STANDARD

ANSI/ASHRAE/IES Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2016)
Includes ANSI/ASHRAE/IES addenda listed in Appendix I

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

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

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ANSI/ASHRAE/IES Standard 90.1-2019
Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

NOTE

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

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

Foreword

The 2019 edition of Standard 90.1 incorporates over 100 addenda to the 2016 edition and includes numerous energy-saving measures. Notable changes include the following:

a. ***Administration and Enforcement.*** *Commissioning requirements were added to the standard for the first time. Section 4.2.5, "Verification, Testing, and Commissioning," was greatly expanded and requirements were outlined for commissioning in accordance with ASHRAE/IES Standard 202. A new Informative Appendix H provides additional information and guidance.*

b. ***Building Envelope***
   1. *For vertical fenestration, the categories of "nonmetal framed" and "metal framed" products were combined.*
   2. *Minimum criteria for SHGC and U-factor were upgraded across all climate zones.*
   3. *The air leakage section was revised to clarify compliance.*
   4. *Changes to the vestibule section refined the exceptions and added a new option and associated criteria for using air curtains.*

c. ***Lighting***
   1. *Lighting power allowances for the Space-by-Space Method and the Building Area Method were modified to reflect the outcomes of the fully reconstructed Standard 90.1 lighting model, which includes many updates and improvements. The model is more representative of real-world conditions with the inclusion of updated IES recommendations, room cavity ratios, additional surface reflectance categories, light loss factors, and a 100% LED technology baseline with updated efficacy values.*
   2. *A new simplified method for lighting (new Section 9.2) was added to provide a simple approach for contractors and designers who design or renovate office buildings and retail buildings up to 25,000 ft^2.*
   3. *Lighting control requirements for parking garages were updated to account for the use of LED in this application by increasing the stringency of the setback requirement to 50% and reducing the control timeout from 20 minutes to 10 minutes.*
   4. *Daylight responsive requirements were updated from continuous dimming or stepped control to continuous dimming required for all spaces, and a definition was added for continuous dimming based on NEMA LSD-64-2014.*
   5. *Side-lighting requirements were updated to clarify that the setback distance is a horizontal measurement, and the exception was amended to include natural objects as an obstruction.*

d. ***Mechanical***
   1. *New requirements were defined to allow designers the option to use ASHRAE Standard 90.4 instead of ASHRAE Standard 90.1 requirements in computer rooms that have an IT equipment load larger than 10 kW.*
   2. *Pump definitions, requirements, and efficiency tables are included in the standard for the first time, as they are now covered by the U.S. Department of Energy.*
   3. *Equipment efficiency requirements*
      - *New tables were added, and some existing tables were combined, renumbered, or deleted.*
      - *Where required, tables were updated to align with USDOE requirements.*

- *New Tables F-4 and F-5 were created for U.S. federally covered furnace products and to specify USDOE-covered residential water boiler efficiency requirements.*
- *The efficiency table for liquid-to-liquid heat exchangers was removed.*
- *New requirements and a new table were added for ceiling-mounted computer room units.*
- *New efficiency metrics and minimum efficiency requirements and a new Table 6.8.1-16 were added for heat pump and heat reclaim chillers.*
- *New requirements for vacuum insulating glazing were added to the list of options for reach-in doors in walk-in coolers and freezers in Section 6.4.5.*

4. *Fans and fan systems changes*
   - *The fan efficiency grade (FEG) efficiency metric was replaced with the fan energy index (FEI).*
   - *New requirements were added in Section 6.4.1.3. for reporting fan power for ceiling fans.*
   - *Requirements were updated in Section 6.5.3.1.2 for fan motor selections to increase the design options for load-matching variable-speed fan applications.*
5. *Energy recovery and heat reclaim*
   - *Energy recovery requirements were included for high-rise residential buildings.*
   - *A new requirement was added for condenser heat recovery for acute care inpatient hospitals.*

e. Energy Cost Budget (ECB) Method (Section 11)

1. *Numerous changes were made to ensure continuity.*
2. *The baseline was set for on-site electricity generation systems.*

f. Performance Rating Method (Appendix G)

1. *Appendix G rules and the corresponding baseline efficiency requirement were clarified for when combining multiple thermal zones into a single thermal block.*
2. *Explicit heating and cooling COPs were provided without fan for the baseline packaged cooling equipment.*
3. *Rules were added for modeling the impact of automatic receptacle controls.*
4. *More specific baseline rules were set for infiltration modeling.*
5. *Clarification was added for how plant and coil sizing should be performed.*
6. *Building performance factors in Section 4 were updated.*

g. Both Compliance Paths

1. *Clearer and more specific rules were added related to how renewables are treated.*
2. *Extensive updates were added to the rules for lighting modeling.*

In addition, the 2019 edition includes various changes and clarifications to improve internal consistency and to standardize the structure and language of the document. Affected items include submittal documentation requirements, compliance paths, and terminology.

