABARU AB	478540	32.08	131.45	3A	2472	97
KARUIZAWA	476220	36.35	138.55	5A	1275	50	OBIHIRO	474170	42.92	143.22	6A	1007	40
KATSUURA	476740	35.15	140.32	3A	1873	74	OFUNATO	475120	39.07	141.72	4A	1464	58
KAWAGUCHIKO	476400	35.50	138.77	4A	1671	66	OITA	478150	33.23	131.62	3A	1670	66
KITAMIESASHI	474020	44.93	142.58	6A	1170	46	OKAYAMA	477680	34.67	133.92	3A	1208	48
KOBE	477700	34.70	135.22	3A	1376	54	OKINOERABU	479420	27.43	128.70	2A	2084	82
KOCHI	478930	33.57	133.55	3A	2601	102	OMAEZAKI	476550	34.60	138.22	3A	2069	81
KOFU	476380	35.67	138.55	4A	1304	51	OMINATO AB	475160	41.23	141.13	5A	1288	51
KOMATSU AB	477040	36.40	136.40	4A	2453	97	OMU	474050	44.58	142.97	6A	988	39
KOMATSUSHIMA AB	478840	34.00	134.63	3A	1870	74	ONAHAMA	475980	36.95	140.90	4A	1380	54
KUMAGAYA	476260	36.15	139.38	3A	1311	52	OSAKA	477720	34.68	135.52	3A	1303	51
KUMAMOTO	478190	32.82	130.70	3A	2280	90	OSAKA INTERNATIONAL	477710	34.78	135.43	3A	1431	56
KUMEJIMA	479290	26.33	126.80	2A	1851	73	OSHIMA	476750	34.75	139.38	3A	1880	74
KURE	477660	34.23	132.55	3A	1442	57	OTARU	474110	43.18	141.02	5A	1245	49
KUSHIRO	474180	42.98	144.38	6A	1074	42	OWASE	476630	34.07	136.20	3A	3605	142
KUTCHAN	474330	42.90	140.75	6A	1405	55	OZUKI AB	477870	34.05	131.05	3A	1776	70
KYOTO	477590	35.02	135.73	3A	1662	65	RUMOI	474060	43.95	141.63	6A	1248	49
MAEBASHI	476240	36.40	139.07	4A	1173	46	SAGA	478130	33.27	130.30	3A	1806	71
MAIZURU	477500	35.45	135.32	4A	1886	74	SAIGO	477400	36.20	133.33	4A	1599	63
MAKURAZAKI	478310	31.27	130.30	3A	2254	89	SAKAI	477420	35.55	133.23	3A	1921	76
MATSUE	477410	35.45	133.07	3A	1737	68	SAKATA	475870	38.92	139.85	4A	1883	74
MATSUMOTO	476180	36.25	137.97	4A	1024	40	SAPPORO	474120	43.07	141.33	5A	1120	44
MATSUSHIMA AB	475910	38.40	141.22	4A	1157	46	SASEBO	478120	33.15	129.73	3A	2024	80
MATSUYAMA	478870	33.85	132.78	3A	1443	57	SENDAI	475900	38.27	140.90	4A	1242	49
MIHO AB	477430	35.48	133.23	3A	1894	75	SHIMIZU	478980	32.72	133.02	3A	2465	97
MINAMIDAITOJIMA	479450	25.83	131.23	2A	1596	63	SHIMOFUSA AB	477270	35.80	140.02	3A	1296	51
MINAMITORISHIMA	479910	24.28	153.98	1A	1014	40	SHIMONOSEKI	477620	33.95	130.93	3A	1772	70
MISAWA AB	475800	40.70	141.37	5A	1114	44	SHINJO	475200	38.75	140.32	5A	1669	66
MISHIMA	476570	35.12	138.93	3A	1888	74	SHIONOMISAKI	477780	33.45	135.77	3A	2605	103
MITO	476290	36.38	140.47	4A	1324	52	SHIRAKAWA	475970	37.13	140.22	4A	1367	54
MIYAKEJIMA	476770	34.12	139.52	3A	1880	74	SHIZUHAMA AB	476580	34.82	138.30	3A	2215	87
MIYAKO	475850	39.65	141.97	5A	1306	51	SHIZUOKA	476560	34.98	138.40	3A	2215	87
MIYAKOJIMA	479270	24.80	125.28	1A	2012	79	SUKUMO	478970	32.92	132.70	3A	2007	79
MIYAKONOJO	478290	31.73	131.08	3A	2527	99	SUMOTO	477760	34.33	134.90	3A	1482	58
MIYAZAKI	478300	31.93	131.42	3A	2480	98	SUTTSU	474210	42.80	140.22	5A	1212	48
MOMBETSU	474350	44.35	143.35	6A	851	33	SUWA	476200	36.05	138.12	4A	1205	47
MORIOKA	475840	39.70	141.17	5A	1302	51	TADOTSU	478900	34.28	133.75	3A	1191	47
MURORAN	474230	42.32	140.98	5A	1263	50	TAKADA	476120	37.10	138.25	4A	2619	103
MUROTOMISAKI	478990	33.25	134.18	3A	2455	97	TAKAMATSU	478910	34.32	134.05	3A	1087	43
MUTSU	475760	41.28	141.22	5A	1288	51	TAKAYAMA	476170	36.15	137.25	4A	1653	65
NAGANO	476100	36.67	138.20	4A	1176	46	TANEGASHIMA	478370	30.73	130.98	2A	2157	85
NAGASAKI	478170	32.73	129.87	3A	1898	75	TATEYAMA	476720	34.98	139.87	3A	1797	71
NAGOYA	476360	35.17	136.97	3A	1541	61	TATEYAMA AB	476880	34.98	139.83	3A	1797	71
NAGOYA AIRPORT	476350	35.25	136.92	3A	1541	61	TOKUSHIMA	478950	34.07	134.57	3A	1622	64
NAHA	479360	26.20	127.68	2A	2026	80	TOKUSHIMA AB	478810	34.13	134.62	3A	1622	64

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
TOKYO	476620	35.68	139.77	3A	1441	57
TOKYO INTERNATIONAL	476710	35.55	139.78	3A	1441	57
TOMAKOMAI	474240	42.62	141.55	6A	1229	48
TOTTORI	477460	35.48	134.20	3A	1814	71
TOYAMA	476070	36.72	137.20	4A	2252	89
TOYOOKA	477470	35.53	134.82	4A	2019	80
TSU	476510	34.73	136.52	3A	1768	70
TSUIKI AB	478400	33.68	131.05	3A	1795	71
TSURUGA	476310	35.65	136.07	3A	2264	89
TSUYAMA	477560	35.07	134.02	4A	1578	62
UENO	476490	34.77	136.15	4A	1531	60
UNZENDAKE	478180	32.73	130.27	4A	2576	101
URAKAWA	474260	42.17	142.78	5A	1123	44
USHIBUKA	478380	31.72	130.03	3A	2244	88
UTSUNOMIYA	476150	36.55	139.87	4A	1543	61
UWAJIMA	478920	33.23	132.55	3A	1825	72
WAJIMA	476000	37.40	136.90	4A	2200	87
WAKAMATSU	475700	37.48	139.92	4A	1258	50
WAKAYAMA	477770	34.23	135.17	3A	1458	57
WAKKANAI	474010	45.42	141.68	6A	1116	44
YAKUSHIMA	478360	30.38	130.67	2A	2157	85
YAMAGATA	475880	38.25	140.35	4A	1172	46
YAMAGUCHI	477840	34.17	131.45	3A	1827	72
YOKKAICHI	476840	34.93	136.58	3A	1714	67
YOKOHAMA	476700	35.43	139.65	3A	1561	61
YOKOSUKA	476960	35.28	139.67	3A	1577	62
YOKOTA (JASDF/USAF)	476420	35.75	139.35	4A	1474	58
YONAGO	477440	35.43	133.33	3A	1860	73
YONAGUNIJIMA	479120	24.47	123.02	1A	1708	67
Jersey (JEY)						
JERSEY AIRPORT	038950	49.22	–2.20	4A	850	33
Jordan (JOR)						
AMMAN AIRPORT	402700	31.98	35.98	3B	271	11
AQABA AIRPORT	403400	29.55	35.00	1B	23	1
H-4 IRWAISHED	402500	32.50	38.20	2B	82	3
IRBED	402550	32.55	35.85	3A	483	19
MAAN	403100	30.17	35.78	3B	39	2
MAFRAQ	402650	32.37	36.25	3B	155	6
QUEEN ALIA AIRPORT	402720	31.72	35.98	3B	237	9
Kazakhstan (KAZ)						
AKKOL	350850	52.00	70.95	7	351	14
AKKUDUK	382320	42.97	54.12	5B	131	5
AKTOBE	352290	50.28	57.15	7	305	12
ALMATY	368700	43.23	76.93	5A	635	25
AMANGELDY	353610	50.13	65.23	7	229	9
ARALSKOE MORE	357460	46.78	61.65	6B	144	6
ASTANA	351880	51.13	71.37	7	315	12
ATBASAR	350780	51.82	68.37	7	305	12
ATYRAU	357000	47.12	51.92	5B	156	6
BALHASH	357960	46.80	75.08	6B	144	6
BALKASINO	289780	52.53	68.75	7	359	14
BARSHATAS	364980	48.17	78.67	7	215	8
BERLIK	353760	49.88	69.52	7	240	9
BLACOVESCHENKA	287660	54.37	66.97	7	349	14
BOLSHE NARYMSKOE	364280	49.20	84.52	7	382	15
CARDARA	384390	41.37	68.00	4B	250	10
CELKAR	356330	47.85	59.62	7	185	7
CIRIK-RABAT	380490	44.07	62.90	5B	105	4
DZHAMBEJTY	352170	50.25	52.57	6B	265	10
DZHUSALY	359530	45.50	64.08	5B	140	6
ESIL	350670	51.88	66.33	7	281	11
FORT SHEVCHENKO	380010	44.55	50.25	4B	143	6
IRGIZ	355420	48.62	61.27	7	174	7
IRTYSHSK	298070	53.35	75.45	7	293	12
ISILKUL	286880	54.90	71.25	7	343	14
KARAGANDA	353940	49.80	73.15	7	331	13
KARSAKPAJ	356630	47.83	66.75	7	190	7
KAZALINSK	358490	45.77	62.12	6B	129	5
KOKPEKTY	365350	48.75	82.37	7	315	12
KOKSHETAY	288790	53.28	69.38	7	310	12
KOZASAJ	355290	48.22	57.12	6B	201	8
KULSARY	357150	46.80	53.92	6B	179	7
KUSTANAI	289520	53.22	63.62	7	328	13
KYZYLORDA	380620	44.85	65.50	5B	147	6
KZYLZAR	355760	48.30	69.65	7	193	8
LENINOGORSK	362080	50.33	83.55	7	656	26
MOINTY	357910	47.20	73.35	7	186	7
MUGODZARSKAJA	355320	48.63	58.50	6A	306	12
NOVYJ USHTOGAN	346910	47.90	48.80	5B	181	7
PAVLODAR	360030	52.30	76.93	7	256	10
PETROPAVLOVSK	286790	54.83	69.15	7	368	15
POLTAVKA	287860	54.37	71.75	7	333	13
RUZAEVKA	289660	52.82	66.97	7	332	13
SAM	359250	45.40	56.12	5B	152	6
SEMIJARKA	361520	50.87	78.35	7	227	9
SEMIPALATINSK	361770	50.42	80.30	7	286	11
SHYMKENT	383280	42.32	69.70	4A	554	22
SUCINSK	289840	52.95	70.22	7	328	13
TAIPAK	354060	49.05	51.87	6B	200	8
TASTY	380810	44.80	69.12	5B	166	7
TEMIR	354260	49.15	57.12	6A	273	11
TORGAI	353580	49.63	63.50	7	209	8
TURKESTAN	381980	43.27	68.22	4B	203	8
UC-ARAL	367290	46.17	80.93	6B	285	11
UIL	354160	49.07	54.68	6B	238	9
UJUK	382030	43.78	70.93	5B	213	8
ULANBEL`	380910	44.80	71.07	5B	158	6
URALSK	351080	51.25	51.28	6A	324	13
URDZHAR	366390	47.12	81.62	6A	443	17
URICKY	288670	53.32	65.55	7	343	14
VOLODARSKOE	288770	53.32	68.10	7	392	15
ZAJSAN	366650	47.47	84.92	7	301	12
ZHALTYR	351730	51.62	69.80	7	326	13
ZHAMBYL	383410	42.85	71.38	5B	334	13
ZHARKENT	368590	44.17	80.07	5B	180	7
ZHARYK	354970	48.85	72.87	7	330	13

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
ZHEZKAZGAN	356710	47.80	67.72	7	190	7
ZLIKHA	359690	45.25	67.07	5B	141	6
ZMEINOGORSK	360380	51.15	82.20	7	664	26
ZVERINOGOLOVSKAJA	287560	54.47	64.87	7	343	14
Kenya (KEN)						
EMBU	637200	–0.50	37.45	3C	1173	46
GARISSA	637230	–0.47	39.63	0B	366	14
KISUMU	637080	–0.10	34.75	2A	1345	53
KITALE	636610	1.02	35.00	3A	1237	49
LODWAR	636120	3.12	35.62	0B	167	7
MAKINDU	637660	–2.28	37.83	2B	581	23
MARSABIT	636410	2.30	37.90	2A	821	32
MERU	636950	0.08	37.65	3C	1371	54
MOMBASA	638200	–4.03	39.62	1A	1095	43
MOYALE	636190	3.53	39.03	2A	701	28
NAIROBI/KENYATTA AI	637400	–1.32	36.92	3C	733	29
NAKURU	637140	–0.27	36.10	3C	907	36
NYERI	637170	–0.50	36.97	3C	1696	67
VOI	637930	–3.40	38.57	1B	577	23
Kiribati (KIR)						
TARAWA	916100	1.35	172.92	0A	2092	82
Korea, Democratic People's Republic of (PRK)						
ANJU	470500	39.62	125.65	5A	1162	46
CHANGJIN	470310	40.37	127.25	7	857	34
CHANGJON	470610	38.73	128.18	4A	1607	63
CHONGJIN	470080	41.78	129.82	5A	642	25
CHUNGGANG	470140	41.78	126.88	6A	837	33
HAEJU	470690	38.03	125.70	4A	1153	45
HAMHEUNG	470410	39.93	127.55	5A	966	38
HUICHON	470390	40.17	126.25	5A	1287	51
HYESAN	470160	41.40	128.17	7	675	27
KAESONG	470700	37.97	126.57	5A	1393	55
KANGGYE	470200	40.97	126.60	6A	953	38
KIMCHAEK	470250	40.67	129.20	5A	735	29
KUSONG	470370	39.98	125.25	5A	1308	52
NAMPO	470600	38.72	125.38	5A	976	38
PUNGSAN	470220	40.82	128.15	7	697	27
PYONGGANG	470750	38.42	127.28	5A	1388	55
PYONGYANG	470580	39.03	125.78	5A	1039	41
RYONGYON	470680	38.15	124.88	5A	981	39
SAMJIYON	470050	41.82	128.30	7	908	36
SARIWON	470650	38.52	125.77	5A	1043	41
SENBONG	470030	42.32	130.40	6A	788	31
SINGYE	470670	38.50	126.53	5A	1358	53
SINPO	470460	40.03	128.18	5A	826	33
SINUIJU	470350	40.10	124.38	5A	969	38
SUPUNG	470280	40.45	124.93	5A	1101	43
WONSAN	470550	39.18	127.43	4A	1452	57
YANGDOK	470520	39.22	126.65	5A	1220	48
Korea, Republic of (KOR)						
ANDONG	471360	36.57	128.72	4A	1024	40
BAENGNYEONGDO AB	471030	37.93	124.67	4A	934	37
BUSAN	471590	35.10	129.03	3A	1502	59
CHEJU	471850	33.28	126.17	3A	1326	52
CHEONGJU	471310	36.63	127.45	4A	1208	48
CHEONGJU INTL AIRPO	471280	36.72	127.50	4A	1215	48
CHEORWON	470950	38.15	127.30	5A	1376	54
CHUNCHEON	471010	37.90	127.73	5A	1320	52
CHUPUNGNYEONG	471350	36.22	128.00	4A	1146	45
DAEGU	471430	35.88	128.62	4A	1028	40
DAEGU INTL AIRPORT	471420	35.90	128.67	4A	1028	40
DAEGWALLYEONG	471000	37.68	128.77	6A	1684	66
DAEJEON	471330	36.37	127.37	4A	1368	54
DONGHAE RADAR	471060	37.50	129.13	4A	1299	51
GANGNEUNG	471050	37.75	128.90	4A	1426	56
GANGNEUNG AB	471070	37.75	128.95	4A	1426	56
GIMHAE INTL AIRPORT	471530	35.18	128.93	4A	1498	59
GIMPO INTL AIRPORT	471100	37.57	126.78	5A	1386	55
GUNSAN	471400	36.00	126.77	4A	1188	47
GWANGJU	471560	35.17	126.90	4A	1337	53
GWANGJU AB	471580	35.12	126.82	4A	1337	53
INCHEON	471120	37.47	126.63	4A	1174	46
JEJU	471840	33.52	126.53	3A	1467	58
JEJU INTL AIRPORT	471820	33.52	126.50	3A	1467	58
JEONJU	471460	35.82	127.15	4A	1286	51
JINJU	471920	35.20	128.12	4A	1526	60
KUNSAN (US/KOR-AFB)	471410	35.90	126.62	4A	1205	47
MASAN	471550	35.18	128.57	3A	1532	60
MOESULPO AB	471870	33.20	126.27	3A	1486	59
MOKPO	471650	34.82	126.38	4A	1125	44
OSAN AB	471220	37.10	127.03	4A	1302	51
POHANG	471380	36.03	129.38	4A	1135	45
POHANG AB	471390	35.98	129.42	4A	1135	45
PYONGTAEK (A-511)	471270	36.97	127.03	4A	1250	49
SACHON (KOR-AFB)	471610	35.08	128.08	4A	1525	60
SEOGWIPO	471890	33.25	126.57	3A	1789	70
SEOSAN	471290	36.77	126.50	4A	1199	47
SEOUL	471080	37.57	126.97	4A	1400	55
SEOUL (KOR-AF HQ)	471170	37.50	126.93	4A	1400	55
SEOUL AB	471110	37.43	127.12	4A	1333	52
SOKCHO	470900	38.25	128.57	4A	1327	52
SUWON	471190	37.27	126.98	4A	1296	51
TONGYEONG	471620	34.85	128.43	3A	1423	56
ULJIN	471300	36.98	129.42	4A	1111	44
ULLEUNGDO	471150	37.48	130.90	4A	1334	53
ULSAN	471520	35.55	129.32	4A	1287	51
WANDO	471700	34.40	126.70	4A	1390	55
WONJU	471140	37.33	127.95	4A	1281	50
YECHEON AB	471340	36.63	128.35	4A	1141	45
YEONGWOL	471210	37.18	128.47	5A	1245	49
YEOSU	471680	34.73	127.75	4A	1415	56
Kuwait (KWT)						
KUWAIT INTERNATIONA	405820	29.22	47.97	1B	112	4
Kyrgyzstan (KGZ)						
BISHKEK	383530	42.85	74.53	5A	439	17
DZHALAL-ABAD	386130	40.92	72.95	4A	472	19