Standard 90.1 is a fluid document. To remain viable it must evolve strategically and technically. The project committee welcomes suggestions for improvement, and users are encouraged to use the continuous maintenance proposal (CMP) form located on the ASHRAE website (www.ashrae.org/continuous-maintenance) to propose changes. The committee takes formal action on every CMP received. As addenda are approved, notices are published on the ASHRAE and IES websites. Users are encouraged to sign up for the free ASHRAE and IES Internet listserv for Standard 90.1 to receive notice of all public reviews and approved and published addenda and errata.

1 Purpose

1.1

To establish the minimum *energy efficiency* requirements of *buildings* other than *low-rise residential buildings* 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* in *existing buildings*, and
   4. new *equipment* or *building systems* specifically identified in the standard that are part of industrial or manufacturing processes

   and
b. criteria for determining compliance with these requirements.

2.2

The provisions of this standard do not apply to

a. single-family houses, 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* 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

A

above-grade wall: see *wall*.

access hatch: see *door*.

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

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

air economizer: see *economizer, air*.

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

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

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

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.

B

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.

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.

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1. Schedules and internal loads by *building* area type are at http://sspc901.ashraepcs.org/documents.php.

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

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

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*.)

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.

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 a *building*, *building systems*, or portions thereof.

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

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

continuous 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*.

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

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.

D

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.

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

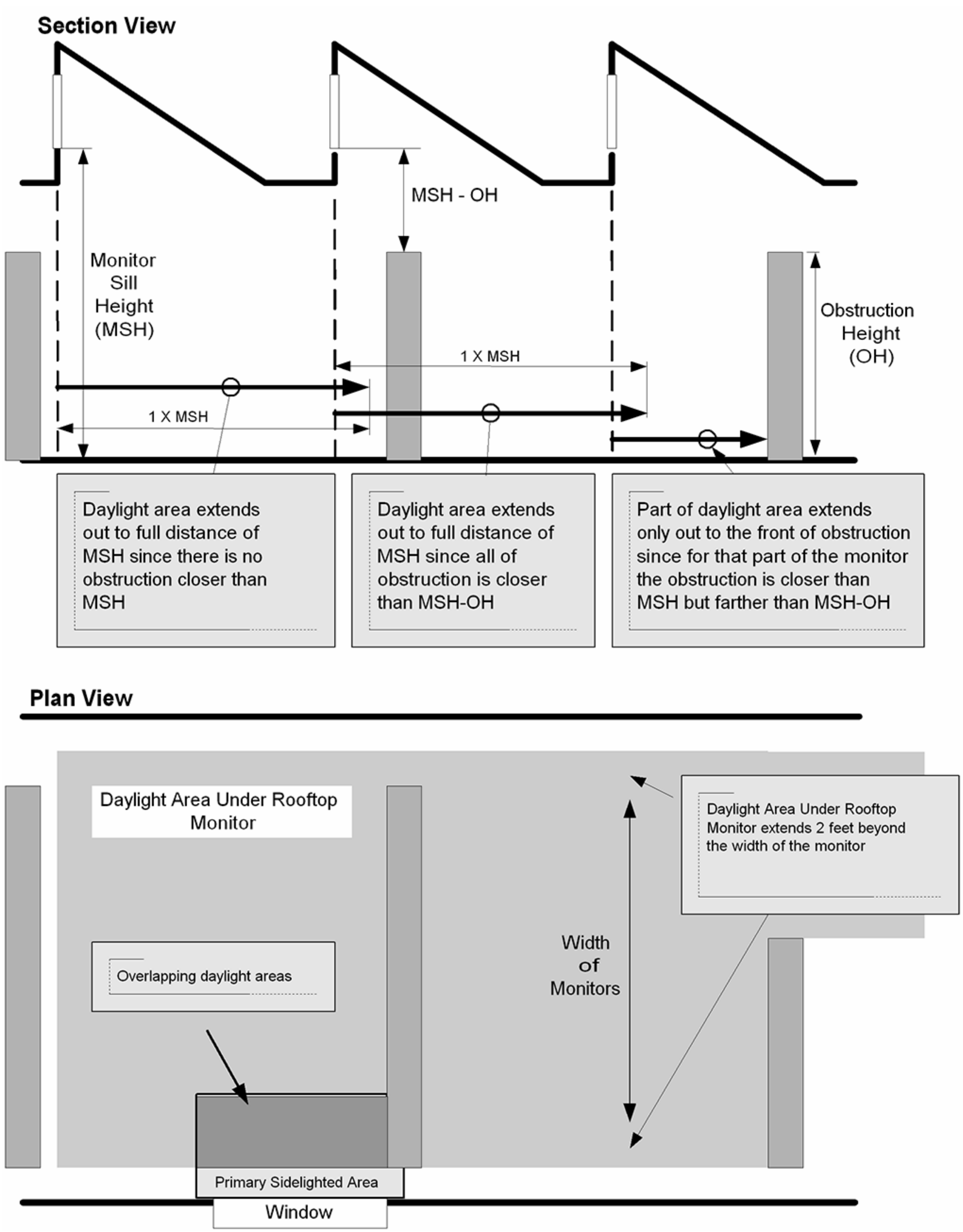


Figure 3.2-1 Computing the *daylight area under roof monitors*.

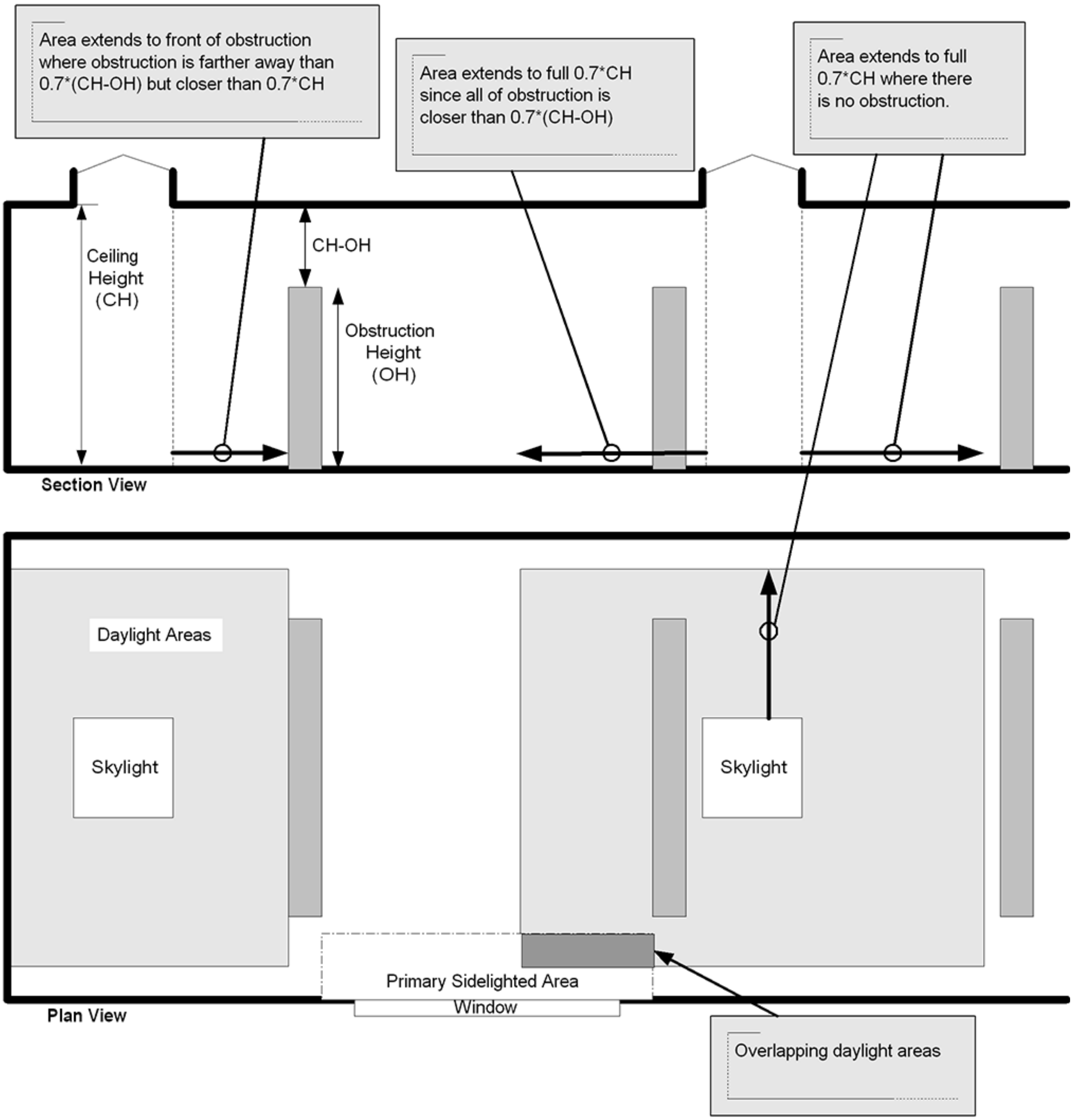


Figure 3.2-2 Computing the *daylight area under skylights*.