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
NARYN	369740	41.43	76.00	7	297	12
OSH	386150	40.53	72.80	4B	333	13
TALAS	383450	42.52	72.22	5A	327	13
TIAN-SHAN	369820	41.88	78.23	8	291	11
TOKMAK	369110	42.83	75.28	4A	452	18
Latvia (LTV)						
AINAZI	262290	57.87	24.37	6A	633	25
DAUGAVPILS	265440	55.87	26.62	6A	631	25
GULBENE	263480	57.13	26.72	6A	665	26
KOLKA	263130	57.75	22.60	6A	613	24
LIEPAJA	264060	56.48	21.02	6A	673	26
MERSRAGS	263240	57.35	23.12	6A	641	25
REZEKNE	264460	56.53	27.27	6A	614	24
RIGA	264220	56.97	24.05	6A	654	26
RIGA	264225	56.92	23.97	6A	654	26
VALGA	262470	57.78	26.03	6A	680	27
Lebanon (LBN)						
BEYROUTH (AEROPORT)	401000	33.82	35.48	2A	784	31
Libya (LBY)						
AGEDABIA	620550	30.72	20.17	2B	152	6
BENINA	620530	32.10	20.27	2B	258	10
MISURATA	620160	32.42	15.05	2B	277	11
SIRTE	620190	31.20	16.58	2B	180	7
TRIPOLI INTERNATION	620100	32.70	13.08	2B	301	12
ZUARA	620070	32.88	12.08	2B	243	10
Liechtenstein (LIE)						
VADUZ (LIECHTENSTEIN)	069900	47.13	9.52	5A	1300	51
Lithuania (LTU)						
BIRZAI	265310	56.20	24.77	6A	608	24
KAUNAS	266290	54.88	23.83	6A	632	25
KLAIPEDA	265090	55.73	21.07	5A	720	28
LAUKUVA	265180	55.62	22.23	6A	801	32
SIAULIAI	265240	55.93	23.32	6A	595	23
UTENA	266330	55.53	25.60	6A	664	26
VILNIUS	267300	54.63	25.28	6A	672	26
Luxembourg (LUX)						
LUXEMBOURG/LUXEMBOU	065900	49.62	6.22	5A	835	33
Macedonia (MKD)						
BITOLA	135830	41.05	21.37	4A	623	25
KRIVA PALANKA	134930	42.20	22.33	5A	586	23
OHRID	135780	41.12	20.80	4A	749	29
SKOPJE- AIRPORT	135860	41.97	21.65	4A	513	20
Macao (MAC)						
TAIPA GRANDE	450110	22.15	113.60	2A	1958	77
Madagascar (MDG)						
ANTANANARIVO/IVATO	670830	–18.80	47.48	3A	1438	57
MAHAJANGA	670270	–15.67	46.35	0A	1429	56
TOAMASINA	670950	–18.12	49.40	1A	3287	129
Malaysia (MYS)						
BINTULU	964410	3.20	113.03	0A	3811	150
KOTA BHARU	486150	6.17	102.28	0A	2627	103
KOTA KINABALU	964710	5.93	116.05	0A	2603	102
KUALA LUMPUR SUBANG	486470	3.12	101.55	0A	2473	97
KUANTAN	486570	3.78	103.22	0A	2981	117
KUCHING	964130	1.48	110.33	0A	4215	166
LABUAN	964650	5.30	115.25	0A	3388	133
MALACCA	486650	2.27	102.25	0A	1940	76
MIRI	964490	4.33	113.98	0A	2847	112
PENANG/BAYAN LEPAS	486010	5.30	100.27	0A	2387	94
SANDAKAN	964910	5.90	118.07	0A	3224	127
SIBU	964210	2.33	111.83	0A	3389	133
SITIAWAN	486200	4.22	100.70	0A	1726	68
TAWAU	964810	4.27	117.88	0A	2218	87
Maldives (MDV)						
MALE	435550	4.20	73.53	0A	1493	59
Mali (MLI)						
BAMAKO/SENOU	612910	12.53	–7.95	0A	944	37
Malta (MLT)						
LUQA	165970	35.85	14.48	3A	517	20
Marshall Islands (MHL)						
KWAJALEIN MISSLE RAN	913660	8.72	167.73	0A	2533	100
MAJURO WSO AP	913760	7.08	171.38	0A	3321	131
Martinique (MTQ)						
LE LAMENTIN	789250	14.60	–61.00	0A	1110	44
Mauritania (MRT)						
NOUADHIBOU	614150	20.93	–17.03	2B	17	1
NOUAKCHOTT	614420	18.10	–15.95	1B	87	3
Mauritius (MUS)						
AGALEGA	619740	–10.43	56.75	0A	1153	45
PLAISANCE (MAURITIUS)	619900	–20.43	57.68	1A	1069	42
RODRIGUES	619880	–19.68	63.42	1A	1027	40
VACOAS (MAURITIUS)	619950	–20.30	57.50	2A	1069	42
Mayotte (MYT)						
DZAOUDZI/PAMANZI	670050	–12.80	45.28	0A	971	38
Mexico (MEX)						
AEROP. INTERNACIONA	766790	19.43	–99.13	3A	764	30
AEROP.INTERNACIONAL	766440	20.98	–89.65	0A	935	37
CANCUN INTL	765906	21.03	–86.87	0A	1283	51
DE GUANAJUATO INTL	765773	20.98	–101.48	2A	698	27
DON MIGUEL Y HIDALG	766133	20.52	–103.30	3A	944	37
GENERAL ABELARDO L	760013	32.53	–116.97	3B	338	13
GENERAL FRANCISCO J	765493	22.28	–97.87	1A	969	38
GENERAL HERIBERTO J	766913	19.13	–96.18	1A	1755	69
GENERAL JUAN N ALVA	768056	16.75	–99.75	0A	1428	56
GENERAL LEOBARDO C	765255	22.88	–102.68	3C	391	15
GENERAL MARIANO ESC	763943	25.77	–100.10	2B	637	25
GENERAL RAFAEL BUEL	764593	23.15	–106.27	1A	943	37
GUANAJUATO	765770	21.00	–101.28	3A	698	27
LICENCIADO ADOLFO L	766753	19.33	–99.57	3A	845	33
LICENCIADO BENITO J	766793	19.43	–99.07	3A	848	33
LICENCIADO GUSTAVO	766013	20.67	–105.25	1A	1092	43
MAZATLAN/G.BUELNA I	764594	23.15	–106.25	1A	968	38
MONTERREY (CITY)	763930	25.73	–100.30	2B	637	25
PUERTO VALLARTA	766014	20.68	–105.25	1A	1092	43
SAN LUIS POTOSI	765390	22.18	–100.98	3B	401	16
TAMPICO/GEN FJ MINA	765494	22.28	–97.85	1A	969	38

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
VERACRUZ/GEN JARA	766910	19.15	–96.18	1A	1755	69
Micronesia, Federated States of (FSM)						
CHUUK WSO AP	913340	7.45	151.83	0A	3523	139
POHNPEI WSO	913480	6.97	158.22	0A	4670	184
YAP ISLAND WSO AP	914130	9.48	138.08	0A	3089	122
Moldova (MDA)						
KISINEV	338150	47.02	28.98	5A	543	21
Mongolia (MNG)						
ALTAI	442770	46.40	96.25	8	170	7
ARVAIHEER	442880	46.27	102.78	7	231	9
BAITAG	442650	46.12	91.47	7	87	3
BARUUNHARAA	442410	48.92	106.07	7	290	11
BARUUNTURUUN	442130	49.65	94.40	8	215	8
BARUUN-URT	443050	46.68	113.28	7	183	7
BAYANBULAG	442750	46.83	98.08	8	134	5
BAYANDELGER	443520	45.73	112.37	7	195	8
BAYANHONGOR	442870	46.13	100.68	7	209	8
BAYAN-OVOO	443020	47.78	112.12	7	283	11
BULGAN	442390	48.80	103.55	7	313	12
CHOIBALSAN	442590	48.08	114.55	7	100	4
CHOIR	442980	46.45	108.22	7	170	7
DALANZADGAD	443730	43.58	104.42	7	121	5
DASHBALBAR	442560	49.55	114.40	7	318	13
ERDENEMANDAL	442370	48.53	101.38	7	281	11
GALUUT	442840	46.70	100.13	8	210	8
HATGAL	442070	50.43	100.15	8	277	11
HOVD	442180	48.02	91.57	7	114	4
HUJIRT	442850	46.90	102.77	7	295	12
HUTAG	442320	49.38	102.70	7	141	6
KHALKH-GOL	443130	47.62	118.62	7	299	12
MAANTI	442940	47.30	107.48	8	224	9
MANDALGOBI	443410	45.77	106.28	7	141	6
MATAD	443140	47.17	115.63	7	233	9
MUREN	442310	49.63	100.17	7	235	9
OMNO-GOBI	442150	49.02	91.72	7	125	5
RINCHINLHUMBE	442030	51.12	99.67	8	269	11
SAIKHAN-OVOO	443360	45.45	103.90	7	123	5
SAINSHAND	443540	44.90	110.12	7	111	4
TARIALAN	442300	49.57	102.00	7	297	12
TOSONTSENGEL	442250	48.73	98.20	8	206	8
TSETSERLEG	442820	47.45	101.47	7	330	13
TSOGT-OVOO	443470	44.42	105.32	7	95	4
ULAANBAATAR	442920	47.92	106.87	7	298	12
ULAANGOM	442120	49.80	92.08	8	132	5
ULGI	442140	48.93	89.93	7	107	4
ULIASTAI	442720	47.75	96.85	8	203	8
UNDERKHAAN	443040	47.32	110.63	7	249	10
ZAMYN-UUD	443580	43.73	111.90	7	119	5
Morocco (MAR)						
AGADIR	602500	30.38	–9.57	3B	255	10
AGADIR AL MASSIRA	602520	30.32	–9.40	2B	234	9
AL HOCEIMA	601070	35.18	–3.85	3B	328	13
BENI-MELLAL	601910	32.37	–6.40	3A	419	16
CASABLANCA	601550	33.57	–7.67	3A	428	17
ERRACHIDIA	602100	31.93	–4.40	2B	141	6
ESSAOUIRA	602200	31.52	–9.78	3C	303	12
FES-SAIS	601410	33.93	–4.98	3A	532	21
MARRAKECH	602300	31.62	–8.03	2B	245	10
MEKNES	601500	33.88	–5.53	3A	581	23
MIDELT	601950	32.68	–4.73	3B	212	8
NADOR-AROUI	603400	34.98	–3.02	3B	358	14
NOUASSEUR	601560	33.37	–7.58	3A	381	15
OUARZAZATE	602650	30.93	–6.90	2B	88	3
OUJDA	601150	34.78	–1.93	3B	335	13
RABAT-SALE	601350	34.05	–6.77	3A	563	22
SAFI	601850	32.28	–9.23	3A	388	15
TANGER (AERODROME)	601010	35.73	–5.90	3A	750	30
TAZA	601270	34.22	–4.00	3A	681	27
TETUAN/SANIA RAMEL	603180	35.58	–5.33	3A	684	27
Mozambique (MOZ)						
MAPUTO/MAVALANE	673410	–25.92	32.57	2A	791	31
Namibia (NAM)						
WALVIS BAY (PELICAN BAY)	681040	–22.88	14.43	3C	12	0
WINDHOEK	681100	–22.57	17.10	2B	354	14
Netherlands (NLD)						
AMSTERDAM AP SCHIPH	062400	52.30	4.77	5A	829	33
DE BILT	062600	52.10	5.18	5A	818	32
DE KOOY	062350	52.92	4.78	5A	768	30
DEELEN	062750	52.07	5.88	5A	858	34
EINDHOVEN	063700	51.45	5.42	5A	796	31
F3-FB-1	062390	54.85	4.70	5A	956	38
GILZE RIJEN	063500	51.57	4.93	5A	806	32
GRONINGEN AP EELDE	062800	53.13	6.58	5A	791	31
HERWIJNEN AWS	063560	51.87	5.15	4A	801	32
HOEK VAN HOLLAND	063300	51.98	4.10	4A	818	32
HOOGEVEEN	062790	52.75	6.52	5A	807	32
HOUTRIB	062680	52.53	5.43	5A	810	32
HUPSEL AWS	062830	52.07	6.65	5A	795	31
IJMUIDEN	062250	52.47	4.57	4A	816	32
K13-A	062520	53.22	3.22	4A	865	34
LEEUWARDEN	062700	53.22	5.77	5A	808	32
LELYSTAD AWS	062690	52.45	5.53	5A	832	33
MAASTRICHT AP ZUID	063800	50.92	5.78	5A	773	30
MARKNESSE AWS	062730	52.70	5.88	5A	796	31
NIEUW BEERTA AWS	062860	53.20	7.15	5A	747	29
ROTTERDAM AP ZESTIE	063440	51.95	4.45	5A	829	33
SOESTERBERG	062650	52.13	5.28	5A	818	32
TERSCHELLING(LGT-H)	062500	53.37	5.22	5A	956	38
TWENTHE	062900	52.27	6.90	5A	786	31
VALKENBURG	062100	52.18	4.42	5A	838	33
VLIELAND	062420	53.25	4.92	4A	783	31
VLISSINGEN	063100	51.45	3.60	4A	743	29
VOLKEL	063750	51.65	5.70	5A	758	30
WILHELMINADORP AWS	063230	51.53	3.90	4A	778	31
WOENSDRECHT	063400	51.45	4.33	4A	796	31
New Caledonia (NCL)						
ILE SURPRISE	915700	–18.48	163.08	1A	1088	43
KOUMAC (NLLE-CALEDONIE)	915770	–20.57	164.28	2A	1036	41

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
LA ROCHE (ILE MARE)	915870	–21.48	168.03	2A	1332	52
LA TONTOUTA (NLLE-CALEDONIE)	915900	–22.02	166.22	2A	951	37
MATTHEW (ILOT)	915980	–22.33	171.33	2A	1245	49
MOUE (ILE DES PINS)	915960	–22.60	167.45	2A	1168	46
NOUMEA (NLLE-CALEDONIE)	915920	–22.27	166.45	2A	1047	41
OUANAHAM (ILE LIFOU)	915820	–20.77	167.23	2A	1694	67
OULOUP (ILE OUVEA)	915790	–20.65	166.58	1A	1321	52
POINDIMIE (NLLE-CAL)	915830	–20.93	165.32	1A	2565	101
New Zealand (NZL)						
AUCKLAND AERO AWS	931100	–37.00	174.80	3A	1140	45
AUCKLAND AIRPORT	931190	–37.02	174.80	3A	1140	45
CAMPBELL ISLAND AWS	939470	–52.55	169.15	6A	1342	53
CAPE CAMPBELL AWS	935970	–41.73	174.20	4A	690	27
CAPE REINGA AWS	930040	–34.43	172.68	3A	975	38
CASTLEPOINT	934980	–40.90	176.23	3A	881	35
CHATHAM ISLANDS AWS	939870	–43.95	–176.57	4A	870	34
CHRISTCHURCH	937800	–43.48	172.55	4A	584	23
CHRISTCHURCH AERO A	937810	–43.48	172.52	4A	614	24
ENDERBY ISLAND AWS	939290	–50.48	166.30	5A	1029	41
FAREWELL SPIT AWS	935270	–40.55	173.00	3A	1665	66
GISBORNE AERODROME	932920	–38.65	177.98	3A	1032	41
HAAST AWS	937090	–43.87	169.00	4A	3012	119
HICKS BAY AWS	931960	–37.55	178.30	3A	1460	57
HOKITIKA AERODROME	936150	–42.72	170.98	4A	2795	110
INVERCARGILL AERODR	938440	–46.42	168.32	5A	1088	43
INVERCARGILL AIRPOR	938450	–46.42	168.33	5A	1088	43
KAIKOURA	936780	–42.42	173.70	4A	729	29
KAITAIA	930120	–35.10	173.27	3A	1338	53
MOKOHINAU AWS	930690	–35.90	175.10	3A	956	38
NAPIER AERODROME AW	933730	–39.45	176.85	3A	800	31
NELSON AERODROME AW	935460	–41.28	173.23	4A	1092	43
NEW PLYMOUTH AWS	933090	–39.02	174.18	3A	1439	57
PALMERSTON NORTH AW	934040	–40.32	175.60	4A	934	37
PARAPARAUMU AWS	934200	–40.90	174.98	3A	979	39
PURERUA	930230	–35.12	174.02	3A	1175	46
PUYSEGUR POINT AWS	938050	–46.17	166.63	4A	2428	96
QUEENSTOWN AERODROM	938310	–45.02	168.73	5A	988	39
RAOUL ISLAND (AUT)	939940	–29.25	–177.92	3A	1468	58
SECRETARY ISLAND AW	938000	–45.22	166.88	4A	3712	146
SOUTH WEST CAPE AWS	939090	–47.27	167.45	4A	1200	47
TAIAROA HEAD	938960	–45.77	170.73	4A	707	28
TAUPO AWS	932450	–38.73	176.07	4A	1009	40
TAURANGA AERO AWS	931860	–37.67	176.20	3A	1238	49
TIMARU AERODROME AW	937730	–44.30	171.23	4A	587	23
WAIOURU AWS	933340	–39.47	175.68	5A	1782	70
WELLINGTON AIRPORT	934360	–41.33	174.80	3A	1056	42
WESTPORT AERODROME	935150	–41.73	171.57	4A	1843	73
Nicaragua (NIC)						
MANAGUA A.C.SANDINO	787410	12.15	–86.17	0A	1107	44
Niger (NER)						
AGADEZ	610240	16.97	7.97	0B	117	5
BIRNI-NKONNI	610750	13.80	5.25	0B	482	19
GAYA	610990	11.88	3.45	0B	791	31
GOURE	610450	13.98	10.30	0B	282	11
MAGARIA	610910	12.98	8.93	0B	545	21
MAINE-SOROA	610960	13.23	11.98	0B	350	14
MARADI	610800	13.47	7.08	0B	490	19
NGUIGMI	610490	14.25	13.12	0B	191	8
NIAMEY-AERO	610520	13.48	2.17	0B	539	21
TAHOUA	610430	14.90	5.25	0B	369	15
TILLABERY	610360	14.20	1.45	0B	399	16
ZINDER	610900	13.78	8.98	0B	411	16
Niue (NIU)						
ALOFI	918220	–19.07	–169.92	1A	2083	82
Norfolk Island (NFK)						
NORFOLK ISLAND AERO	949960	–29.03	167.93	3A	1267	50
North Mariana Islands (MNP)						
SAIPAN	912320	15.12	145.70	0A	1310	52
Norway (NOR)						
ALTA LUFTHAVN	010490	69.98	23.37	7	419	16
ANDOYA	010100	69.30	16.13	7	1117	44
BANAK	010590	70.07	24.98	7	431	17
BARDUFOSS	010230	69.07	18.53	7	848	33
BERGEN/FLESLAND	013110	60.28	5.23	6A	2026	80
BERGEN/FLORIDA	013170	60.38	5.33	5A	2199	87
BODO VI	011520	67.27	14.37	6A	1050	41
EKOFISK OIL PLTFRM	014033	56.55	3.25	5C	1102	43
FAGERNES	013670	60.98	9.23	7	586	23
FERDER FYR	014820	59.03	10.53	5A	897	35
FOKSTUA II	012380	62.12	9.28	7	457	18
FRUHOLMEN FYR	010550	71.10	24.00	7	613	24
GEILO-GEILOSTOLEN	013640	60.52	8.22	7	754	30
GULLFAX (PLATFORM)	013755	61.03	2.03	5A	1595	63
HAMMERFEST	010520	70.67	23.67	7	772	30
JAN MAYEN	010010	70.93	–8.67	7	677	27
KAUTOKEINO	010470	69.00	23.03	8	409	16
KIRKENES	010890	69.73	29.90	7	458	18
KONGSBERG IV	014770	59.67	9.65	6A	973	38
KRISTIANSAND/KJEVIK	014520	58.20	8.08	6A	1312	52
LISTA FYR	014270	58.12	6.57	5A	1834	72
LYNGOR FYR	014670	58.63	9.15	5A	1140	45
MYKEN	011150	66.77	12.48	6A	1310	52
OKSOY FYR	014480	58.07	8.05	5A	1312	52
ORLAND III	012410	63.70	9.60	6A	1021	40
OSLO/FORNEBU	014880	59.90	10.62	6A	772	30
OSLO/GARDERMOEN	013840	60.20	11.08	6A	865	34
OSLO-BLINDERN	014920	59.95	10.72	6A	772	30
RENA-HAUGEDALEN	013890	61.17	11.45	7	740	29
RYGGE	014940	59.38	10.78	6A	866	34
SKLINNA FYR	011020	65.20	11.00	6A	1307	51
SKROVA FYR	011600	68.15	14.65	6A	2304	91
SLATTEROY FYR	014060	59.92	5.07	5A	1750	69
SLETTNES FYR	010780	71.10	28.22	7	605	24
SORTLAND	011670	68.70	15.42	7	1471	58
STAVANGER/SOLA	014150	58.88	5.63	5A	1187	47
SULA	012280	63.85	8.47	6A	1138	45