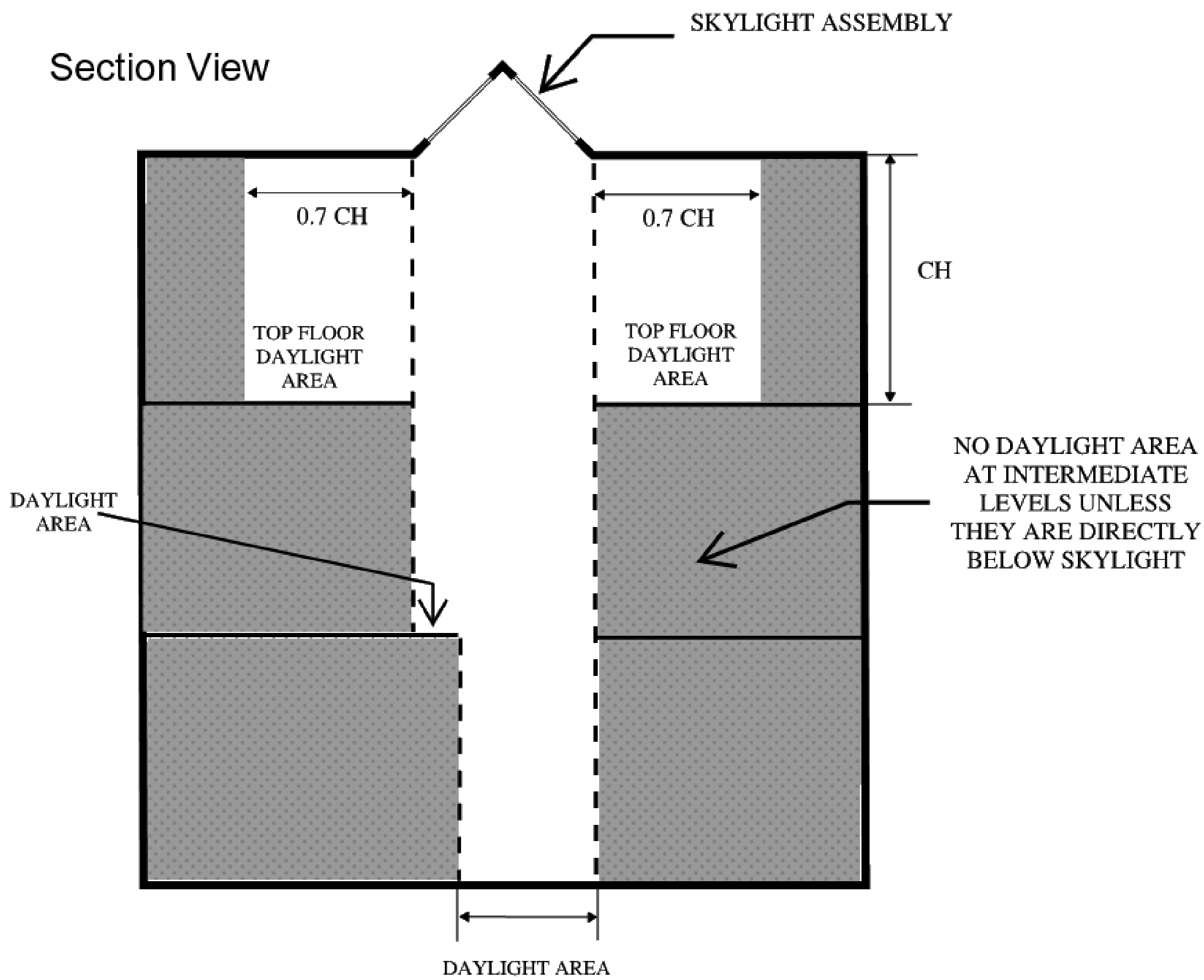


Figure 3.2-3 Computing the *daylight area under skylights* in multistory spaces.