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
SVINOY FYR	012050	62.33	5.27	5A	1557	61
TAFJORD	012180	62.23	7.42	5A	1143	45
TORSVAG FYR	010330	70.25	19.50	6A	968	38
TROMSO/LANGNES	010250	69.68	18.92	7	973	38
TRONDHEIM/VERNES	012710	63.47	10.93	6A	971	38
TVEITSUND	014550	59.03	8.52	6A	1036	41
UTSIRA FYR	014030	59.30	4.88	5A	1584	62
VARDO	010980	70.37	31.10	7	571	22
Oman (OMN)						
BURAIMI	412440	24.23	55.78	0B	89	3
FAHUD	412620	22.33	56.48	0B	52	2
MASIRAH	412880	20.67	58.90	0B	33	1
SALALAH	413160	17.03	54.08	1B	74	3
SEEB INTL AIRPORT	412560	23.58	58.28	0B	87	3
SOHAR MAJIS	412460	24.47	56.63	0B	108	4
SUR	412680	22.53	59.47	0B	95	4
THUMRAIT	413140	17.67	54.02	0B	67	3
Pakistan (PAK)						
ISLAMABAD AIRPORT	415710	33.62	73.10	2A	1054	41
KARACHI AIRPORT	417800	24.90	67.13	0B	213	8
LAHORE AIRPORT	416410	31.52	74.40	1B	550	22
Palau (PLW)						
KOROR WSO	914080	7.33	134.48	0A	3753	148
Palestinian Territory, Occupied (PSE)						
JERUSALEM AIRPORT	402900	31.87	35.22	3A	590	23
Panama (PAN)						
MARCOS A GELABERT I	783842	8.97	–79.55	0A	1799	71
TOCUMEN	787920	9.05	–79.37	0A	2154	85
Paraguay (PRY)						
ASUNCION/AEROPUERTO	862180	–25.25	–57.52	2A	1401	55
VILLARRICA	862330	–25.75	–56.43	2A	1598	63
Peru (PER)						
AREQUIPA	847520	–16.33	–71.57	3C	87	3
CHICLAYO	844520	–6.78	–79.82	2B	19	1
CUZCO	846860	–13.53	–71.93	4A	664	26
IQUITOS	843770	–3.78	–73.30	0A	2858	113
LIMA-CALLAO/AEROP.	846280	–12.00	–77.12	2B	17	1
PISCO	846910	–13.73	–76.22	2B	10	0
PIURA	844010	–5.20	–80.60	1B	43	2
PUCALLPA	845150	–8.37	–74.57	0A	1603	63
SAN JUAN	847210	–15.38	–75.17	2B	4	0
TACNA	847820	–18.05	–70.27	3B	18	1
TALARA	843900	–4.57	–81.23	2B	10	0
TRUJILLO	845010	–8.08	–79.10	2B	29	1
TUMBES	843700	–3.55	–80.40	1B	438	17
Philippines (PHL)						
BAGUIO	983280	16.42	120.60	2A	3686	145
CAGAYAN DE ORO	987480	8.48	124.63	0A	1667	66
CALAPAN	984310	13.42	121.18	0A	1885	74
CATANDUANES RADAR	984470	13.98	124.32	1A	3343	132
CATBALOGAN	985480	11.78	124.88	0A	2555	101
CLARK AB	983270	15.17	120.57	0A	2059	81
CUBI POINT NF	984260	14.80	120.27	0A	3685	145

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
DAET	984400	14.13	122.98	0A	3563	140
DAGUPAN	983250	16.05	120.33	0A	2429	96
DAVAO AIRPORT	987530	7.12	125.65	0A	1805	71
DUMAGUETE	986420	9.30	123.30	0A	1215	48
GEN. SANTOS	988510	6.12	125.18	0A	1044	41
IBA	983240	15.33	119.97	0A	3802	150
ILOILO	986370	10.70	122.57	0A	2024	80
INFANTA	984340	14.75	121.65	0A	3937	155
LAOAG	982230	18.18	120.53	0A	2226	88
LEGASPI	984440	13.13	123.73	0A	2618	103
LUMBIA AIRPORT	987470	8.43	124.28	0A	1888	74
MACTAN	986460	10.30	123.97	0A	1607	63
MALAYBALAY	987510	8.15	125.08	1A	2580	102
MANILA	984250	14.58	120.98	0A	2134	84
MASBATE	985430	12.37	123.62	0A	1793	71
MUNOZ	983290	15.72	120.90	0A	1942	76
NINOY AQUINO INTERN	984290	14.52	121.00	0A	2134	84
PUERTO PRINCESA	986180	9.75	118.73	0A	1541	61
ROXAS	985380	11.58	122.75	0A	1990	78
SAN JOSE	985310	12.35	121.03	0A	2352	93
SANGLEY POINT	984280	14.50	120.92	0A	1907	75
SCIENCE GARDEN	984300	14.63	121.02	0A	2134	84
SINAIT	982220	17.88	120.45	0A	2478	98
TACLOBAN	985500	11.25	125.00	0A	2241	88
TAGBILARAN	986440	9.60	123.85	0A	1411	56
TAYABAS	984270	14.03	121.58	1A	2439	96
ZAMBOANGA	988360	6.90	122.07	0A	1221	48
Poland (POL)						
BIALYSTOK	122950	53.10	23.17	6A	594	23
BIELSKO-BIALA	126000	49.80	19.00	5A	892	35
CHOJNICE	122350	53.72	17.55	5A	563	22
CZESTOCHOWA	125500	50.82	19.10	5A	620	24
ELBLAG	121600	54.17	19.43	5A	681	27
GDANSK-REBIECHOWO	121500	54.38	18.47	6A	551	22
GDANSK-SWIBNO	121550	54.33	18.93	5A	562	22
GORZOW WLKP	123000	52.75	15.28	5A	547	22
HEL	121350	54.60	18.82	5A	556	22
JELENIA GORA	125000	50.90	15.80	5A	861	34
KALISZ	124350	51.78	18.08	5A	517	20
KASPROWY WIERCH	126500	49.23	19.98	7	1151	45
KATOWICE	125600	50.23	19.03	5A	750	30
KETRZYN	121850	54.07	21.37	6A	598	24
KIELCE	125700	50.82	20.70	6A	620	24
KLODZKO	125200	50.43	16.62	5A	775	31
KOLO	123450	52.20	18.67	5A	525	21
KOLOBRZEG	121000	54.18	15.58	5A	668	26
KOSZALIN	121050	54.20	16.15	5A	708	28
KOZIENICE	124880	51.57	21.55	5A	567	22
KRAKOW	125660	50.08	19.80	5A	696	27
LEBA	121200	54.75	17.53	5A	654	26
LEBORK	121250	54.55	17.75	5A	655	26
LEGNICA	124150	51.20	16.20	5A	629	25
LESKO	126900	49.47	22.35	5A	960	38

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
LESZNO	124180	51.83	16.53	5A	544	21
LODZ	124650	51.73	19.40	5A	565	22
LUBLIN RADAWIEC	124950	51.22	22.40	5A	580	23
MIKOLAJKI	122800	53.78	21.58	5A	596	23
MLAWA	122700	53.10	20.35	5A	567	22
NOWY SACZ	126600	49.62	20.70	5A	775	31
OLSZTYN	122720	53.77	20.42	6A	642	25
OPOLE	125300	50.80	17.97	5A	580	23
OSTROLEKA	122850	53.08	21.57	5A	569	22
PILA	122300	53.13	16.75	5A	564	22
PLOCK	123600	52.58	19.73	5A	534	21
POZNAN	123300	52.42	16.85	5A	521	21
PRZEMYSL	126950	49.80	22.77	5A	676	27
RACIBORZ	125400	50.05	18.20	5A	635	25
RESKO	122100	53.77	15.42	5A	666	26
RZESZOW-JASIONKA	125800	50.10	22.05	5A	655	26
SANDOMIERZ	125850	50.70	21.72	5A	581	23
SIEDLCE	123850	52.25	22.25	5A	541	21
SNIEZKA	125100	50.73	15.73	7	996	39
SULEJOW	124690	51.35	19.87	5A	564	22
SUWALKI	121950	54.13	22.95	6A	594	23
SWINOUJSCIE	122000	53.92	14.23	5A	567	22
SZCZECIN	122050	53.40	14.62	5A	535	21
SZCZECINEK	122150	53.72	16.68	5A	613	24
TARNOW	125750	50.03	20.98	5A	719	28
TERESPOL	123990	52.07	23.62	5A	601	24
TORUN	122500	53.05	18.58	5A	538	21
USTKA	121150	54.58	16.87	5A	698	27
WARSZAWA-OKECIE	123750	52.17	20.97	5A	523	21
WIELUN	124550	51.22	18.57	5A	606	24
WLODAWA	124970	51.55	23.53	5A	552	22
WROCLAW II	124240	51.10	16.88	5A	577	23
ZAKOPANE	126250	49.30	19.97	6A	1120	44
ZAMOSC	125950	50.70	23.25	5A	603	24
ZIELONA GORA	124000	51.93	15.53	5A	594	23
Portugal (PRT)						
BEJA	085620	38.02	–7.87	3A	583	23
BRAGANCA	085750	41.80	–6.73	4C	735	29
CASTELO BRANCO	085700	39.83	–7.48	3A	779	31
COIMBRA	085490	40.20	–8.42	3A	998	39
EVORA	085570	38.57	–7.90	3A	638	25
EVORA/C. COORD	085580	38.53	–7.90	3A	638	25
FARO/AEROPORTO	085540	37.02	–7.97	3A	502	20
FLORES (ACORES)	085010	39.45	–31.13	3A	986	39
FUNCHAL	085220	32.63	–16.90	2A	607	24
FUNCHAL/S.CATARINA	085210	32.68	–16.77	3A	398	16
HORTA/CASTELO BRANC	085050	38.52	–28.72	3A	799	31
LAJES (ACORES)	085090	38.77	–27.10	3A	1154	45
LISBOA/PORTELA	085360	38.77	–9.13	3A	713	28
PONTA DELGADA/NORDE	085120	37.73	–25.70	3C	1025	40
PORTALEGRE	085710	39.28	–7.42	3A	881	35
PORTO SANTO	085240	33.07	–16.35	3B	376	15
PORTO/PEDRAS RUBRAS	085450	41.23	–8.68	3C	1252	49
SAGRES	085380	37.00	–8.95	3C	461	18
SANTA MARIA (ACORES)	085150	36.97	–25.17	3A	742	29
SINES/MONTES CHAOS	085410	37.95	–8.87	3C	551	22
VIANA DO CASTELO	085430	41.70	–8.80	3C	1422	56
VILA REAL	085660	41.32	–7.73	4C	1112	44
VILA REAL	085670	41.27	–7.72	4C	1112	44
VISEU	085600	40.72	–7.88	4C	1255	49
Qatar (QAT)						
DOHA INTERNATIONAL	411700	25.25	51.57	0B	72	3
Reunion (REU)						
SAINT-DENIS/GILLOT	619800	–20.88	55.52	1A	1523	60
Romania (ROU)						
ARAD	152000	46.13	21.35	5A	592	23
BACAU	151500	46.53	26.92	5A	546	22
BAIA MARE	150140	47.67	23.50	5A	854	34
BARLAD	151970	46.23	27.65	5A	514	20
BISTRITA	150850	47.15	24.50	5A	706	28
BLAJ	152090	46.18	23.93	5A	552	22
BOTOSANI	150200	47.73	26.65	5A	571	22
BUCURESTI AFUMATI	154210	44.48	26.18	5A	612	24
BUCURESTI INMH-BANE	154200	44.48	26.12	5A	612	24
BUZAU	153500	45.13	26.85	4A	521	20
CALAFAT	154820	43.98	22.95	4A	544	21
CALARASI	154600	44.20	27.33	4A	492	19
CARANSEBES	152920	45.42	22.25	5A	906	36
CEAHLAU TOACA	151080	46.98	25.95	7	627	25
CLUJ-NAPOCA	151200	46.78	23.57	5A	584	23
CONSTANTA	154800	44.22	28.65	4A	422	17
CRAIOVA	154500	44.32	23.87	4A	584	23
DEVA	152300	45.87	22.90	5A	596	23
DROBETA TURNU SEVER	154100	44.63	22.63	4A	668	26
FAGARAS	152350	45.83	24.93	5A	713	28
FETESTI	154440	44.37	27.85	4A	454	18
GALATI	153100	45.48	28.03	5A	485	19
GIURGIU	154910	43.88	25.95	4A	583	23
GRIVITA	154050	44.75	27.30	5A	475	19
IASI	150900	47.17	27.63	5A	587	23
INTORSURA BUZAULUI	152610	45.68	26.02	6A	659	26
JURILOVCA	154090	44.77	28.88	4A	398	16
KOGALNICEANU	154810	44.33	28.43	4A	420	17
MANGALIA	154990	43.82	28.58	4A	405	16
MIERCUREA CIUC	151700	46.37	25.73	6A	566	22
ORADEA	150800	47.03	21.90	5A	596	23
ORAVITA	153380	45.03	21.68	4A	759	30
PETROSANI	152960	45.42	23.38	5A	812	32
PLOIESTI	153770	44.95	26.00	5A	620	24
PREDEAL	153020	45.50	25.58	6A	950	37
RARAU (MONASTERY)	150520	47.45	25.57	7	789	31
RIMNICU VALCEA	153460	45.10	24.37	4A	722	28
ROMAN	151110	46.97	26.92	5A	505	20
ROSIORI DE VEDE	154700	44.10	24.98	4A	534	21
SATU MARE	150100	47.72	22.88	5A	594	23
SIBIU	152600	45.80	24.15	5A	651	26

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
SIGHETUL MARMATIEI	150040	47.93	23.92	5A	820	32
SUCEAVA	150230	47.63	26.25	5A	595	23
SULINA	153600	45.17	29.73	4B	270	11
TARGOVISTE	153750	44.93	25.43	5A	663	26
TG. JIU	153400	45.03	23.27	5A	806	32
TG. MURES	151450	46.53	24.53	5A	601	24
TIMISOARA	152470	45.77	21.25	4A	611	24
TR. MAGURELE	154900	43.75	24.88	4A	547	22
TULCEA	153350	45.18	28.82	4A	434	17
VARFU OMU	152800	45.45	25.45	8	935	37
ZALAU	150630	47.18	23.08	5A	643	25
Russian Federation (RUS)						
ABAKAN	298650	53.75	91.40	7	324	13
ACINSK	294670	56.28	90.50	7	422	17
ADLER	371710	43.43	39.90	4A	1559	61
AGATA	233830	66.88	93.47	8	464	18
AGINSKOE	296760	55.25	94.88	7	461	18
AGINSKOE	308590	51.10	114.52	8	371	15
AGZU	318250	47.60	138.40	7	663	26
AJAN	311680	56.45	138.15	8	887	35
AKJAR	350370	51.87	58.18	7	361	14
AKSA	309570	50.27	113.27	7	386	15
ALATYR`	276790	54.82	46.58	7	518	20
ALDAN	310040	58.62	125.37	8	676	27
ALEJSKAJA	299370	52.52	82.77	7	431	17
ALEKSANDROV-GAJ	343910	50.15	48.55	6A	316	12
ALEKSANDROVSKIJ ZAV	309710	50.92	117.93	8	399	16
ALEKSANDROVSKOE	239550	60.43	77.87	8	501	20
ALEKSANDROVSK-SAHAL	320610	50.90	142.17	7	622	24
AMDERMA	230220	69.75	61.70	8	380	15
AMGA	249620	60.90	131.98	8	256	10
ANADYR	255630	64.78	177.57	8	333	13
ANAPA	370010	44.88	37.28	4A	520	20
ANDREYA ISLAND	213010	76.80	110.83	8	210	8
ANTIPAJETA	230580	69.08	76.85	8	268	11
ANUCINO	319810	43.97	133.07	7	719	28
APUKA	259560	60.43	169.67	8	515	20
ARHANGELSK	225500	64.55	40.58	7	579	23
ARHARA	315940	49.42	130.08	7	640	25
ARKA	249880	60.08	142.33	8	446	18
ARMAVIR	370310	44.98	41.12	5A	572	23
ASTRAHAN	348800	46.28	48.05	5B	214	8
ASTRAHANKA	319210	44.72	132.07	7	582	23
ATKA	259020	60.85	151.77	8	328	13
B. PRONCHISHCHEVOY	214050	75.53	113.52	8	212	8
BABAEVO	270080	59.40	35.93	7	621	24
BABUSKIN	308220	51.72	105.85	7	523	21
BAEVO	298270	53.27	80.77	7	328	13
BAGDARIN	305540	54.47	113.58	8	378	15
BAJANDAJ	306270	53.10	105.53	8	375	15
BAKALY	286150	55.18	53.80	7	462	18
BAKCHAR	293280	57.08	81.92	7	464	18
BALAGANSK	306120	54.00	103.07	8	326	13
BALASOV	341520	51.55	43.15	6A	500	20
BARABINSK	296120	55.33	78.37	7	377	15
BARENCBURG	201070	78.07	14.25	8	468	18
BARNAUL	298380	53.43	83.52	7	441	17
BATAMAJ	246560	63.52	129.48	8	293	12
BEJA	299620	53.05	90.92	7	399	16
BELOGORSK	315130	50.92	128.47	7	554	22
BELYJ	265850	55.85	32.95	6A	709	28
BEREZOVO	236310	63.93	65.05	8	526	21
BERINGOVSKAJA	256770	63.05	179.32	8	574	23
BEZECK	272170	57.80	36.70	7	541	21
BIJSK ZONALNAJA	299390	52.68	84.95	7	534	21
BIKIN	318320	46.80	134.27	7	645	25
BIRILIUSSY	293670	57.13	90.70	7	501	20
BIROBIDZHAN	317130	48.73	132.95	7	666	26
BIRSK	286210	55.42	55.53	7	580	23
BLAGOVESCENSK	315100	50.25	127.57	7	559	22
BODAJBO	302530	57.85	114.23	8	447	18
BOGORODSKOE	314390	52.38	140.47	8	504	20
BOGOTOL	295530	56.23	89.58	7	499	20
BOGUCANY	292820	58.38	97.45	8	339	13
BOGUCAR	343360	49.93	40.57	6A	514	20
BOL`SIE-UKI	284910	56.93	72.67	7	447	18
BOLOGOE	262980	57.90	34.05	7	629	25
BOLSHAJA MURTA	294710	56.90	93.13	7	413	16
BOLSHERECHE	285930	56.10	74.63	7	364	14
BOLSOJ SANTAR	311740	54.83	137.53	8	524	21
BOMNAK	312530	54.72	128.93	8	574	23
BOR	238840	61.60	90.02	8	588	23
BORZJA	309650	50.40	116.52	8	296	12
BRATOLJUBOVKA	315210	50.78	129.33	8	564	22
BRATSK	303090	56.28	101.75	8	374	15
BRJANSK	268980	53.25	34.32	6A	649	26
BUDENNOVSK	370610	44.78	44.13	5A	406	16
BUGULMA	287110	54.58	52.80	7	523	21
BUHTA PROVIDENJA	255940	64.42	–173.23	8	666	26
BUJ	272420	58.48	41.53	7	633	25
BURUKAN	313480	53.05	136.03	8	642	25
BUZULUK	289090	52.82	52.22	7	470	19
CAJVO	320360	52.37	143.18	8	683	27
CAPE BOLVANSKIJ	209460	70.45	59.07	8	256	10
CAPE KAMENNYJ	231460	68.47	73.60	8	389	15
CAPE MENSHIKOVA	209430	70.72	57.62	8	588	23
CAPE STERLEGOVA	204760	75.42	88.90	8	296	12
CAPE VASILEVA	322170	50.02	155.40	7	1240	49
CEKUNDA	315320	50.87	132.25	8	672	26
CELINA	347470	46.55	41.05	5A	546	21
CEMAL	360580	51.43	86.00	7	513	20
CENTRALNYJ RUDNIK	296540	55.22	87.65	7	951	37
CEREPOVEC	271130	59.25	37.97	7	667	26
CERLAK	287990	54.17	74.80	7	348	14
CERNUSKA	284280	56.50	56.13	7	559	22
CHANY	296020	55.28	76.60	7	338	13