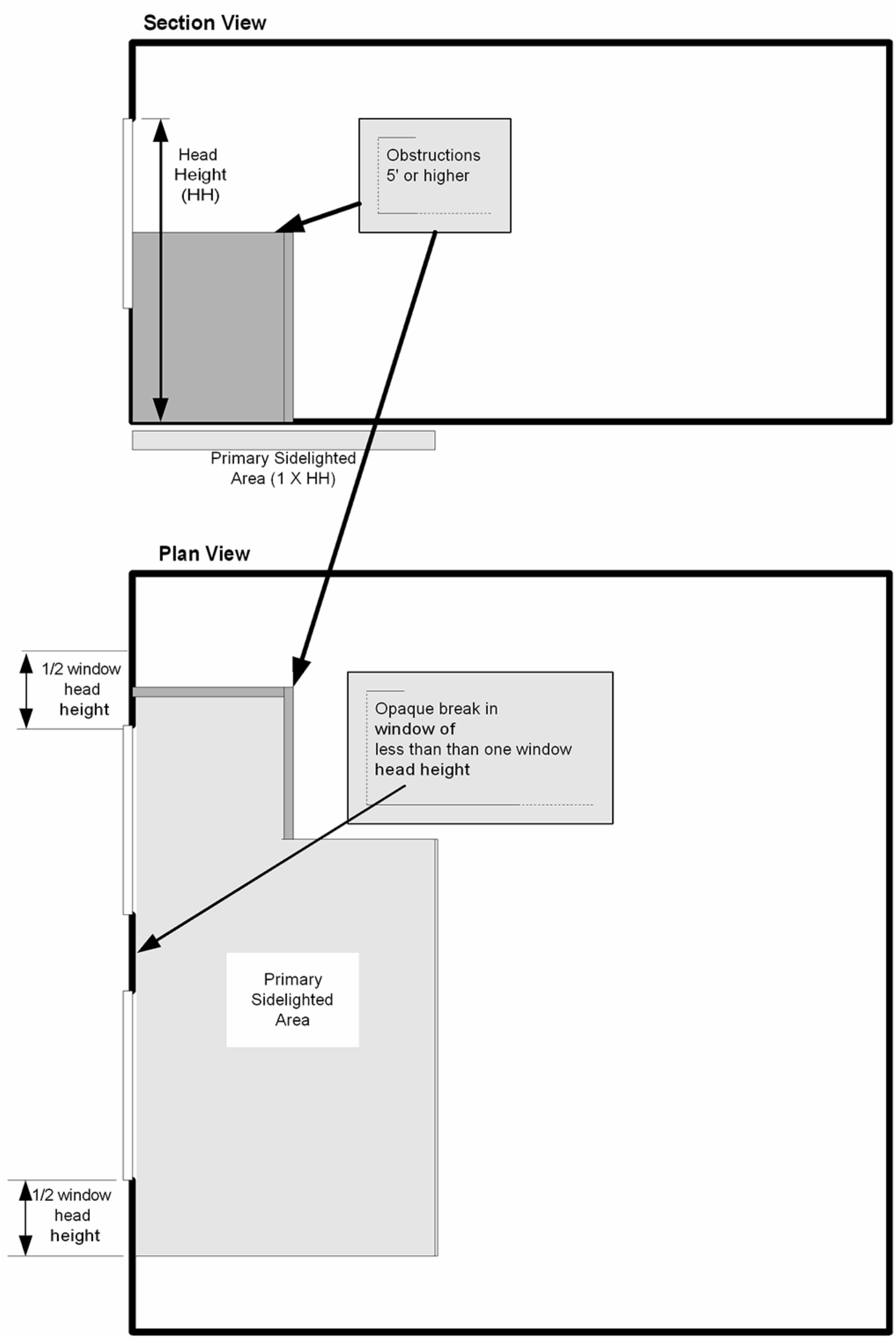


Figure 3.2-4 Computing the *primary sidelighted area*.

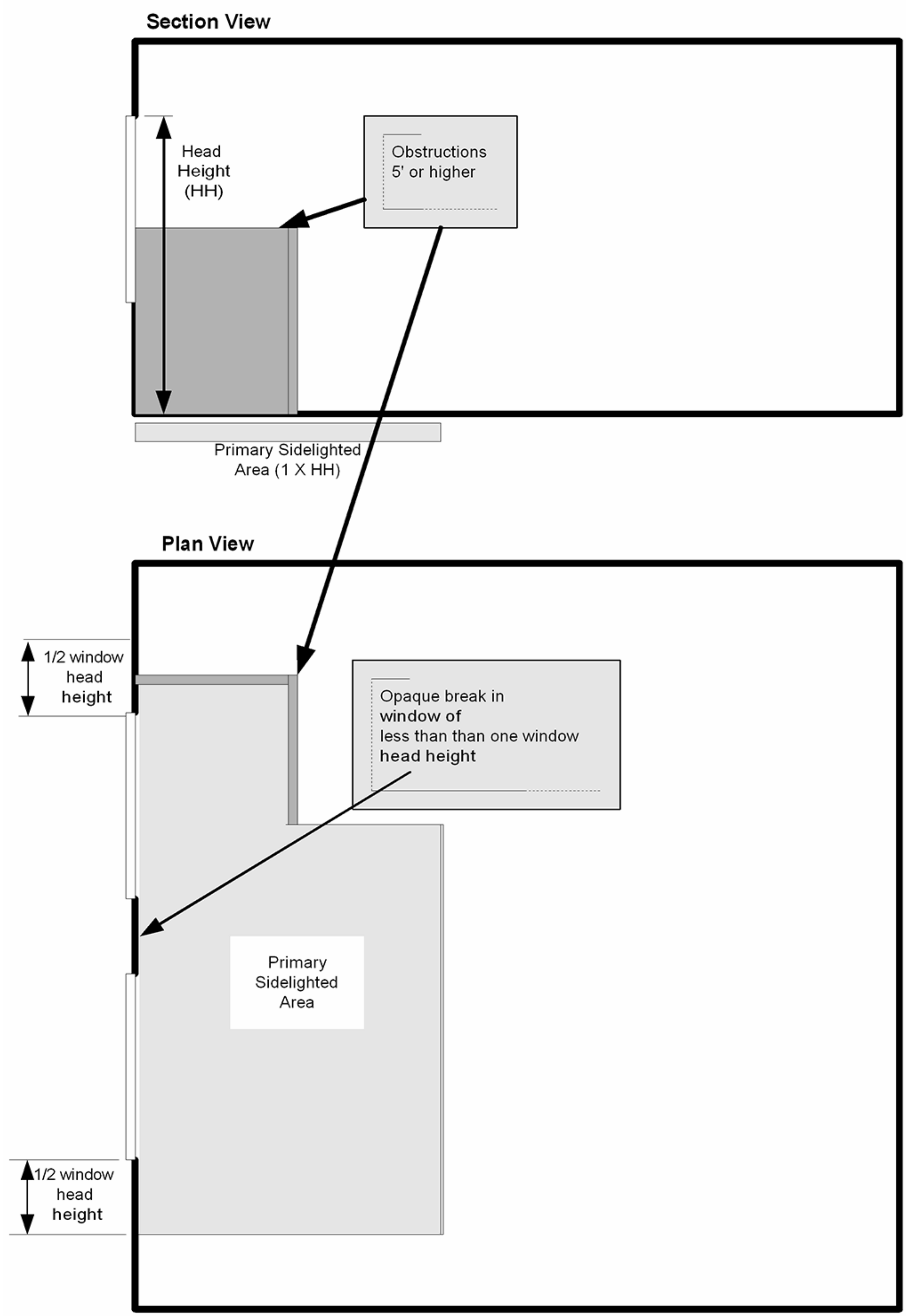


Figure 3.2-5 Computing the *secondary sidelighted area*.

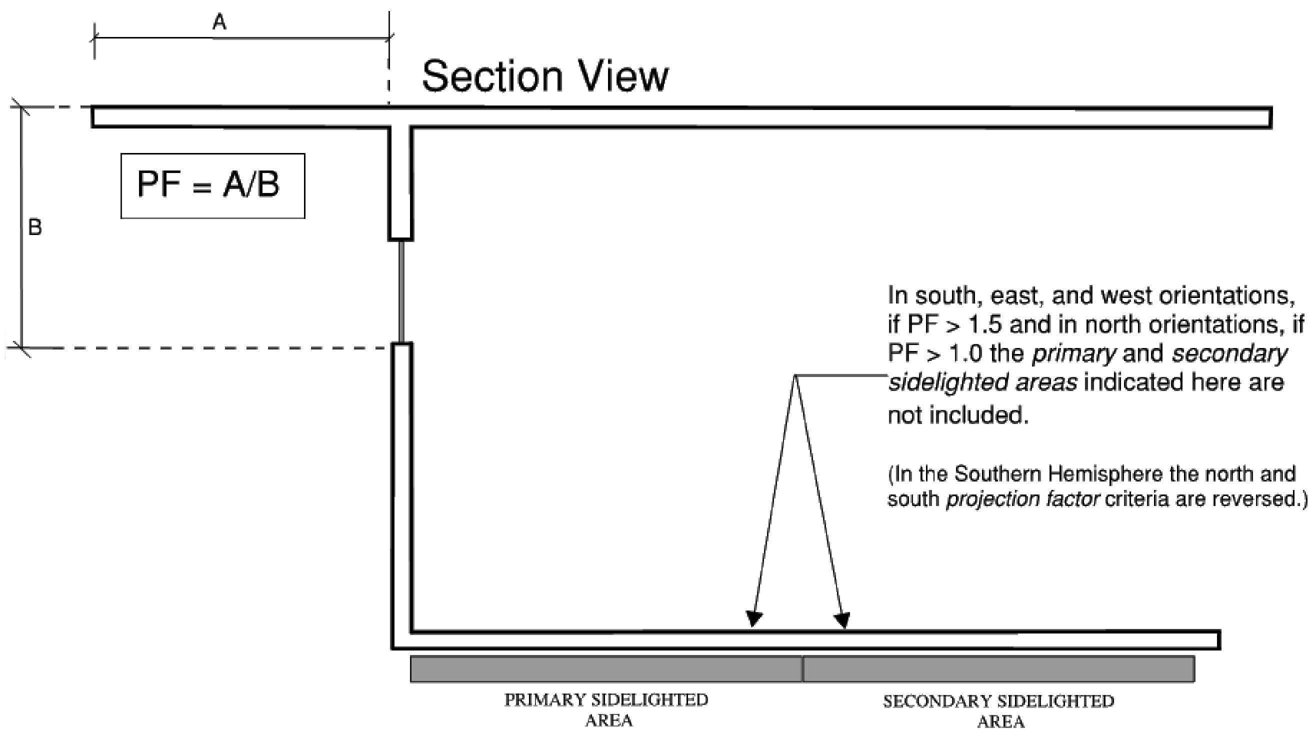


Figure 3.2-6 Computing the *primary* and *secondary sidelighted areas* with external projections.

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.

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.

DX-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.

E

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. (See *coefficient of performance [COP]—cooling*.)

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

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.*

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.

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*.

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

exterior building envelope: see *building envelope*.

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

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

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

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

fan 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.

fan system electrical power: the sum of the fan electrical power 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/or return it to the source or exhaust it to the outdoors.

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.

G

general lighting: see *lighting, general*.

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*.

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.

H

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

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

heated space: see *space*.

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

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

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

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;
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 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*.

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

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

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

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

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

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).

J

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

K

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

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

L

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

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

lighting power density (LPD): the 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.

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

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

M

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

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

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

mass floor: see *floor*.

mass wall: see *wall.*

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

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

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

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

> ***metal building roof:*** see *roof.*
>
> ***metal building wall:*** see *wall.*

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.