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
CHARA	303720	56.90	118.27	8	346	14
CHELJABINSK-BALANDI	286420	55.30	61.53	7	441	17
CHERDYN	239140	60.40	56.52	7	712	28
CHERNISHEVSKIJ	247240	63.03	112.50	8	337	13
CHERNJAEVO	313710	52.78	126.00	8	485	19
CHERSKIJ	251230	68.75	161.28	8	210	8
CHITA	307580	52.08	113.48	8	346	14
CHOKURDAH	219460	70.62	147.88	8	217	9
CJULBJU	311230	57.77	130.90	8	384	15
CUGUEVKA	319390	44.15	133.87	7	719	28
CULMAN	303930	56.83	124.87	8	530	21
CULYM	296250	55.10	80.97	7	379	15
CURAPCA	247680	62.03	132.60	8	245	10
DALNERECHENSK	318730	45.87	133.73	7	637	25
DEMJANSKOE	280760	59.60	69.28	7	534	21
DIVNOE	348580	45.92	43.35	5A	434	17
DUDINKA	230740	69.40	86.17	8	456	18
DUKI	314820	51.72	135.93	8	646	25
DUVAN	285370	55.70	57.90	7	515	20
DZALINDA	306950	53.47	123.90	8	471	19
DZARDZAN	241430	68.73	124.00	8	304	12
DZERZHINSKOE	294810	56.85	95.22	7	350	14
EGVEKINOT	253780	66.35	–179.12	8	389	15
EKATERINBURG	284400	56.83	60.63	7	511	20
EKATERINO-NIKOLSKOE	317070	47.73	130.97	7	625	25
EKIMCHAN	313290	53.07	132.98	8	693	27
ELABUGA	285060	55.77	52.07	7	544	21
ELAT`MA	276480	54.95	41.77	7	605	24
ELEC	279280	52.63	38.52	6A	579	23
ENISEJSK	292630	58.45	92.15	8	470	19
ERBOGACEN	248170	61.27	108.02	8	340	13
ERMAKOVSKOE	298690	53.30	92.42	7	528	21
EROFEJ PAVLOVIC	306830	53.97	121.93	8	419	16
ERSOV	341860	51.37	48.30	6A	393	15
GAJNY	239090	60.28	54.35	7	626	25
GAR	313840	52.57	129.07	8	574	23
GARI	280490	59.43	62.33	7	468	18
GLAZOV	282140	58.13	52.58	7	587	23
GMO IM.E.K. FEDOROV	202920	77.72	104.30	8	213	8
GORIN	314890	51.20	136.80	8	606	24
GORJACINSK	307310	52.98	108.28	7	400	16
GOR'KIJ	275530	56.22	43.82	7	606	24
GRIDINO	224220	65.90	34.77	7	429	17
GROSSEVICHI	318230	47.97	139.53	7	694	27
GROZNYJ	372350	43.35	45.68	5A	462	18
GUGA	314210	52.70	137.53	8	474	19
GVASJUGI	318010	47.67	136.18	7	915	36
HABAROVSK	317350	48.52	135.17	7	673	27
HADAMA	298920	53.95	98.82	8	529	21
HAKASSKAJA	298620	53.77	91.32	7	310	12
HANTY-MANSIJSK	239330	61.02	69.03	8	535	21
HATANGA	208910	71.98	102.47	8	283	11
HILOK	308440	51.35	110.47	8	380	15
HOLM	263780	57.15	31.18	6A	645	25
HOLMSK	321280	47.05	142.05	6A	795	31
HORINSK	307390	52.17	109.78	8	283	11
HOSEDA-HARD	232190	67.08	59.38	8	455	18
HULARIN	314840	51.42	135.08	7	605	24
ICA	324110	55.58	155.58	7	741	29
IDRINSKOE	297660	54.37	92.13	7	382	15
IGARKA	232740	67.47	86.57	8	494	19
IGNASINO	306860	53.47	122.40	8	421	17
IKEJ	305070	54.18	100.08	8	470	18
ILYINSKIY	321210	47.98	142.20	7	856	34
IM POLINY OSIPENKO	314160	52.42	136.50	8	471	19
IM. M.V. POPOVA	206670	73.33	70.05	8	206	8
IRBEJSKOE	295870	55.63	95.47	7	434	17
IRKUTSK	307100	52.27	104.32	7	475	19
ISIM	285730	56.10	69.43	7	377	15
ISIT	249510	60.82	125.32	8	290	11
IVDEL	239210	60.68	60.45	7	510	20
IZHEVSK	284110	56.83	53.45	7	527	21
JAKUTSK	249590	62.02	129.72	8	234	9
JALTUROVOSK	284650	56.68	66.35	7	423	17
JANAUL	284190	56.27	54.90	7	479	19
JARCEVO	239870	60.25	90.23	8	590	23
JARENSK	227980	62.17	49.12	7	599	24
JASKUL	348660	46.18	45.35	5B	249	10
JUBILEJNAJA	219310	70.77	136.22	8	245	10
JUR`EVEC	273550	57.33	43.12	7	600	24
JUZHNO-KURILSK	321650	44.02	145.87	6A	1238	49
JUZHNO-SAHALINSK	321500	46.95	142.72	7	863	34
KACUG	306220	53.97	105.90	8	310	12
KAJLASTUJ	309780	49.83	118.38	7	341	13
KALAC	342470	50.42	41.05	6A	486	19
KALACINSK	286960	55.03	74.58	7	340	13
KALAKAN	304690	55.12	116.77	8	395	16
KALEVALA	224080	65.22	31.17	7	533	21
KALININGRAD	267020	54.72	20.55	5A	796	31
KALUGA	277030	54.57	36.40	6A	642	25
KAMEN-NA-OBI	298220	53.82	81.27	7	330	13
KAMENSKOE	257440	62.43	166.08	8	413	16
KAMYSIN	343630	50.07	45.37	6A	378	15
KAMYSLOV	284510	56.85	62.72	7	459	18
KANDALAKSA	222170	67.15	32.35	7	509	20
KANIN NOS	221650	68.65	43.30	7	431	17
KANSK	295810	56.20	95.63	7	312	12
KARASUK	298140	53.70	78.07	7	299	12
KARGASOK	291220	59.05	80.95	8	449	18
KARGOPOL	228450	61.50	38.93	7	617	24
KAZACHINSK	303370	56.32	107.62	8	400	16
KAZAN	275950	55.60	49.28	7	532	21
KEDON	256210	64.00	158.92	8	274	11
KEM	225220	64.95	34.65	7	434	17
KEMCHUG	295620	56.10	91.67	7	507	20
KEMEROVO	296420	55.23	86.12	7	465	18

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
KESTENGA	224030	65.88	31.83	7	540	21
KINGISEPP	260590	59.37	28.60	6A	686	27
KIRENSK	302300	57.77	108.07	8	383	15
KIROV	271960	58.65	49.62	7	613	24
KIROV	271990	58.60	49.63	7	613	24
KIROVSKIJ	318780	45.08	133.53	7	670	26
KIRS	280090	59.37	52.22	7	607	24
KJAHTA	309250	50.37	106.45	7	350	14
KJUSJUR	219210	70.68	127.40	8	343	14
KLJUCHI	323890	56.32	160.83	7	618	24
KLJUCI	360210	52.25	79.13	7	318	13
KOCHKI	297240	54.30	80.50	7	358	14
KOCUBEJ	370850	44.40	46.55	4B	243	10
KOJNAS	225830	64.75	47.65	7	609	24
KOLBA	296750	55.08	93.37	7	591	23
KOLPASEVO	292310	58.32	82.95	7	504	20
KOLYVAN	296310	55.30	82.75	7	411	16
KOMMUNAR	297590	54.33	89.28	7	860	34
KORF	259540	60.35	166.00	8	423	17
KOTEL`NIKOVO	346550	47.63	43.15	5A	402	16
KOTLAS	228870	61.23	46.72	7	538	21
KOZ`MODEM`JANSK	274790	56.33	46.58	7	586	23
KRASNODAR	349290	45.03	39.15	4A	702	28
KRASNOJARSK	295740	56.00	92.88	7	495	19
KRASNOJARSK OPYTNOE	295700	56.03	92.75	7	495	19
KRASNOOZERSK	298130	53.97	79.23	7	355	14
KRASNOSCELE	222350	67.35	37.05	8	519	20
KRASNOUFIMSK	284340	56.65	57.78	7	531	21
KRASNYE BAKI	273690	57.13	45.17	7	631	25
KRASNYJ CHIKOJ	309350	50.37	108.75	8	347	14
KRASNYJ JAR	318450	46.53	135.32	7	872	34
KRESCHENKA	295240	55.85	80.03	7	422	17
KUDYMKAR	281160	58.98	54.65	7	548	22
KUPINO	297060	54.37	77.28	7	308	12
KUR	316320	49.93	134.63	7	752	30
KURGAN	286610	55.47	65.40	7	380	15
KURSK	340090	51.77	36.17	6A	627	25
KYRA	309490	49.57	111.97	7	377	15
KYSTOVKA	294050	56.60	76.57	7	416	16
KYZYL	360960	51.72	94.50	8	233	9
LAKE TAJMYR	205940	74.50	102.50	8	227	9
LENSK	249230	60.72	114.88	8	375	15
LEUSI	280640	59.62	65.72	7	488	19
LJUBAN	260780	59.35	31.23	7	635	25
LOKSAK	312630	54.73	130.45	8	577	23
LOSINOBORSKOE	292530	58.43	89.37	8	553	22
LOVOZERO	221270	68.00	35.03	8	486	19
LUKOJANOV	276650	55.03	44.50	7	572	23
MAGADAN	259130	59.55	150.78	8	528	21
MAGDAGACI	312950	53.47	125.82	8	470	18
MAGNITOGORSK	288380	53.35	59.08	7	365	14
MAHACKALA	374720	43.02	47.48	4B	336	13
MAJSK	292090	57.78	77.28	7	494	19
MAKUSINO	286660	55.25	67.30	7	366	14
MALYE KARMAKULY	207440	72.37	52.70	8	343	13
MAMA	301570	58.32	112.87	8	554	22
MARESALE	230320	69.72	66.80	8	258	10
MARIINSK	295510	56.22	87.75	7	441	17
MARKOVO	255510	64.68	170.42	8	397	16
MASLJANINO	297360	54.33	84.22	7	454	18
MATUA	322070	48.07	153.22	7	1321	52
MEDVEZEGORSK	227210	62.92	34.43	7	672	26
MELEUZ	289250	52.95	55.97	7	443	17
MEZEN	224710	65.87	44.22	7	509	20
MINERALNYE VODY	370540	44.23	43.07	5A	524	21
MOGOCA	306730	53.75	119.73	8	426	17
MONDY	308020	51.68	100.98	8	332	13
MOROZOVSK	345450	48.35	41.87	5A	414	16
MOSKVA	276120	55.83	37.62	6A	684	27
MOZDOK	371450	43.73	44.67	5A	531	21
MURMANSK	221130	68.97	33.05	7	473	19
MUZI	234260	65.38	64.72	8	514	20
MYS SHALAUROVA	216470	73.18	143.23	8	116	5
MYS SHMIDTA	251730	68.90	–179.37	8	248	10
MYS UELEN	253990	66.17	–169.83	8	377	15
MYS ZELANIJA	203530	76.85	68.55	8	314	12
NAGORNYJ	304930	55.97	124.88	8	568	22
NAJAHAN	258210	61.95	158.97	8	448	18
NAPAS	290230	59.85	81.95	8	569	22
NARJAN-MAR	232050	67.63	53.03	8	463	18
NAZYVOEVSK	285880	55.57	71.37	7	378	15
NELKAN	311520	57.67	136.15	8	407	16
NERCHINSKIJ ZAVOD	308790	51.32	119.62	8	438	17
NIKOL`SK	270660	59.53	45.47	7	606	24
NIKOLAEVSK-NA-AMURE	313690	53.15	140.70	8	640	25
NIKOLAEVSKOE	261670	58.57	29.80	6A	652	26
NIKOLO-POLOMA	272520	58.35	43.38	7	620	24
NIKOLSKOE	326180	55.20	165.98	7	673	26
NIZHNEANGARSK	304330	55.78	109.55	8	360	14
NIZHNEUDINSK	296980	54.88	99.03	7	404	16
NIZHNYJ TAGIL	282400	57.88	60.07	7	532	21
NIZNIJ NOVGOROD	274590	56.27	44.00	7	608	24
NJAKSIMVOL	237240	62.43	60.87	8	528	21
NJANDOMA	228540	61.67	40.18	7	729	29
NJURBA	246390	63.28	118.33	8	283	11
NOGLIKI	320530	51.92	143.13	7	693	27
NOLINSK	273930	57.55	49.95	7	641	25
NORSK	313880	52.35	129.92	8	559	22
NOVOKUZNETSK	298460	53.82	86.88	7	462	18
NOVOSELENGINSK	308290	51.10	106.65	7	268	11
NOVOSIBIRSK	296340	55.08	82.90	7	436	17
NOZOVKA	283190	57.08	54.75	7	531	21
OBJACEVO	229960	60.37	49.65	7	606	24
OBLUCE	317020	49.00	131.08	7	720	28
ODESSKOE	287970	54.20	72.97	7	330	13
OHANSK	283210	57.72	55.38	7	549	22

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

					Precipitation	
Country/LOCATION	WMO#	Lat	Long	CZ	mm	in.
OHOTSK	310880	59.37	143.20	8	489	19
OKTJABRSKOE	237340	62.45	66.05	8	591	23
OLEKMINSK	249440	60.40	120.42	8	307	12
OLENEK	241250	68.50	112.43	8	290	11
OLOVJANNAJA	309610	50.95	115.58	7	327	13
OMSK	286980	55.02	73.38	7	381	15
ONEGA	226410	63.90	38.12	7	591	23
ONGUDAJ	362310	50.73	86.15	7	363	14
OPARINO	270830	59.85	48.28	7	658	26
ORDYNSKOE	297260	54.37	81.95	7	398	16
OREL	279060	52.93	36.00	6A	639	25
ORENBURG	351210	51.68	55.10	7	365	14
OSTASKOV	263890	57.13	33.12	7	615	24
OSTROV CHETYREHSTOL	219650	70.63	162.48	8	88	3
OSTROV DIKSON	206740	73.50	80.40	8	348	14
OSTROV GOLOMJANNYJ	200870	79.55	90.62	8	226	9
OSTROV KOTELNYJ	214320	76.00	137.87	8	135	5
OSTROV PREOBRAZENIJ	215040	74.67	112.93	8	158	6
OSTROV UEDINENIJA	202740	77.50	82.20	8	158	6
OSTROV VIZE	200690	79.50	76.98	8	209	8
OSTROV VRANGELJA	219820	70.98	–178.48	8	171	7
OZERNAJA	325940	51.48	156.48	7	809	32
PADUN	221060	68.60	31.85	7	525	21
PARTIZANSK	319870	43.15	133.02	6A	782	31
PAVELEC	278230	53.78	39.25	7	542	21
PECHORA	234180	65.12	57.10	8	569	22
PENZA	279620	53.12	45.02	7	540	21
PERM	282250	57.95	56.20	7	614	24
PERVOMAJSKOE	293480	57.07	86.22	7	439	17
PETROPAVLOVSK-KAMCH	325400	53.08	158.58	7	1127	44
PETROPAVLOVSK-KAMCH	325830	52.98	158.65	7	1152	45
PETROVSKIJ ZAVOD	308380	51.32	108.87	8	328	13
PETROZAVODSK	228200	61.82	34.27	7	574	23
PIHTOVKA	295340	55.98	82.70	7	410	16
PILVO	320690	50.05	142.17	7	639	25
PINEGA	225630	64.70	43.38	7	557	22
PIROVSKOE	293630	57.63	92.27	8	481	19
PJALICA	223490	66.18	39.53	7	447	18
POGIBI	320270	52.22	141.63	8	570	22
POGRANICHNOE	320760	50.40	143.77	8	751	30
POGRANICHNYJ	319150	44.40	131.38	7	618	24
POJARKOVO	315870	49.62	128.65	7	533	21
POKROVSKAJA	248560	61.48	129.15	8	269	11
POLARGMO IM. E.T. K	200460	80.62	58.05	8	256	10
POLTAVKA	319170	44.03	131.32	7	588	23
PORONAJSK	320980	49.22	143.10	7	750	30
POSET	319690	42.65	130.80	6A	742	29
PREOBRAZHENIE	319890	42.90	133.90	6A	784	31
PRIARGUNSK	309750	50.40	119.07	8	357	14
PRIMORSKO-AHTARSK	348240	46.03	38.15	5A	565	22
PSKOV	262580	57.82	28.42	6A	629	25
PUDINO	293130	57.53	79.37	7	452	18
PUDOZ	228310	61.80	36.52	7	690	27
RA-IZ	233310	66.90	65.67	8	774	30
REBOLY	226020	63.83	30.82	7	596	23
REBRIHA	299230	53.07	82.30	7	409	16
REMONTNOE	347590	46.57	43.67	5A	379	15
RJAZAN'	277310	54.62	39.72	6A	584	23
RJAZAN`	277300	54.63	39.70	6A	584	23
ROMANOVKA	306500	53.20	112.78	8	359	14
ROSLAVL	268820	53.93	32.83	6A	604	24
ROSTOV	273290	57.20	39.42	7	590	23
ROSTOV-NA-DONU	347310	47.25	39.82	5A	593	23
RUBCOVSK	360340	51.50	81.22	7	341	13
RUDNAJA PRISTAN	319590	44.37	135.85	7	776	31
RUSSKAYA GAVAN`	203570	76.18	62.57	8	377	15
RYBINSK	272250	58.10	38.68	7	671	26
RZEV	264980	56.27	34.32	6A	626	25
SADRINSK	285520	56.07	63.65	7	433	17
SAIM	239290	60.32	64.22	7	457	18
SAKUN`JA	273730	57.67	46.63	7	600	24
SALEHARD	233300	66.53	66.67	8	442	17
SAMARA	289000	53.25	50.45	7	530	21
SAMARY	283340	57.35	58.22	7	660	26
SANGARY	246520	63.97	127.47	8	311	12
SAR`JA	272710	58.37	45.53	7	643	25
SARAN-PAUL	235270	64.28	60.88	8	499	20
SARATOV	341720	51.57	46.03	6A	431	17
SARGATSKOE	285980	55.60	73.48	7	399	16
SEGEZA	226210	63.77	34.28	7	586	23
SEJAHA	209670	70.17	72.52	8	364	14
SEJMCHAN	257030	62.92	152.42	8	311	12
SEKTAGLI	315340	50.43	131.02	8	724	29
SELAGONCY	243290	66.25	114.28	8	292	11
SELEMDZA	313380	53.13	133.97	8	666	26
SEMJACHIK	325090	54.12	159.98	7	1297	51
SENKURSK	227680	62.10	42.90	7	568	22
SERAFIMOVIC	343570	49.57	42.75	6A	435	17
SERBAKUL	287910	54.63	72.43	7	338	13
SEROV	280440	59.60	60.53	7	487	19
SEVERNOE	294180	56.35	78.35	7	443	17
SEVERO-KURILSK	322150	50.68	156.13	7	1731	68
SHEREMETYEVO	275155	55.97	37.42	7	674	27
SHILKA	308620	51.87	116.03	8	339	13
SIMANOVSK	314420	51.98	127.65	8	534	21
SIMUSIR	321950	46.85	151.87	7	1310	52
SIRA	297560	54.50	89.93	7	454	18
SKOVORODINO	306920	54.00	123.97	8	434	17
SLAVGOROD	299150	52.97	78.65	7	304	12
SMIDOVICH	317250	48.62	133.83	7	699	28
SMOLENSK	267810	54.75	32.07	6A	674	27
SOFIJSKIJ PRIISK	314780	52.27	133.98	8	739	29
SOJNA	222710	67.88	44.13	8	401	16
SOLNETHNAYA	305370	54.03	108.27	7	267	10
SOLOVEVSK	309670	49.90	115.75	7	303	12
SORTAVALA	228020	61.72	30.72	7	606	24