N

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*.)

nonstandard part-load value (NPLV): a single-number part-load *efficiency* figure of merit calculated and referenced to conditions other than *IPLV.I-P* 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 45 degrees of true north in the northern hemisphere (however, facing within 45 degrees of true south in the southern hemisphere).

O

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* generated from renewable sources produced 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.

P

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

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

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

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 USDOE 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*.

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

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

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

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

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 *fen-*

estration to the bottom of the farthest point of the external shading projection, in consistent units.

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

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

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

pump: 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

R-value: see *thermal resistance*.

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

rated motor power: see *motor power, rated*.

rated R-value of insulation: the *thermal resistance* of the insulation alone as specified by the *manufacturer* in units of h·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* or bid documents.

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

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*.

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

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

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

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

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

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

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

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

S

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

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

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

secondary sidelighted area: see *daylight area.*

sectional garage door: see *door*.

semiexterior building envelope: see *building envelope*.

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

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:

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

where "*Vertical Fenestration VT*" is the *visible transmittance* of *vertical fenestration* as determined in accordance with Section 5.8.2.5.

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*.

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

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

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

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

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

where

skylight area	=	total *fenestration area* of *skylights*
skylight VT	=	area-weighted average *visible transmittance* of *skylights* as determined in accordance with Section 5.8.2.5.
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*.)

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

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

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*.)

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.

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.”

T

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 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, which is not intended to transfer heat between the panel and the occupants and/or the indoor *space*.

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

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.

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

U

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.

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*.)

V

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*.

W

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

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

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

> ***above-grade wall:*** a *wall* that is not a *below-grade wall*.
>
> ***below-grade wall:*** that portion of a *wall* in the *building envelope* that is entirely below the finish *grade* and in contact with the ground.
>
> ***mass wall:*** a *wall* with a *heat capacity* exceeding (1) 7 Btu/ft^2·°F or (2) 5 Btu/ft^2·°F, provided that the *wall* has a material unit weight not greater than 120 lb/ft^3.
>
> ***metal building wall:*** a *wall* whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain *wall systems*).
>
> ***steel-framed wall:*** a *wall* with a cavity (insulated or otherwise) whose exterior surfaces are separated by steel framing members (i.e., typical steel stud *walls* and curtain *wall systems*).
>
> ***wood-framed and other walls:*** all other *wall* types, including wood stud *walls*.

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

warm-up: increase in *space* temperature to occupied *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*.

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

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

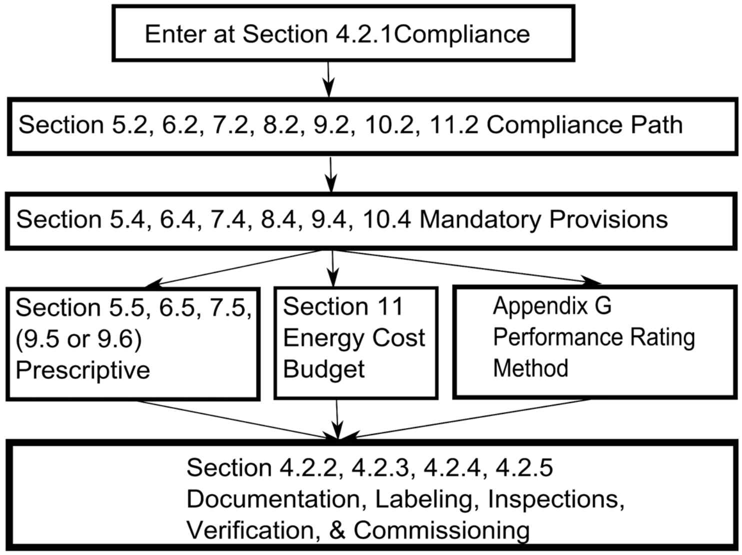
3.3 Abbreviations and Acronyms

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*
bhp	brake horsepower
BSR	Board of Standards Review

Btu	British thermal unit
Btu/h	British thermal unit per hour
Btu/ft^2·°F	British thermal unit per square foot per degree Fahrenheit
Btu/h·ft^2	British thermal unit per hour per square foot
Btu/h·ft·°F	British thermal unit per hour per linear foot per degree Fahrenheit
Btu/h·ft^2·°F	British thermal unit per hour per square foot per degree Fahrenheit
$CCOP_C$	*combined coefficient of performance*
CDD	*cooling degree-day*
CDD50	*cooling degree-days* base 50°F
cfm	cubic feet per minute
c.i.	*continuous insulation*
COP	*coefficient of performance*
CTI	Cooling Technology Institute
db	dry bulb
DCV	*demand control ventilation*
DDC	*direct digital control*
DOE	U.S. Department of Energy
DX	direct expansion
E_c	combustion *efficiency*
EER	*energy efficiency ratio*
EF	*energy factor*
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*
FPT	*functional performance testing*
ft	foot
gr	grains of moisture per pound of dry air
h	hour
HC	*heat capacity*
HDD	*heating degree-day*
HDD65	*heating degree-days* base 65°F
h·ft^2·°F/Btu	hour per square foot per degree Fahrenheit per British thermal unit
HID	high-intensity discharge
hp	horsepower
HSPF	*heating seasonal performance factor*
HVAC	heating, ventilating, and air conditioning
HVACR	heating, ventilating, air conditioning, and refrigeration
IEC	International Electrotechnical Commission
IEER	*integrated energy efficiency ratio*
IES	Illuminating Engineering Society
IL	inline
in.	inch