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.	Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
SOSNOVO-OZERSKOE	307450	52.53	111.55	8	345	14	TROICKO-PECHERSKOE	237110	62.70	56.20	8	633	25
SOSUNOVO	318660	46.53	138.33	7	729	29	TROIZK	287480	54.08	61.62	7	370	15
SOSVA	236250	63.65	62.10	8	487	19	TRUBCEVSK	269970	52.58	33.77	6A	644	25
SOVETSKAYA GAVAN	317700	48.97	140.30	7	739	29	TUAPSE	370180	44.10	39.07	4A	1469	58
SREDNY VASJUGAN	291110	59.22	78.23	7	550	22	TULA	277190	54.23	37.62	6A	620	24
SRETENSK	307770	52.23	117.70	8	353	14	TULUN	305040	54.60	100.63	7	416	16
ST.PETERSBURG	260630	59.97	30.30	6A	625	25	TUMNIN	316830	49.67	140.12	7	561	22
STARAJA RUSSA	262750	58.02	31.32	6A	605	24	TUNGOKOCEN	306640	53.53	115.62	8	390	15
STAVROPOL	349490	45.12	42.08	5A	551	22	TUNKA	308110	51.73	102.53	8	372	15
STERLITAMAK	288250	53.58	56.00	7	520	20	TURA	245070	64.27	100.23	8	362	14
STRELKA	292740	58.08	93.00	7	480	19	TURINSK	282550	58.05	63.68	7	485	19
SUHAJA	307260	52.57	107.13	7	304	12	TUROCAK	360610	52.27	87.17	7	852	34
SUHINICI	277070	54.10	35.58	6A	624	25	TURUHANSK	234720	65.78	87.93	8	559	22
SUHOBUZIMSKOE	294770	56.50	93.28	7	378	15	TVER	274020	56.90	35.88	7	645	25
SUMIHA	286550	55.23	63.32	7	409	16	TYNDA	304990	55.18	124.67	8	578	23
SUNTAR	247380	62.15	117.65	8	280	11	UAKIT	304550	55.47	113.62	8	365	14
SURA	226760	63.58	45.63	7	542	21	UEGA	249820	60.72	142.78	8	439	17
SURGUT	238490	61.25	73.50	8	549	22	UFA	287220	54.72	55.83	7	590	23
SUTUR	315380	50.07	132.13	8	688	27	UHTA	236060	63.55	53.82	7	542	21
SVETLOGRAD	349540	45.35	42.85	5A	485	19	UJAR	295760	55.80	94.33	7	447	18
SVOBODNYJ	314450	51.45	128.12	8	565	22	ULAN-UDE	308230	51.83	107.60	7	272	11
SYKTYVKAR	238040	61.68	50.78	7	569	22	ULETY	308460	51.35	112.47	7	332	13
SYM	239750	60.35	88.37	8	513	20	ULYANOVSK	277860	54.32	48.33	7	491	19
SYZRAN`	279830	53.18	48.40	6A	455	18	UMBA	223240	66.68	34.35	7	489	19
TADIBE-YAKHA	209640	70.35	74.13	8	349	14	UNAHA	311990	55.03	126.80	8	585	23
TAJSHET	295940	55.95	98.00	7	427	17	URJUPINSK	342400	50.80	42.00	6A	475	19
TAMBEY	208640	71.48	71.82	8	320	13	URMI	316240	49.40	133.23	7	854	34
TAMBOV	279470	52.80	41.33	6A	556	22	URUP	321860	46.20	150.50	7	1263	50
TANGUJ	304050	55.38	101.03	7	364	14	UST-BARGUZIN	306350	53.42	109.02	8	372	15
TANHOJ	308240	51.57	105.12	7	795	31	UST-CILMA	234050	65.43	52.27	8	550	22
TARA	284930	56.90	74.38	7	442	17	UST-ILIMSK	301170	58.20	102.75	8	391	15
TARKO-SALE	235520	64.92	77.82	8	501	20	UST-ISIM	283820	57.72	–71.18	7	525	21
TASTYP	299560	52.80	89.92	7	460	18	UST-JUDOMA	310540	59.18	135.15	8	360	14
TATARSK	296050	55.20	75.97	7	376	15	UST-KAMCHATSK	324080	56.22	162.47	7	692	27
TAZOVSKOE	232560	67.47	78.73	8	447	18	UST-KULOM	238030	61.68	53.68	7	625	25
TERIBERKA	220280	69.20	35.12	7	491	19	UST-KUT	303200	56.87	105.70	8	525	21
TERNEJ	319090	45.00	136.60	7	828	33	UST-MAJA	249660	60.38	134.45	8	307	12
TEVRIZ	283830	57.52	72.40	7	474	19	UST-NJUKZHA	303850	56.58	121.48	8	439	17
TIHORECK	348380	45.85	40.08	5A	622	25	UST-OLOJ	253250	66.55	159.42	8	256	10
TIHVIN	260940	59.65	33.55	7	701	28	USTORDYNSKIJ	307130	52.82	104.77	8	314	12
TIKSI	218240	71.58	128.92	8	227	9	UST-UDA	305140	54.17	103.02	8	302	12
TISUL	295570	55.75	88.32	7	542	21	UST-UMALTA	314740	51.63	133.32	8	777	31
TIVJAKU	317540	48.60	137.05	8	890	35	UST-USA	234120	65.97	56.92	8	509	20
TJUHTET	294560	56.53	89.32	7	508	20	UST-VOJAMPOLKA	322520	58.50	159.17	8	477	19
TJUKALINSK	285860	55.87	72.20	7	391	15	USUGLI	307640	52.65	115.17	8	360	14
TJUMEN	283670	57.12	65.43	7	470	19	UYBAT	298640	53.72	90.37	7	288	11
TOBOLSK	282750	58.15	68.25	7	473	19	UZUR	296530	55.30	89.82	7	414	16
TOGUCHIN	296360	55.23	84.40	7	438	17	VANZIL-KYNAK	239660	60.35	84.08	8	577	23
TOKO	311370	56.28	131.13	8	473	19	VELIKIE LUKI	264770	56.35	30.62	6A	596	23
TOMPA	304390	55.12	109.75	8	357	14	VELSK	228670	61.08	42.07	7	594	23
TOMSK	294300	56.50	84.92	7	527	21	VERESCAGINO	282160	58.08	54.68	7	580	23
TOT`MA	270510	59.88	42.75	7	647	25	VERHNEE PENZINO	255380	64.22	164.23	8	322	13
TROICKOE	316550	49.45	136.57	7	658	26	VERHNEIMBATSK	236780	63.15	87.95	8	561	22

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
VERHNIJ BASKUNCAK	345790	48.22	46.73	5B	269	11
VERHNIJ UFALEJ	285410	56.08	60.30	7	535	21
VERHNJAJA TOJMA	227780	62.23	45.02	7	596	23
VERHNJAJA TOM	314590	51.35	130.43	8	665	26
VERHOTUR`E	281440	58.87	60.78	7	520	20
VESELAJA GORKA	314180	52.28	135.80	7	607	24
VESLJANA	237010	62.98	50.90	7	581	23
VIKULOVO	284810	56.82	70.62	7	427	17
VILJUJSK	246410	63.77	121.62	8	264	10
VITIM	300540	59.45	112.58	8	433	17
VJAZMA	266950	55.17	34.40	7	660	26
VLADIMIR	275320	56.12	40.35	7	620	24
VLADIVOSTOK	319600	43.12	131.93	6A	795	31
VNUKOVO	275185	55.58	37.25	6A	667	26
VOLCIHA	360220	52.02	80.37	7	343	14
VOLGOGRAD	345600	48.78	44.37	6A	387	15
VOLOGDA	270370	59.32	39.92	7	561	22
VORKUTA	232260	67.48	64.02	8	574	23
VOROGOVO	239730	61.03	89.63	8	575	23
VORONEZ	341220	51.65	39.25	6A	570	22
VORONEZ	341230	51.70	39.22	6A	570	22
VOZEGA	229540	60.47	40.20	7	672	26
VYBORG	228920	60.72	28.73	7	693	27
VYTEGRA	228370	61.02	36.45	7	671	26
WLADIKAVKAZ	372280	43.05	44.65	5A	895	35
ZAMETCINO	278570	53.48	42.63	6A	496	20
ZAMOKTA	307410	52.77	109.97	8	471	19
ZAVITAJA	315270	50.12	129.47	7	595	23
ZDVINSK	297120	54.70	78.67	7	332	13
ZEJA	313000	53.70	127.30	8	527	21
ZERDEVKA	340470	51.83	41.48	6A	504	20
ZHIGALOVO	305210	54.80	105.22	8	333	13
ZHIGANSK	243430	66.77	123.40	8	274	11
ZILAIR	350260	52.22	57.40	7	569	22
ZILOVO	306690	53.07	117.48	8	401	16
ZIMA	306030	53.93	102.05	7	348	14
ZIZGIN	224380	65.20	36.82	7	371	15
ZOHOVA ISLAND	213580	76.15	152.83	8	201	8
ZOLOTOJ	318290	47.32	138.98	7	912	36
ZURAVLEVKA	319420	44.75	134.47	7	656	26
ZYRJANKA	254000	65.73	150.90	8	275	11
Saint Lucia (LCA)						
HEWANORRA INTL AIRP	789480	13.75	–60.95	0A	1128	44
Samoa (WSM)						
APIA	917620	–13.80	–171.78	0A	2971	117
Saudi Arabia (SAU)						
ABHA	411120	18.23	42.65	3B	224	9
AL-AHSA	404200	25.30	49.48	0B	90	4
AL-BAHA	410550	20.30	41.65	2B	157	6
AL-JOUF	403610	29.78	40.10	2B	56	2
AL-MADINAH	404300	24.55	39.70	0B	61	2
AL-QAISUMAH	403730	28.32	46.13	1B	136	5
AL-TAIF	410360	21.48	40.55	2B	150	6
AL-WEJH	404000	26.20	36.48	1B	35	1
ARAR	403570	30.90	41.13	2B	59	2
BISHA	410840	19.98	42.63	1B	117	5
DHAHRAN	404160	26.27	50.17	0B	79	3
GASSIM	404050	26.30	43.77	1B	187	7
GIZAN	411400	16.88	42.58	0B	136	5
GURIAT	403600	31.40	37.28	2B	66	3
HAIL	403940	27.43	41.68	2B	125	5
JEDDAH (KING ABDUL AZIZ INTL)	410240	21.70	39.18	0B	57	2
KHAMIS MUSHAIT	411140	18.30	42.80	2B	214	8
KING KHALED INT. AI	404370	24.93	46.72	1B	127	5
MAKKAH	410300	21.43	39.77	0B	102	4
NAJRAN	411280	17.62	44.42	1B	76	3
RAFHA	403620	29.62	43.48	2B	81	3
RIYADH OBS. (O.A.P.)	404380	24.70	46.73	0B	130	5
SHARORAH	411360	17.47	47.10	0B	66	3
TABUK	403750	28.38	36.60	2B	54	2
TURAIF	403560	31.68	38.73	3B	102	4
YENBO	404390	24.13	38.07	0B	38	2
Senegal (SEN)						
DAKAR/YOFF	616410	14.73	–17.50	1B	423	17
KAOLACK	616790	14.13	–16.07	0B	597	24
LINGUERE	616270	15.38	–15.12	0B	432	17
MATAM	616300	15.65	–13.25	0B	369	15
SAINT-LOUIS	616000	16.05	–16.45	1B	255	10
TAMBACOUNDA	616870	13.77	–13.68	0B	765	30
ZIGUINCHOR	616950	12.55	–16.27	0A	1264	50
Serbia (SRB)						
BANATSKI KARLOVAC	131800	45.05	21.03	4A	627	25
BEOGRAD	132740	44.80	20.47	4A	674	27
BEOGRAD/SURCIN	132720	44.82	20.28	4A	666	26
CRNI VRH	132890	44.12	21.95	6A	684	27
CUPRIJA	133840	43.93	21.38	4A	652	26
DIMITROVGRAD	133970	43.02	22.75	5A	618	24
KIKINDA	131740	45.85	20.47	4A	544	21
KOPAONIK	133780	43.28	20.80	7	845	33
KRALJEVO	133760	43.70	20.70	4A	785	31
KRUSEVAC	133830	43.57	21.35	4A	648	26
LESKOVAC	133890	42.98	21.95	4A	610	24
LOZNICA	132620	44.55	19.23	4A	832	33
NEGOTIN	132950	44.23	22.55	4A	592	23
NIS	133880	43.33	21.90	4A	615	24
NOVI SAD RIMSKI SAN	131680	45.33	19.85	4A	581	23
PALIC	130670	46.10	19.77	4A	539	21
PEC	134730	42.67	20.30	4A	863	34
PLEVLJA	133630	43.35	19.35	5A	936	37
PODGORICA	134624	42.35	19.25	3A	1707	67
PODGORICA/GOLUBOVCI	134620	42.37	19.25	3A	1707	67
PRISTINA	134810	42.65	21.15	5A	629	25
PRIZREN	134770	42.22	20.73	4A	852	34
SJENICA	133690	43.28	20.00	6A	763	30
SMEDEREVSKA PALANKA	132790	44.37	20.95	4A	644	25
SOMBOR	131600	45.77	19.15	4A	591	23

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
SREMSKA MITROVICA	132660	45.10	19.55	4A	618	24
TIVAT	134570	42.40	18.73	3A	2205	87
VALJEVO	132690	44.32	19.92	4A	783	31
VELIKO GRADISTE	132850	44.75	21.52	4A	644	25
VRANJE	134890	42.55	21.92	4A	611	24
VRSAC	131830	45.15	21.32	4A	678	27
ZLATIBOR	133670	43.73	19.72	5A	951	37
ZRENJANIN	131730	45.37	20.42	4A	567	22
Seychelles (SYC)						
SEYCHELLES INTERNAT	639800	–4.67	55.52	0A	2337	92
Singapore (SGP)						
SINGAPORE/CHANGI AI	486980	1.37	103.98	0A	2068	81
Sint Maarten, Dutch part (SXM)						
PRINSES JULIANA	788660	18.03	–63.12	0A	1056	42
Slovakia (SVK)						
BRATISLAVA-LETISKO	118160	48.20	17.20	5A	578	23
CHOPOK	119160	48.98	19.60	7	990	39
DUDINCE	118800	48.17	18.87	5A	579	23
HURBANOVO	118580	47.87	18.20	5A	554	22
KAMENICA NAD CIROCH	119930	48.93	22.00	5A	733	29
KOSICE	119680	48.67	21.22	5A	613	24
LIESEK	119180	49.37	19.68	6A	895	35
LOMNICKY STIT	119300	49.20	20.22	8	1156	46
LUCENEC	119270	48.33	19.73	5A	664	26
MILHOSTOV	119780	48.67	21.73	5A	599	24
NITRA	118550	48.28	18.13	5A	590	23
PIESTANY	118260	48.62	17.83	5A	603	24
POPRAD/TATRY	119340	49.07	20.25	6A	590	23
PRIEVIDZA	118670	48.77	18.60	5A	739	29
SLIAC	119030	48.65	19.15	5A	690	27
STRBSKE PLESO	119330	49.12	20.08	7	1156	46
STROPKOV/TISINEC	119760	49.22	21.65	5A	698	27
TELGART	119380	48.85	20.18	6A	801	32
ZILINA/HRICOV	118410	49.23	18.62	5A	787	31
Slovenia (SVN)						
KREDARICA	140080	46.38	13.85	7	1998	79
LISCA	140240	46.07	15.28	5A	1132	45
LJUBLJANA/BEZIGRAD	140150	46.07	14.52	4A	1364	54
LJUBLJANA/BRNIK	130140	46.22	14.48	5A	1500	59
MARIBOR	130260	46.48	15.68	5A	1099	43
MURSKA SOBOTA	140310	46.65	16.18	5A	894	35
NOVA GORICA	141060	45.90	13.63	4A	1520	60
NOVO MESTO	141210	45.80	15.18	5A	1208	48
PORTOROZ	131050	45.52	13.57	4A	1116	44
SLAVONSKI BROD	131500	45.17	18.00	5A	822	32
Solomon Islands (SLB)						
HONIARA/HENDERSON	915200	–9.42	160.05	0A	2004	79
South Africa (ZAF)						
BETHLEHEM	684610	–28.25	28.33	3A	690	27
BLOEMFONTEIN AIRPOR	684420	–29.10	26.30	3B	568	22
CALVINIA	686180	–31.47	19.77	3B	210	8
CAPE COLUMBINE	687120	–32.83	17.85	3C	273	11
CAPE TOWN INTNL. AI	688160	–33.97	18.60	3C	521	21
DE AAR	685380	–30.65	24.00	3B	331	13
DURBAN INTNL. AIRPO	685880	–29.97	30.95	2A	909	36
EAST LONDON	688580	–33.03	27.83	3A	875	34
GEORGE AIRPORT	688280	–34.02	22.38	3A	741	29
GOUGH ISLAND	689060	–40.35	–9.88	4A	3191	126
JOHANNESBURG INTNL.	683680	–26.15	28.23	3A	727	29
KIMBERLEY	684380	–28.80	24.77	3B	421	17
LANGEBAANWEG	687140	–32.97	18.17	3B	281	11
MAFIKENG WO	682420	–25.82	25.55	3B	562	22
MARION ISLAND	689940	–46.88	37.87	6A	2280	90
MOSSEL BAY (CAPE ST BLAIZE)	689280	–34.18	22.15	3B	379	15
PIETERSBURG	681740	–23.87	29.45	3B	487	19
PORT ELIZABETH	688420	–33.98	25.62	3A	608	24
PRETORIA (IRENE)	682630	–25.92	28.22	3A	714	28
PRETORIA-EENDRACHT	682620	–25.73	28.18	3A	681	27
SPRINGBOK	685120	–29.67	17.90	3B	192	8
UPINGTON	684240	–28.40	21.27	2B	195	8
Spain (ESP)						
ALBACETE/LOS LLANOS	082800	38.95	–1.85	4B	357	14
ALICANTE/EL ALTET	083600	38.28	–0.55	3B	319	13
ALMERIA/AEROPUERTO	084870	36.85	–2.38	3B	200	8
BARCELONA/AEROPUERT	081810	41.28	2.07	3A	623	25
BILBAO/SONDICA	080250	43.30	–2.90	3A	1231	48
CACERES	082610	39.47	–6.33	3A	569	22
CIUDAD REAL	083480	38.98	–3.92	3B	428	17
COIMBRA/CERNACHE	085480	40.15	–8.47	3C	998	39
GERONA/COSTA BRAVA	081840	41.90	2.77	3A	727	29
GRANADA/AEROPUERTO	084190	37.18	–3.78	3A	507	20
IBIZA/ES CODOLA	083730	38.88	1.38	3B	414	16
LA CORUNA	080010	43.37	–8.42	3C	1014	40
LAS PALMAS DE GRAN	600300	27.93	–15.38	2B	125	5
LOGRONO/AGONCILLO	080840	42.45	–2.33	3A	718	28
MADRID/BARAJAS RS	082210	40.45	–3.55	4A	454	18
MADRID/TORREJON	082270	40.48	–3.45	4A	461	18
MALAGA/AEROPUERTO	084820	36.67	–4.48	3A	558	22
MENORCA/MAHON	083140	39.87	4.23	3A	580	23
MORON DE LA FRONTER	083970	37.15	–5.62	3A	556	22
MURCIA	084300	38.00	–1.17	3B	283	11
OVIEDO	080150	43.35	–5.87	4A	1043	41
PALMA DE MALLORCA/S	083060	39.55	2.73	3A	620	24
ROTA NAS	084490	36.65	–6.35	3A	535	21
SALAMANCA/MATACAN	082020	40.95	–5.50	4C	459	18
SAN SEBASTIAN/IGUEL	080270	43.30	–2.03	3A	1715	68
SANTANDER	080230	43.48	–3.80	3C	1171	46
SANTIAGO/LABACOLLA	080420	42.90	–8.43	4C	1649	65
SEVILLA/SAN PABLO	083910	37.42	–5.90	3A	604	24
STA. CRUZ DE TENERI	600200	28.45	–16.25	2B	221	9
TENERIFE SUR	600250	28.05	–16.57	2B	286	11
VALENCIA/AEROPUERTO	082840	39.50	–0.47	3B	437	17
VALLADOLID	081410	41.65	–4.77	4A	454	18
VIGO/PEINADOR	080450	42.23	–8.63	3C	1587	62
VITORIA	080800	42.88	–2.72	4A	1042	41
ZARAGOZA (USAFB)	081605	41.67	–1.05	3B	311	12

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
ZARAGOZA/AEROPUERTO	081600	41.67	–1.00	3B	311	12
Sri Lanka (LKA)						
KATUNAYAKE	434500	7.17	79.88	0A	2031	80
St. Helena, Ascension, and Tristan de Cunha (SHN)						
ST. HELENA IS.	619010	–15.93	–5.67	3C	44	2
WIDE AWAKE FIELD (ASI)	619020	–7.97	–14.40	1B	117	5
Suriname (SUR)						
ZANDERIJ	812250	5.45	–55.20	0A	2249	89
Svalbard and Jan Mayen (SJM)						
BJORNOYA	010280	74.52	19.02	8	391	15
HOPEN	010620	76.50	25.07	8	431	17
SVALBARD LUFTHAVN	010080	78.25	15.47	8	186	7
Sweden (SWE)						
ANGELHOLM	025635	56.30	12.85	5A	742	29
ARJEPLOG	021240	66.05	17.87	7	588	23
ARVIKA	024040	59.67	12.58	6A	702	28
BJUROKLUBB (LGT-H)	022960	64.48	21.58	7	588	23
BLOMSKOG	024080	59.22	12.08	6A	812	32
BORLANGE	024350	60.43	15.52	6A	638	25
EDSBYN	023380	61.37	15.72	7	589	23
FALSTERBO	026160	55.38	12.82	5A	502	20
FARO ISLAND	025880	57.90	19.17	6A	535	21
FLODA	024760	59.05	16.40	6A	575	23
FOLKARNA	024440	60.17	16.32	6A	602	24
FRANSTA	023420	62.50	16.18	7	545	21
GADDEDE	022220	64.50	14.17	7	799	31
GALLIVARE	020490	67.15	20.65	7	526	21
GAVLE	024530	60.72	17.17	6A	632	25
GLADHAMMAR	025760	57.78	16.60	6A	538	21
GOTEBORG	025130	57.72	12.00	5A	813	32
GOTEBORG/LANDVETTER	025260	57.67	12.30	6A	931	37
GOTEBORG/SAVE	025120	57.78	11.88	6A	813	32
GOTSKA SANDON	025840	58.40	19.20	6A	537	21
GUNNARN	021280	65.02	17.68	7	597	24
HAGSHULT	025560	57.30	14.13	6A	769	30
HALLANDS VADERO	026050	56.45	12.55	5A	667	26
HANO	026280	56.02	14.85	5A	577	23
HAPARANDA	021960	65.83	24.15	7	577	23
HARSTENA	025860	58.25	17.02	6A	664	26
HELSINGBORG	026110	56.03	12.77	5A	729	29
HOBURG	026800	56.92	18.15	5A	507	20
HOLMOGADD	022880	63.60	20.75	7	572	23
IDVATTNET	022520	64.45	17.08	7	605	24
JOKKMOKK (SWE-AFB)	021420	66.63	19.65	8	501	20
JONKOPING/AXAMO	025500	57.75	14.08	6A	690	27
JUNSELE	022440	63.68	16.95	7	575	23
KALMAR	026700	56.68	16.30	5A	501	20
KALMAR	026720	56.73	16.30	6A	501	20
KARESUANDO	020800	68.45	22.45	8	456	18
KARLSBORG(SAFB)	025440	58.52	14.53	6A	582	23
KARLSTAD FLYGPLATS	024180	59.45	13.47	6A	638	25
KATTERJAKK	020200	68.42	18.17	8	817	32
KIRUNA	020440	67.82	20.33	8	502	20
KLIMPFJALL	021080	65.07	14.80	7	736	29
KRANGEDE	022470	63.15	16.17	7	579	23
KUGGOREN	023550	61.70	17.53	6A	683	27
KULLEN (LGT-H)	026060	56.30	12.45	5A	573	23
KVIKKJOKK-ARRENJARK	021200	66.88	17.75	7	629	25
LAINIO	020860	67.77	22.35	8	535	21
LANDSORT	025820	58.75	17.87	6A	446	18
LINKOPING/MALMSLATT	025620	58.40	15.53	6A	552	22
LJUNGBY	026220	56.85	13.88	6A	825	32
LJUNGBYHED	020001	56.08	13.20	5A	798	31
LULEA-KALLAX	021860	65.55	22.13	7	532	21
MALILLA	025660	57.40	15.82	6A	572	23
MALMO/STURUP	026360	55.55	13.37	5A	696	27
MALUNG	024100	60.68	13.72	7	704	28
MASESKAR	025050	58.10	11.33	5A	648	25
NAIMAKKA	020600	68.68	21.53	8	462	18
NIDINGEN	025180	57.30	11.90	5A	742	29
NIKKALUOKTA	020360	67.85	19.03	8	513	20
NORRKOPING/BRAVALLA	025700	58.62	16.12	6A	549	22
NORRKOPING/KUNGSANG	025710	58.58	16.15	6A	549	22
OLANDS NORRA UDDE	025920	57.37	17.10	5A	422	17
OLANDS SODRA UDDE	026440	56.20	16.40	5A	726	29
OREBRO	024320	59.23	15.05	6A	650	26
ORSKAR	024880	60.53	18.38	6A	475	19
OSBY	026260	56.37	13.95	6A	796	31
OSTERSUND FROSON	022260	63.20	14.50	7	486	19
OSTMARK	024000	60.35	12.65	7	799	31
OVERKALIX SVARTBYN	021810	66.27	22.85	7	549	22
PAJALA	020960	67.22	23.40	7	586	23
PALKEM	021640	66.38	21.63	7	670	26
PITE-RONNSKAR	021760	65.03	21.57	7	446	18
RANGEDALA	025360	57.78	13.17	6A	933	37
RITSEM	020120	67.73	17.47	7	608	24
RONNEBY/KALLINGE	026640	56.27	15.27	6A	655	26
RORBACKSNAS	023060	61.13	12.82	7	753	30
SARNA	023160	61.70	13.18	7	686	27
SATENAS	025200	58.43	12.72	6A	689	27
SINGO ISLAND	024740	60.17	18.75	6A	640	25
SKAGSUDDE	022690	63.18	19.02	6A	532	21
SKAVSTA	024853	58.78	16.90	6A	534	21
SKILLINGE	026250	55.48	14.32	5A	557	22
SODERHAMN	022861	61.25	17.10	6A	636	25
STOCKHOLM/ARLANDA	024600	59.65	17.95	6A	556	22
STOCKHOLM/BROMMA	024640	59.37	17.90	6A	550	22
STORLIEN	022060	63.30	12.12	7	986	39
SVEG	023240	62.02	14.37	7	631	25
SVENSKA HOGARNA	024960	59.45	19.50	6A	453	18
TANNAS	023080	62.45	12.67	7	614	24
TIMRA/MIDLANDA	023660	62.52	17.45	7	597	23
UMEA	022860	63.80	20.28	7	596	23
UNGSKAR	026660	56.03	15.80	5A	537	21

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
UPPSALA	024580	59.90	17.60	6A	570	22
VASTERAS/HASSLO AFB	024460	59.58	16.63	6A	544	21
VIDSEL	021540	65.88	20.15	7	615	24
VILHELMINA	022450	64.58	16.85	7	594	23
VISBY	025900	57.67	18.35	6A	521	21
VUOGGATJALME	021120	66.57	16.35	8	621	24
Switzerland (CHE)						
AIGLE	067120	46.33	6.92	5A	1324	52
ALTDORF	066720	46.87	8.63	5A	1715	68
CHUR-EMS	067860	46.87	9.53	5A	1123	44
CIMETTA	067590	46.20	8.80	6A	1748	69
COMPROVASCO	067560	46.47	8.93	4A	1568	62
CORVATSCH	067910	46.42	9.82	8	1061	42
DISENTIS	067820	46.70	8.85	6A	1357	53
FAHY	066160	47.43	6.95	5A	1245	49
GENEVE-COINTRIN	067000	46.25	6.13	4A	957	38
GUETSCH	067500	46.65	8.62	7	1613	63
HOERNKI	066890	47.37	8.95	6A	1341	53
INTERLAKEN	067340	46.67	7.87	5A	1304	51
JUNGFRAUJOCH	067300	46.55	7.98	8	1304	51
LA CHAUX-DE-FONDS	066120	47.08	6.80	6A	1301	51
LA DOLE	067020	46.43	6.10	7	1268	50
LAEGERN	066690	47.48	8.40	5A	1116	44
LOCARNO-MAGADINO	067620	46.17	8.88	4A	1748	69
LOCARNO-MONTI	067600	46.17	8.78	4A	1748	69
LUGANO	067700	46.00	8.97	4A	1593	63
MONTANA	067240	46.32	7.48	6A	1097	43
NAPF	066390	47.00	7.93	6A	1332	52
NEUCHATEL	066040	47.00	6.95	5A	978	38
PAYERNE	066100	46.82	6.95	5A	897	35
PIOTTA	067530	46.52	8.68	5A	1613	63
PLAFFEIEN-OBERSCHRO	066280	46.75	7.27	6A	1350	53
ROBBIA	067940	46.35	10.07	6A	1022	40
SAENTIS	066800	47.25	9.35	7	2474	97
SAMEDAM-FLUGPLATZ	067920	46.53	9.88	7	1001	39
SAN BERNARDINO	067830	46.47	9.18	7	1543	61
SION	067200	46.22	7.33	5A	871	34
ST. GALLEN	066810	47.43	9.40	5A	1459	57
STABIO	067710	45.85	8.93	4A	1626	64
WYNAU	066430	47.25	7.78	5A	1273	50
ZUERICH METEOSCHWEI	066600	47.38	8.57	5A	1131	45
ZURICH-KLOTEN	066700	47.48	8.53	5A	1191	47
Syria (SYR)						
ALEPPO INT. AEROPOR	400070	36.18	37.20	3B	326	13
DAMASCUS INT. AIRPO	400800	33.42	36.52	3B	172	7
DARAA	400950	32.60	36.10	3B	268	11
DEIR EZZOR	400450	35.32	40.15	2B	154	6
HAMA	400300	35.12	36.75	3A	373	15
LATTAKIA	400220	35.53	35.77	3A	769	30
NABK	400830	34.03	36.72	4A	279	11
PALMYRA	400610	34.55	38.30	2B	131	5
SAFITA	400660	34.82	36.13	3A	977	38
Taiwan, Province of China (TWN)						
CHIANG KAI SHEK	466860	25.08	121.22	2A	1827	72
CHIAYI	467480	23.50	120.45	2A	1793	71
CHIAYI (TW-AFB)	467460	23.47	120.38	2A	1793	71
CHIHHANG (TW-AFB)	467600	22.80	121.18	1A	1943	77
CHILUNG	466940	25.15	121.80	2A	3111	122
CHINMEM/SHATOU(AFB)	467360	24.43	118.37	2A	1110	44
DONGSHA DAO	597920	20.67	116.72	1A	1445	57
HENGCHUN	467520	21.93	120.83	1A	1982	78
HENGCHUN	595590	22.00	120.75	1A	1982	78
HSINCHU (TW-AFB)	467560	24.82	120.93	2A	1697	67
HSINCHU CITY	467570	24.83	120.93	2A	1697	67
HUA-LIEN CITY	466990	23.98	121.60	2A	2129	84
HULIEN AB (=593620)	467630	24.03	121.62	2A	2129	84
ILAN CITY	467080	24.75	121.78	2A	2621	103
KANGSHAN (TW-AFB)	467450	22.78	120.27	1A	1571	62
KAOHSIUNG	467440	22.63	120.28	1A	1619	64
KAOHSIUNG INTL ARPT	467400	22.58	120.35	1A	1619	64
LAN YU	595670	22.03	121.55	2A	1862	73
MAKUNG AB (=593450)	467340	23.58	119.62	2A	951	37
MAZU	588490	26.17	119.93	3A	1242	49
NANSHA DAO	599970	10.38	114.37	0A	1891	74
PENGHU ISLANDS	467350	23.50	119.50	2A	1606	63
PENGJIA YU	589740	25.63	122.07	2A	1657	65
PINGTUNG NORTH(AFB)	467580	22.70	120.48	1A	1619	64
PINGTUNG SOUTH(AFB)	467500	22.68	120.47	1A	1619	64
SUAO MET STATION	467060	24.60	121.85	2A	2621	103
SUNGSHAN/TAIPEI	466960	25.07	121.55	2A	2218	87
TAIBEI	589680	25.03	121.52	2A	2218	87
TAICHUNG (TW-AFB)	467510	24.18	120.65	2A	1603	63
TAIDONG	595620	22.75	121.15	1A	1878	74
TAINAN	593580	23.00	120.22	1A	1585	62
TAINAN (TW-AFB)	467430	22.95	120.20	1A	1585	62
TAIZHONG	591580	24.15	120.68	1A	1603	63
TAOYUAN AB (=589650)	466970	25.07	121.23	2A	1827	72
WU-CHI OBSERVATORY	467770	24.25	120.52	2A	1652	65
WUCHIA OBSERVATORY	467700	24.27	120.62	2A	1464	58
Tajikistan (TJK)						
DUSHANBE	388360	38.55	68.78	3A	671	26
KHOROG	389540	37.50	71.50	5B	239	9
KHUDJAND	385990	40.22	69.73	4B	162	6
Tanzania, United Republic of (TZA)						
DAR ES SALAAM AIRPO	638940	–6.87	39.20	1A	1125	44
Thailand (THA)						
ARANYAPRATHET	484620	13.70	102.58	0A	1426	56
BANGKOK METROPOLIS	484550	13.73	100.57	0A	1500	59
BHUMIBOL DAM	483770	17.25	99.02	0A	1061	42
BUA CHUM	484180	15.27	101.18	0A	1131	45
CHAIYAPHUM	484030	15.80	102.03	0A	1207	48
CHANTHABURI	484800	12.60	102.12	0A	2902	114
CHIANG MAI	483270	18.78	98.98	1A	1183	47
CHIANG RAI	483030	19.97	99.88	1A	1671	66
CHON BURI	484590	13.37	100.98	0A	1323	52
CHUMPHON	485170	10.48	99.18	0A	2354	93
DON MUANG	484560	13.92	100.60	0A	1438	57
HAT YAI	485690	6.92	100.43	0A	1779	70

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
HUA HIN	484750	12.58	99.95	0A	1002	39
KAM PAENG PHET	483800	16.48	99.53	0A	1277	50
KANCHANABURI	484500	14.02	99.53	0A	1095	43
KHLONG YAI	485010	11.77	102.88	0A	4583	180
KHON KAEN	483810	16.43	102.83	0A	1167	46
KO LANTA	485660	7.53	99.05	0A	2181	86
KO SAMUI	485500	9.47	100.05	0A	1954	77
KO SICHANG	484600	13.17	100.80	0A	1218	48
LAMPANG	483280	18.28	99.52	0A	1132	45
LAMPHUN	483290	18.57	99.03	0A	1062	42
LOEI	483530	17.45	101.73	1A	1218	48
LOP BURI	484260	14.80	100.62	0A	1239	49
MAE HONG SON	483000	19.30	97.83	0A	1313	52
MAE SARIANG	483250	18.17	97.93	0A	1282	50
MAE SOT	483750	16.67	98.55	1A	1584	62
MUKDAHAN	483830	16.53	104.72	0A	1564	62
NAKHON PHANOM	483570	17.42	104.78	0A	2422	95
NAKHON RATCHASIMA	484310	14.97	102.08	0A	1055	42
NAKHON SAWAN	484000	15.80	100.17	0A	1140	45
NAKHON SI THAMMARAT	485520	8.53	99.95	0A	2520	99
NAN	483310	18.77	100.77	0A	1307	51
NARATHIWAT	485830	6.42	101.82	0A	2713	107
NONG KHAI	483520	17.87	102.72	0A	1670	66
PATTANI	485800	6.78	101.15	0A	1873	74
PHATTHAYA	484610	12.92	100.87	0A	1225	48
PHAYAO	483100	19.13	99.90	1A	1127	44
PHETCHABUN	483790	16.43	101.15	0A	1149	45
PHETCHABURI	484650	13.15	100.07	0A	1002	39
PHITSANULOK	483780	16.78	100.27	0A	1345	53
PHRAE	483300	18.17	100.17	0A	1141	45
PHUKET	485640	7.88	98.40	0A	2350	93
PHUKET AIRPORT	485650	8.13	98.32	0A	2656	105
PRACHIN BURI	484300	14.05	101.37	0A	2063	81
PRACHUAP KHIRIKHAN	485000	11.82	99.82	0A	1142	45
RANONG	485320	9.98	98.62	0A	4304	169
RAYONG	484780	12.63	101.35	0A	1433	56
ROI ET	484050	16.05	103.68	0A	1461	58
SAKON NAKHON	483560	17.15	104.13	0A	1615	64
SATTAHIP	484770	12.68	100.98	0A	1274	50
SONGKHLA	485680	7.20	100.62	0A	2116	83
SUPHAN BURI	484250	14.47	100.13	0A	1238	49
SURAT THANI	485510	9.12	99.15	0A	1801	71
SURIN	484320	14.88	103.50	0A	1289	51
TAK	483760	16.88	99.15	0A	1081	43
THA TUM	484160	15.32	103.68	0A	1382	54
THONG PHA PHUM	484210	14.75	98.63	0A	2273	89
TRANG	485670	7.52	99.62	0A	2274	90
UBON RATCHATHANI	484070	15.25	104.87	0A	1644	65
UDON THANI	483540	17.38	102.80	0A	1481	58
UTTARADIT	483510	17.62	100.10	0A	1481	58
Togo (TGO)						
LOME	653870	6.17	1.25	0A	856	34
Tonga (TON)						
FUAAMOTU	917920	–21.23	–175.15	1A	1732	68
HAAPAI	917840	–19.80	–174.35	1A	1680	66
Trinidad and Tobago (TTO)						
CROWN POINT AIRPORT	789620	11.15	–60.83	0A	1452	57
PIARCO INT. AIRPORT	789700	10.62	–61.35	0A	1781	70
Tunisia (TUN)						
BIZERTE	607140	37.25	9.80	3A	612	24
DJERBA MELLITA	607690	33.87	10.77	2B	232	9
GABES	607650	33.88	10.10	2B	203	8
GAFSA	607450	34.42	8.82	2B	163	6
HABIB BOURGUIBA INT	607403	35.75	10.75	2B	375	15
JENDOUBA	607250	36.48	8.80	3B	466	18
KAIROUAN	607350	35.67	10.10	2B	289	11
KELIBIA	607200	36.85	11.08	3A	534	21
MONASTIR-SKANES	607400	35.67	10.75	2B	375	15
SFAX EL-MAOU	607500	34.72	10.68	2B	225	9
TABARKA	607100	36.95	8.75	3A	1007	40
THALA	607380	35.55	8.68	3B	420	17
TOZEUR	607600	33.92	8.17	2B	99	4
TUNIS-CARTHAGE	607150	36.83	10.23	3A	466	18
Turkey (TUR)						
ADANA	173520	36.98	35.30	2A	696	27
ADANA/INCIRLIK AB	691464	37.00	35.43	3A	696	27
ADANA/INCIRLIK AFB	173500	37.00	35.42	3A	696	27
AFYON	171900	38.75	30.53	4C	413	16
AKHISAR	171840	38.92	27.85	3A	587	23
ANTALYA	173000	36.87	30.73	3A	1091	43
AYDIN	172340	37.85	27.85	3A	585	23
BALIKESIR	171500	39.62	27.92	4A	554	22
BANDIRMA	171150	40.32	27.97	4A	725	29
BODRUM	172900	37.03	27.43	2A	698	27
BOLU	170700	40.73	31.60	4A	551	22
BURSA	171160	40.18	29.07	3A	682	27
CANAKKALE	171120	40.13	26.40	3A	619	24
CORUM	170840	40.55	34.95	5C	437	17
DALAMAN	172950	36.70	28.78	3A	868	34
DIKILI	171800	39.07	26.88	3A	645	25
DIYARBAKIR	172800	37.88	40.18	4A	480	19
EDIRNE	170500	41.67	26.57	4A	590	23
ELAZIG	172020	38.60	39.28	4A	503	20
ERZINCAN	170920	39.70	39.52	5A	386	15
ERZURUM	170960	39.95	41.17	7	407	16
ESENBOGA	171280	40.12	33.00	5C	421	17
ESKISEHIR	171240	39.78	30.57	4A	390	15
ETIMESGUT	171290	39.95	32.68	4A	375	15
GAZIANTEP	172600	37.08	37.37	3A	583	23
GOKCEADA	171100	40.18	25.90	3A	733	29
GOLCUK/DUMLUPINAR	170670	40.67	29.83	3A	738	29
INEBOLU	170240	41.98	33.78	4A	1007	40
ISKENDERUN	173700	36.58	36.17	2A	766	30
ISPARTA	172400	37.75	30.55	4A	537	21
ISTANBUL/ATATURK	170600	40.97	28.82	3A	640	25
IZMIR/A. MENDERES	172190	38.27	27.15	3A	692	27
IZMIR/CIGLI	172180	38.52	27.02	3A	672	26
KAYSERI/ERKILET	171950	38.82	35.43	5C	384	15
KONYA	172440	37.97	32.55	4B	322	13
MALATYA/ERHAC	172000	38.43	38.08	4A	407	16

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

					Precipitation	
Country/LOCATION	**WMO#**	**Lat**	**Long**	**CZ**	**mm**	**in.**
MERZIFON	170820	40.85	35.58	4C	406	16
MUGLA	172920	37.22	28.37	3A	1168	46
SAMSUN	170300	41.28	36.30	3A	698	27
SILIFKE	173300	36.38	33.93	2A	564	22
SINOP	170260	42.03	35.17	3A	651	26
SIVAS	170900	39.75	37.02	5A	431	17
TEKIRDAG	170560	40.98	27.55	4A	566	22
TRABZON	170380	41.00	39.72	3A	771	30
USAK	171880	38.68	29.40	4A	515	20
VAN	171700	38.45	43.32	5C	387	15
ZONGULDAK	170220	41.45	31.80	4A	1202	47
Turkmenistan (TKM)						
ASHGABAT KESHI	388800	37.92	58.33	3B	236	9
BAJRAMALY	388950	37.60	62.18	3B	178	7
BAKHERDEN	387740	38.43	57.42	3B	238	9
BYRDALYK	388060	38.47	64.37	3B	175	7
CARSANGA	389150	37.52	66.02	2B	197	8
CHARDZHEV	386870	39.08	63.60	4B	129	5
DASHKHOVUZ	383920	41.75	59.82	4B	102	4
EKEZHE	383880	41.03	57.77	4B	128	5
ERBENT	386560	39.32	58.60	4B	106	4
ESENGYLY	387500	37.47	53.97	3B	207	8
GAZANDZHYK	386470	39.25	55.52	3B	171	7
GYSHGY	389870	35.28	62.35	3B	292	11
GYZYLARBAT	387630	38.98	56.28	4B	203	8
KERKI	389110	37.83	65.20	3B	181	7
SARAGT	389740	36.53	61.22	3B	203	8
TEDZHEN	388860	37.38	60.52	3B	169	7
TURKMENBASHI	385070	40.05	53.00	4B	137	5
UCHADZHY	387990	38.08	62.80	3B	143	6
Tuvalu (TUV)						
FUNAFUTI NF	916430	–8.53	179.22	0A	3467	136
Ukraine (UKR)						
BORYSPIL	333470	50.33	30.97	6A	551	22
CHERNIHIV	331350	51.47	31.25	6A	596	23
CHERNIVTSI	336580	48.37	25.90	5A	641	25
CHORNOMORSKE	339240	45.52	32.70	4A	399	16
DNIPROPETROVSK	345040	48.37	35.08	5A	509	20
DONETSK	345190	48.07	37.77	5A	533	21
HENICHESK	339100	46.17	34.82	5A	391	15
IVANO-FRANKIVSK	335260	48.97	24.70	5A	716	28
IZIUM	344150	49.18	37.30	5A	553	22
IZMAIL	338890	45.37	28.85	5A	478	19
KERCH	339830	45.40	36.42	5A	440	17
KHARKIV	343000	49.97	36.13	6A	533	21
KHERSON	339020	46.63	32.57	5A	433	17
KHMELNYTSKYI	334290	49.43	26.98	6A	664	26
KIROVOHRAD	337110	48.52	32.20	5A	499	20
KONOTOP	332610	51.23	33.20	6A	609	24
KRYVYI RIH	337910	48.03	33.22	5A	484	19
KYIV	333450	50.40	30.57	5A	633	25
LIUBASHIVKA	337610	47.85	30.27	5A	548	22
LUBNY	333770	50.00	33.02	6A	625	25
LUHANSK	345230	48.57	39.25	5A	474	19
LVIV	333930	49.82	23.95	5A	741	29
MARIUPOL	347120	47.03	37.50	5A	527	21
MOHYLIV-PODILSKYI	336630	48.45	27.78	5A	612	24
MYRONIVKA	334660	49.67	31.00	5A	565	22
NIZHYN	332460	51.05	31.90	6A	607	24
NOVA KAKHOVKA	338690	46.78	33.37	5A	439	17
ODESA	338370	46.43	30.77	5A	446	18
POLTAVA	335060	49.60	34.55	5A	566	22
RIVNE	333010	50.58	26.13	6A	589	23
SARNY	330880	51.28	26.62	5A	633	25
SHEPETIVKA	333170	50.17	27.03	6A	712	28
SIMFEROPOL	339460	45.02	33.98	5A	498	20
SUMY	332750	50.85	34.67	6A	603	24
SVITLOVODSK	336140	49.05	33.25	5A	552	22
TERNOPIL	334150	49.53	25.67	6A	610	24
UMAN	335870	48.77	30.23	5A	630	25
UZHHOROD	336310	48.63	22.27	5A	729	29
VINNYTSIA	335620	49.23	28.60	6A	632	25
VOLODYMYR-VOLYNSKYI	331770	50.83	24.32	5A	620	24
VOZNESENSK	337770	47.57	31.33	5A	506	20
YALTA	339900	44.48	34.17	4A	603	24
ZAPORIZHZHIA	346010	47.80	35.02	5A	504	20
ZHYTOMYR	333250	50.23	28.73	6A	607	24
United Arab Emirates (ARE)						
ABU DHABI BATEEN AI	412160	24.43	54.47	0B	72	3
ABU DHABI INTER. AI	412170	24.43	54.65	0B	68	3
AL AIN INTERNATIONA	412180	24.27	55.60	0B	73	3
DUBAI INTERNATIONAL	411940	25.25	55.33	0B	117	5
FUJAIRAH	411980	25.10	56.33	0B	90	4
RAS AL KHAIMAH INTE	411840	25.62	55.93	0B	128	5
SHARJAH INTER. AIRP	411960	25.33	55.52	0B	84	3
United Kingdom (GBR)						
ABERDARON	034050	52.78	–4.73	4A	1296	51
ABERDEEN/DYCE AIRPO	030910	57.20	–2.22	5A	813	32
ABERPORTH	035020	52.13	–4.57	5A	1224	48
ABOYNE	030800	57.08	–2.83	5A	901	35
ALCONBURY RAF	035620	52.37	–0.22	5A	537	21
ALTNAHARRA NO2	030440	58.28	–4.43	5A	1243	49
ANDREWSFIELD	036840	51.88	0.45	4A	575	23
AONACH MOR	030410	56.82	–4.97	7	1758	69
AUGHTON	033220	53.55	–2.92	5A	881	35
AULTBEA NO2	030340	57.87	–5.63	5A	1635	64
AVIEMORE	030630	57.20	–3.83	6A	1019	40
BALLYKELLY	039080	55.07	–7.02	5A	1099	43
BALLYPATRICK FOREST	039160	55.18	–6.17	5A	1269	50
BALTASOUND NO.2	030020	60.75	–0.85	5A	1210	48
BANGOR HARBOUR	039270	54.67	–5.67	4A	892	35
BARRA	030350	57.03	–7.45	5A	1358	53
BEDFORD	035600	52.22	–0.48	5A	569	22
BELFAST/ALDERGROVE	039170	54.65	–6.22	5A	851	34
BENBECULA ISLAND	030220	57.47	–7.37	5A	1358	53
BENSON	036580	51.62	–1.08	5A	655	26

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation	
					mm	in.
BINGLEY NO.2	033440	53.82	–1.87	5A	992	39
BIRMINGHAM AIRPORT	035340	52.45	–1.73	5A	672	26
BLACKPOOL AIRPORT	033180	53.77	–3.03	5A	977	38
BOSCOMBE DOWN	037460	51.17	–1.75	5A	713	28
BOULMER	032400	55.42	–1.60	5A	687	27
BOURNEMOUTH/HURN	038620	50.78	–1.83	4A	808	32
BRACKNELL/BEAUFORT	037630	51.38	–0.78	4A	684	27
BRAWDY(RAF)	036030	51.88	–5.12	5A	1112	44
BRIDLINGTON MRSC	032920	54.10	–0.17	5A	754	30
BRISTOL	037243	51.38	–2.72	5A	922	36
BRISTOL WEA CENTER	037260	51.47	–2.60	4A	894	35
BRIZE NORTON	036490	51.75	–1.58	5A	737	29
BUTT OF LEWIS (LH)	030250	58.52	–6.27	5A	1203	47
CAMBORNE	038080	50.22	–5.32	4A	1116	44
CAPE WRATH (LGT-H)	030490	58.63	–5.00	5A	1434	56
CAPEL CURIG	033050	53.10	–3.93	5A	1539	61
CARDIFF WEATHER CEN	037170	51.48	–3.18	4A	1073	42
CARDIFF-WALES ARPT	037150	51.40	–3.35	4A	947	37
CARDINHAM	038230	50.50	–4.67	5A	1304	51
CARLISLE	032200	54.93	–2.97	5A	776	31
CELLARHEAD	033380	53.03	–2.08	5A	955	38
CHARTERHALL	031580	55.70	–2.38	5A	783	31
CHIVENOR	037070	51.08	–4.15	4A	989	39
CHURCH LAWFORD	035440	52.37	–1.33	5A	674	27
CILFYNYDD	036140	51.63	–3.30	5A	1329	52
COLLAFIRTH HILL	030040	60.53	–1.38	6A	1076	42
COLTISHALL	034950	52.77	1.35	5A	630	25
CONINGSBY	033910	53.08	–0.17	5A	626	25
CORSEWALL PT. (LH)	031180	55.00	–5.15	5A	1183	47
COTTESMORE	034530	52.73	–0.65	5A	607	24
CRANWELL	033790	53.03	–0.50	5A	583	23
CROSBY	033160	53.50	–3.07	4A	773	30
CULDROSE	038090	50.08	–5.25	4A	1086	43
DISFORTH AIRFIELD	032610	54.13	–1.42	5A	647	25
DONNA NOOK NO.2	033850	53.48	0.08	5A	681	27
DRUMALBIN	031550	55.62	–3.73	5A	1104	43
DUMFRIES/DRUNGANS	031540	55.05	–3.65	5A	1050	41
DUNDRENNAN	031530	54.80	–4.00	5A	1215	48
DUNKESWELL AERODROM	038400	50.87	–3.23	5A	936	37
EAST MIDLANDS	034185	52.83	–1.32	5A	622	24
EDINBURGH AIRPORT	031600	55.95	–3.35	5A	661	26
EMLEY MOOR	033450	53.62	–1.67	5A	784	31
ESKDALEMUIR	031620	55.32	–3.20	6A	1606	63
EXETER AIRPORT	038390	50.73	–3.42	4A	811	32
FAIR ISLE	030080	59.53	–1.63	5A	1124	44
FAIRFORD RAF	036440	51.68	–1.78	5A	748	29
FARNBOROUGH	037680	51.28	–0.77	4A	684	27
FIFE NESS	031740	56.30	–2.58	5A	660	26
FINNINGLEY(RAF)	033600	53.48	–1.00	5A	575	23
FOULA	030140	60.12	–2.07	5A	1226	48
FOYERS	030570	57.27	–4.48	5A	932	37
FYLINGDALES	032810	54.37	–0.67	5A	767	30
GLASGOW AIRPORT	031400	55.87	–4.43	5A	1170	46
GLEN OGLE	031480	56.42	–4.32	6A	1675	66
GLENANNE	039230	54.23	–6.50	5A	1026	40
GRAVESEND-BROADNESS	037840	51.47	0.30	4A	643	25
GREAT DUN FELL	032270	54.68	–2.45	7	1249	49
GREENOCK MRCC	031380	55.97	–4.80	5A	1659	65
GWENNAP HEAD	038060	50.03	–5.67	4A	1091	43
HAWARDEN	033210	53.17	–2.98	5A	703	28
HEMSBY	034960	52.68	1.68	5A	589	23
HERSTMONCEUX	038820	50.90	0.32	4A	802	32
HERSTMONCEUX	038840	50.87	0.33	5A	802	32
HIGH WYCOMBE HQSTC	036600	51.68	–0.80	5A	660	26
HILLSBOROUGH	039200	54.48	–6.10	5A	1021	40
HOLBEACH	034690	52.87	0.15	5A	592	23
HONINGTON	035860	52.33	0.77	5A	608	24
HYSKEIR (LGT-H)	030240	56.97	–6.68	5A	1515	60
INVERBERVIE NO.2	030880	56.85	–2.27	5A	810	32
INVERGORDON HARBOUR	030580	57.68	–4.17	5A	711	28
ISLE OF PORTLAND	038570	50.52	–2.45	4A	912	36
KENLEY AIRFIELD	037810	51.30	–0.08	4A	688	27
KESWICK	032120	54.62	–3.17	5A	1364	54
KINLOSS	030660	57.65	–3.57	5A	629	25
KIRKWALL AIRPORT	030170	58.95	–2.90	5A	1017	40
LAKENHEATH RAF	035830	52.42	0.57	4A	607	24
LAKENHEATH RAF	035833	52.40	0.57	5A	607	24
LANGDON BAY	037960	51.13	1.35	5A	696	27
LARKHILL	037430	51.20	–1.80	5A	768	30
LARNE	039280	54.85	–5.80	5A	1172	46
LECONFIELD	033820	53.87	–0.43	5A	681	27
LEEDS BRADFORD	033463	53.87	–1.65	5A	769	30
LEEDS WEATHER CTR	033470	53.80	–1.55	4A	734	29
LEEMING	032570	54.30	–1.53	5A	626	25
LERWICK	030050	60.13	–1.18	6A	1220	48
LEUCHARS	031710	56.40	–2.87	5A	666	26
LINTON-ON-OUSE	032660	54.05	–1.25	5A	658	26
LISCOMBE	037100	51.08	–3.60	5A	1457	57
LITTLE RISSINGTON	036470	51.87	–1.68	5A	714	28
LIVERPOOL	033233	53.33	–2.85	4A	774	30
LOCH GLASCARNOCH	030310	57.72	–4.88	6A	1543	61
LOFTUS SAMOS	032750	54.57	–0.87	5A	696	27
LONDON WEA CENTER	037780	51.52	–0.12	4A	586	23
LONDON WEATHER CENT	037790	51.52	–0.10	4A	586	23
LONDON/GATWICK ARPT	037760	51.15	–0.18	4A	762	30
LONDON/HEATHROW AIR	037720	51.48	–0.45	4A	602	24
LOSSIEMOUTH	030680	57.72	–3.32	5A	691	27
LOUGH FEA	039110	54.72	–6.82	5A	1137	45
LUNDY ISL (LGT-H)	037020	51.17	–4.65	4A	947	37
LUTON	036733	51.87	–0.37	5A	693	27
LYNEHAM	037400	51.50	–1.98	5A	716	28
MACHRIHANISH	031110	55.43	–5.70	5A	1343	53
MADLEY	035210	52.03	–2.85	5A	806	32
MANCHESTER AIRPORT	033340	53.35	–2.28	5A	832	33
MANSTON	037970	51.35	1.37	4A	576	23
MARHAM	034820	52.65	0.57	5A	623	25

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
MIDDLE WALLOP	037490	51.15	–1.57	4A	749	29
MILDENHALL RAF	035773	52.37	0.48	4A	586	23
MILFORD HAVEN	036040	51.70	–5.05	4A	861	34
MUCKLE FLUGGA	030010	60.85	–0.88	5A	1210	48
MUCKLE HOLM	030070	60.58	–1.27	5A	1076	42
MUMBLES	036090	51.57	–3.98	4A	1198	47
NEWCASTLE	032433	55.03	–1.68	5A	668	26
NEWCASTLE WEATHER C	032460	54.98	–1.60	5A	666	26
NEWHAVEN (LGT-H)	038800	50.78	0.05	4A	841	33
NORTH RONA	030110	59.12	–5.82	5A	1398	55
NORTHOLT	036720	51.55	–0.42	4A	602	24
NORWICH WEA CNTRE	034920	52.63	1.32	4A	648	26
NOTTINGHAM/WATNALL	033540	53.00	–1.25	5A	715	28
OBAN	031140	56.42	–5.47	5A	2131	84
ODIHAM	037610	51.23	–0.95	4A	799	31
ORSAY (LGT-H)	031020	55.67	–6.50	5A	1266	50
PEMBREY SANDS	036050	51.72	–4.37	4A	1215	48
PENDENNIS POINT	038100	50.15	–5.07	4A	1117	44
PENDINE (AUT)	036080	51.75	–4.52	4A	1212	48
PERSHORE	035290	52.15	–2.03	5A	633	25
PETERHEAD HARBOUR	030920	57.50	–1.77	5A	724	29
PLYMOUTH MOUNT BATT	038270	50.35	–4.12	4A	1004	40
PORTGLENONE	039150	54.87	–6.45	5A	1098	43
PORTLAND HELIPORT	038580	50.57	–2.45	4A	912	36
PRESTWICK RNAS	031360	55.52	–4.58	5A	949	37
PRESTWICK(CIV/NAVY)	031350	55.50	–4.58	5A	949	37
REDESDALE CAMP	032300	55.28	–2.28	5A	957	38
RHYL	033130	53.25	–3.50	4A	1007	40
SCILLY: ST MARYS AI	038030	49.92	–6.30	4A	909	36
SELLA NESS	030060	60.45	–1.27	5A	1106	44
SENNYBRIDGE	035070	52.07	–3.62	5A	1495	59
SHAP	032250	54.50	–2.68	5A	1373	54
SHAWBURY	034140	52.80	–2.67	5A	658	26
SHEERNESS	037910	51.45	0.75	4A	599	24
SHOBDON	035200	52.25	–2.88	5A	827	33
SHOEBURYNESS	036930	51.55	0.83	4A	504	20
SHOREHAM AIRPORT	038760	50.83	–0.28	4A	715	28
SKYE/LUSA	030370	57.25	–5.80	5A	2115	83
SOLENT M.R.S.C.	038740	50.80	–1.22	4A	786	31
SOUTHAMPTON WX CNTR	038650	50.90	–1.40	4A	789	31
SOUTHEND	036913	51.57	0.68	4A	558	22
SPADEADAM	032240	55.05	–2.55	5A	1226	48
ST ANGELO	039030	54.40	–7.65	5A	1300	51
ST BEES HEAD NO.2	032100	54.52	–3.60	5A	1136	45
ST. CATHERINES POIN	038660	50.58	–1.30	4A	764	30
ST. MAWGAN	038170	50.43	–5.00	4A	1148	45
STANSTED AIRPORT	036830	51.88	0.23	5A	623	25
STORNOWAY	030260	58.22	–6.32	5A	1188	47
STRATHALLEN AIRFIEL	031440	56.32	–3.73	5A	954	38
SULE SKERRY	030100	59.08	–4.40	5A	1278	50
SUMBURGH (CAPE)	030030	59.88	–1.30	5A	1124	44
TAIN RANGE	030620	57.82	–3.97	5A	770	30
THAMES TOWER (AUT)	036950	51.67	1.10	4A	557	22
THORNEY ISLAND	038720	50.82	–0.92	4A	793	31
TIREE	031000	56.50	–6.88	5A	1182	47
TRAWSGOED	035030	52.35	–3.95	5A	1174	46
TULLOCH BRIDGE	030470	56.87	–4.70	5A	1553	61
TYNEMOUTH	032620	55.02	–1.42	5A	646	25
UPPER HEYFORD RAF	036553	51.93	–1.25	5A	645	25
VALLEY	033020	53.25	–4.53	4A	839	33
WADDINGTON	033770	53.17	–0.52	5A	603	24
WAINFLEET	033920	53.08	0.27	5A	584	23
WALNEY ISLAND	032140	54.12	–3.25	5A	1238	49
WALTON-ON-NAZE	036960	51.85	1.28	4A	546	21
WARCOP RANGE	032260	54.57	–2.42	5A	1249	49
WATTISHAM	035900	52.12	0.97	5A	582	23
WEST FREUGH	031320	54.85	–4.95	5A	977	38
WEYBOURNE	034880	52.95	1.13	4A	667	26
WICK	030750	58.45	–3.08	5A	787	31
WITTERING	034620	52.62	–0.47	5A	580	23
WYTON(RAF)	035660	52.35	–0.12	5A	537	21
YEOVILTON	038530	51.00	–2.63	4A	727	29
Uruguay (URY)						
ARTIGAS	863300	–30.38	–56.50	3A	1486	59
CARRASCO	865800	–34.83	–56.00	3A	950	37
COLONIA	865600	–34.45	–57.83	3A	1108	44
PASO DE LOS TOROS	864600	–32.80	–56.52	3A	1315	52
PRADO	865850	–34.85	–56.20	3A	1069	42
RIVERA	863500	–30.88	–55.53	3A	1500	59
ROCHA	865650	–34.48	–54.30	3A	1051	41
SALTO	863600	–31.38	–57.95	3A	1264	50
TREINTA Y TRES	865000	–33.22	–54.38	3A	1335	53
Uzbekistan (UZB)						
AK-BAJTAL	381780	43.15	64.33	5B	117	5
BUHARA	386830	39.72	64.62	4B	146	6
BUZAUBAJ	384030	41.75	62.47	4B	88	3
CHIMBAJ	382620	42.95	59.82	5B	120	5
DARGANATA	385450	40.47	62.28	4B	140	6
DZIZAK	385790	40.12	67.83	4B	385	15
FERGANA	386180	40.37	71.75	4B	175	7
KARSHI	388120	38.80	65.72	3B	253	10
KUNGRAD	381490	43.08	58.93	5B	118	5
NAMANGAN	386110	40.98	71.58	4B	189	7
NUKUS	382640	42.45	59.62	5B	106	4
NURATA	385650	40.55	65.68	4B	238	9
PSKEM	384620	41.90	70.37	5C	854	34
SAMARKAND	386960	39.57	66.95	4B	340	13
SYR-DARJA	385830	40.82	68.68	4A	312	12
TAMDY	384130	41.73	64.62	4B	127	5
TASHKENT	384570	41.27	69.27	4A	435	17
TERMEZ	389270	37.23	67.27	3B	148	6
URGENCH	383960	41.57	60.57	4B	92	4
Vanuatu (VUT)						
ANEITYUM	915680	–20.23	169.77	1A	1416	56
BAUERFIELD (EFATE)	915570	–17.70	168.30	1A	2249	89
PEKOA AIRPORT (SANTO)	915540	–15.52	167.22	1A	2823	111

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Table Annex1-3 ASHRAE Standard 169-2013, Table A-6: International Stations and Climate Zones *(Continued)*

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
Venezuela (VEN)						
CARACAS/MAIQUETIA A	804150	10.60	–66.98	0B	492	19
GUANARE	804280	9.02	–69.73	0A	1403	55
SAN ANTONIO DEL TAC	804470	7.85	–72.45	0A	746	29
Viet Nam (VNM)						
BACH LONG VI	488390	20.13	107.72	1A	1719	68
CA MAU	489140	9.18	105.15	0A	2379	94
CAO BANG	488080	22.67	106.25	2A	1536	60
CON SON	489180	8.68	106.60	0A	1781	70
DA NANG	488550	16.07	108.35	1A	2350	93
DONG HOI	488480	17.48	106.60	1A	2247	88
HA NOI	488200	21.03	105.80	1A	1652	65
HUE	488520	16.43	107.58	1A	2846	112
LANG SON	488300	21.83	106.77	2A	1426	56
LAO CAI	488030	22.50	103.97	1A	2178	86
NAM DINH	488230	20.43	106.15	1A	1802	71
NHA TRANG	488770	12.22	109.22	0A	1471	58
PHAN THIET	488870	10.93	108.10	0A	1153	45
PHU LIEN	488260	20.80	106.63	1A	1718	68
PHU QUOC	489170	10.22	103.97	0A	2380	94
QUY NHON	488700	13.77	109.22	0A	2053	81
SON LA	488060	21.33	103.90	2A	1422	56
TAN SON HOA	489000	10.82	106.67	0A	1862	73
THANH HOA	488400	19.75	105.78	1A	1748	69
VINH	488450	18.67	105.68	1A	2125	84
Wallis and Futuna (WLF)						
HIHIFO (ILE WALLIS)	917530	–13.23	–176.17	0A	2132	84
MAOPOOPO (ILE FUTUNA)	917540	–14.32	–178.12	0A	1989	78
Zimbabwe (ZWE)						
HARARE (KUTSAGA)	677750	–17.92	31.13	3A	803	32
MASVINGO	679750	–20.07	30.87	2B	605	24

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SECTION ANNEX1-1
ASHRAE STANDARD 169-2013, SECTION A3: CLIMATE ZONE DEFINITIONS

A3. CLIMATE ZONE DEFINITIONS

To determine the climate zones for locations not listed in this standard, use the following information to determine climate zone numbers and letters.

Determine the thermal climate zone, 0–8, from Table A-3, using the heating and cooling degree-days for the location.

Determine the moisture zone (Marine, Dry or Humid):

a. If monthly average temperature and precipitation data are available, use the Marine, Dry, and Humid definitions below to determine the moisture zone (C, B, or A).
b. If annual average temperature information (including degree-days) and annual precipitation (i.e. annual mean) are available, use the following to determine the moisture zone:
   1. If thermal climate zone is 3 and CDD50°F ≤ 4500 (CDD10°C ≤ 2500), climate zone is Marine (3C).
   2. If thermal climate zone is 4 and CDD50°F ≤ 2700 (CDD10°C ≤ 1500), climate zone is Marine (4C).
   3. If thermal climate zone is 5 and CDD50°F ≤ 1800 (CDD10°C ≤ 1000), climate zone is Marine (5C).

   Use the the third criteria below for determining the Dry/Humid threshold if not Marine (C).
c. If only degree-day information is available, use the following to determine the moisture zone:
   1. If thermal climate zone is 3 and CDD50°F ≤ 4500 (CDD10°C ≤ 2500), climate zone is Marine (3C).
   2. If thermal climate zone is 4 and CDD50°F ≤ 2700 (CDD10°C ≤ 1500), climate zone is Marine (4C).
   3. If thermal climate zone is 5 and CDD50°F ≤ 1800 (CDD10°C ≤ 1000), climate zone is Marine (5C).

   It is not possible to assign Dry/Humid splits in this case.

Marine (C) Zone Definition—Locations meeting all four of the following criteria:

a. Mean temperature of coldest month between 27°F (–3°C) and 65°F (18°C)
b. Warmest month mean < 72°F (22°C)
c. At least four months with mean temperatures over 50°F (10°C)
d. 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:

a. Not Marine (C)
b. If 70% or more of the precipitation, P, occurs during the high sun period, then the dry/humid threshold is
$$P < 0.44 \times (T - 7) \quad \text{(I-P)}$$
$$P < 20.0 \times (T + 14) \quad \text{(SI)}$$
c. If between 30% and 70% of the precipitation, P, occurs during the high sun period, then the dry/humid threshold is
$$P < 0.44 \times (T - 19.5) \quad \text{(I-P)}$$
$$P < 20.0 \times (T + 7) \quad \text{(SI)}$$
d. If 30% or less of the precipitation, P, occurs during the high sun period, then the dry/humid threshold is
$$P < 0.44 \times (T - 32) \quad \text{(I-P)}$$
$$P < 20 \times T \quad \text{(SI)}$$

where

P	=	annual precipitation, in. (mm)
T	=	annual mean temperature, °F (°C)
Summer or high sun period	=	April through September in the Northern Hemisphere and October through March in the Southern Hemisphere
Winter or cold season	=	October through March in the Northern Hemisphere and April through September in the Southern Hemisphere

Humid (A) Definition—Locations that are not Marine (C) and not Dry (B)

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Table Annex1-4 ASHRAE Standard 169-2013, Table A-3: Thermal Climate Zone Definitions

Thermal Zone	Name	I-P Units	SI Units
0	Extremely hot	10,800 < CDD50°F	6000 < CDD10°C
1	Very hot	9000 < CDD50°F ≤ 10,800	5000 < CDD10°C ≤ 6000
2	Hot	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3	Warm	CDD50°F ≤ 6300 and HDD65°F ≤ 3600	CDD10°C < 3500 and HDD18°C ≤ 2000
4	Mixed	CDD50°F ≤ 6300 and 3600 < HDD65°F ≤ 5400	CDD10°C < 3500 and 2000 < HDD18°C ≤ 3000
5	Cool	CDD50°F ≤ 6300 and 5400 < HDD65°F ≤ 7200	CDD10°C ≤ 3500 and 3000 < HDD18°C ≤ 4000
6	Cold	7200 < HDD65°F ≤ 9000	4000 < HDD18°C ≤ 5000
7	Very cold	9000 < HDD65°F ≤ 12600	5000 < HDD18°C ≤ 7000
8	Subarctic/arctic	12600 < HDD65°F	7000 < HDD18°C

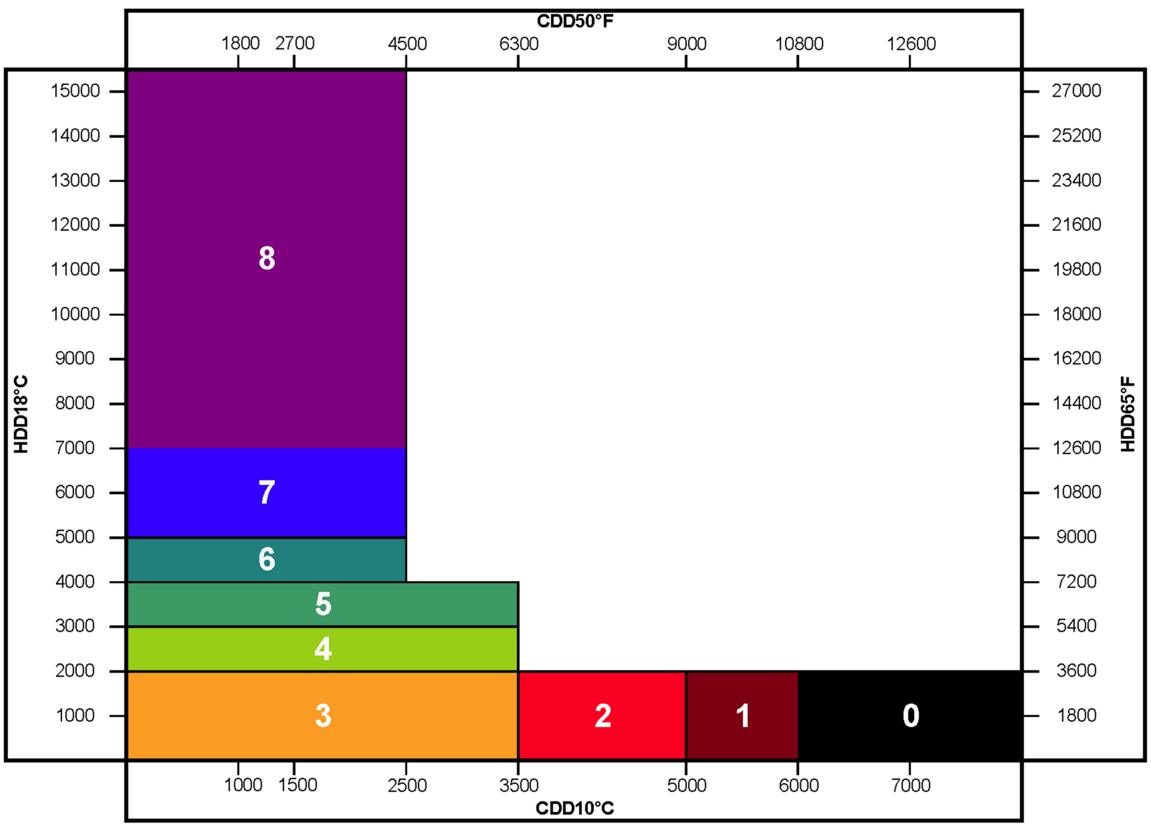

Figure Annex1-2 ASHRAE Standard 169-2013, Figure A-1: Thermal climate zones as a function of heating and cooling degree-days.

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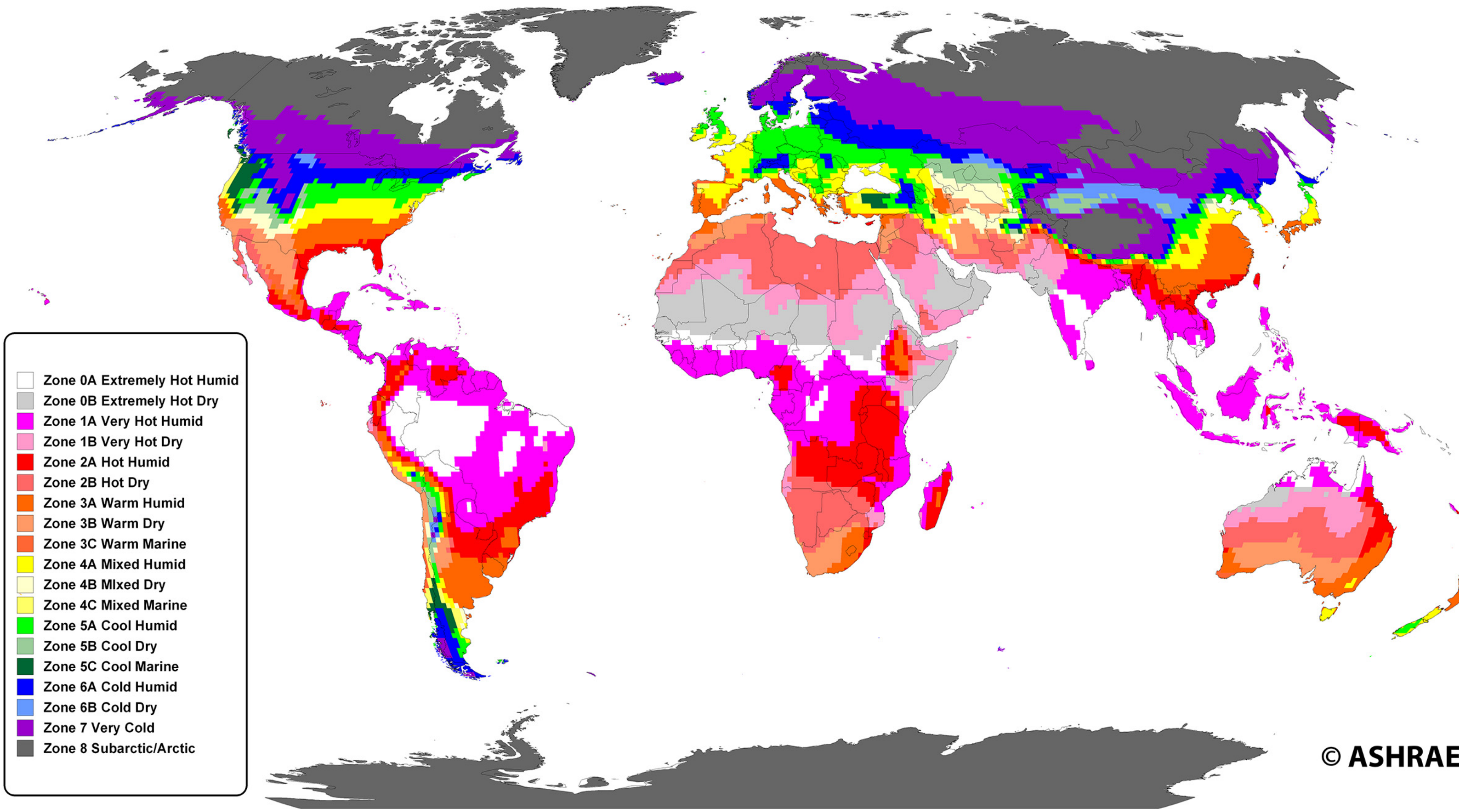

Figure Annex1-3 ASHRAE Standard 169-2013, Figure C-2: World climate zones map.

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SECTION ANNEX1-2
ASHRAE STANDARD 169-2013, SECTION 4:
CLIMATIC DESIGN DATA AND CLIMATE ZONES

4. CLIMATIC DESIGN DATA AND CLIMATE ZONES

Normative Appendix A comprises data for 5564 U.S., Canadian, and international locations. This information generally represents annual and monthly percentiles of occurrence of temperature, various measures of humidity, and wind speed for use in the design of building energy and ventilation systems. These data also include HDD and CDD annual average values and the number of hours between 8 a.m. and 4 p.m. when the dry-bulb temperature is between 55°F and 69°F (13°C and 21°C). A sample of this climatic data is provided in Table A-1 for Atlanta, Georgia, USA. Design conditions for all 5564 locations are located online at the following location:

www.ashrae.org/169_2013data

Table A-4 in Normative Appendix A lists climate zones and other key climatic data for U.S., Canadian, and international locations and includes links to the design conditions.

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ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

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Product code: 86327 12/22