I-P	inch-pound
IPLV.I-P	*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*
LED	light-emitting diode
lb	pound
lin	linear
lin ft	linear foot
LPD	*lighting power density*
Ls	*liner system*
LSG	light-to-solar-gain ratio
MICA	Midwest Insulation Contractors Association
MRE	*moisture removal efficiency*
MSH	monitor seal height
NAECA	U.S. National Appliance Energy Conservation Act
NEMA	National Electric Manufacturers Association
NFPA	National Fire Protection Association
NFRC	National Fenestration Rating Council
NPLV	*nonstandard part-load value*
PEI	pump energy index
PER	pump energy rating
PF	*projection factor*
PRV	*power roof/wall ventilator*
PTAC	*packaged terminal air conditioner*
PTHP	*packaged terminal heat pump*
R	*R-value* (*thermal resistance*)
R_c	*thermal resistance* of a material or *construction* from surface to surface
RCR	*room cavity ratio*
R_u	total *thermal resistance* of a material or *construction* including air film resistances
rpm	revolutions per minute
RSV	radially split, multistage, vertical, inline diffuser casing
SC	*shading coefficient*
SCOP	*seasonal coefficient of performance*
SEER	seasonal *energy efficiency ratio*
SERR	series energy recovery ratio
SHGC	*solar heat gain coefficient*
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
T_{db}	dry-bulb temperature
T_{wb}	wet-bulb temperature
UL	Underwriters Laboratories Inc.
UPS	uninterruptible power supply
VAV	variable air volume
VRF	variable refrigerant flow
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



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.

4.1.2 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 12 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 Annexes

The reference standard reproduction annexes contain material that is cited in this standard but contained in another standard. The reference standard reproduction annexes are not part of this standard but are 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 Sections 4.2.2 through 4.2.5 and either the provisions of

a. Section 5, "*Building Envelope*"; Section 6, "Heating, Ventilating, and Air Conditioning"; Section 7, "*Service Water Heating*"; Section 8, "Power"; Section 9, "Lighting"; and Section 10, "Other *Equipment*," or
b. Section 11, "*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:

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

where

PCI	=	Performance Cost Index calculated in accordance with Section G1.2.
BBUEC	=	baseline *building* unregulated *energy* cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *unregulated energy use*.
BBREC	=	baseline *building* regulated *energy* cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *regulated energy use*.
BPF	=	*building* performance factor from Table 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.
BBP	=	*baseline building performance*.
PNA	=	proposed renewable energy contribution not allowed for compliance.

Table 4.2.1.1 *Building* Performance Factor (BPF)

Building Area Type	Climate Zone															
	0A and 1A	0B and 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.68	0.70	0.66	0.66	0.69	0.68	0.59	0.74	0.76	0.74	0.70	0.73	0.75	0.68	0.71	0.68	0.72
Healthcare/ hospital	0.60	0.60	0.58	0.54	0.56	0.55	0.55	0.55	0.54	0.54	0.57	0.52	0.54	0.57	0.52	0.57	0.57
Hotel/motel	0.55	0.53	0.53	0.52	0.53	0.54	0.54	0.53	0.53	0.52	0.50	0.51	0.51	0.50	0.51	0.50	0.50
Office	0.52	0.57	0.50	0.56	0.53	0.56	0.48	0.51	0.52	0.49	0.51	0.51	0.49	0.52	0.51	0.49	0.51
Restaurant	0.63	0.64	0.60	0.60	0.60	0.61	0.58	0.62	0.57	0.61	0.63	0.60	0.64	0.65	0.62	0.67	0.70
Retail	0.51	0.54	0.49	0.55	0.51	0.55	0.53	0.51	0.55	0.54	0.50	0.54	0.55	0.50	0.51	0.48	0.50
School	0.39	0.47	0.38	0.43	0.38	0.42	0.40	0.37	0.40	0.38	0.36	0.40	0.36	0.36	0.37	0.36	0.37
Warehouse	0.38	0.42	0.40	0.42	0.43	0.44	0.43	0.44	0.43	0.46	0.49	0.47	0.48	0.54	0.51	0.57	0.57
All others	0.56	0.57	0.50	0.52	0.50	0.54	0.53	0.53	0.52	0.54	0.51	0.51	0.50	0.50	0.50	0.50	0.46

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.

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

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

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.

4.2.1.2 Additions to Existing Buildings

Additions to *existing buildings* shall comply with the provisions of Sections 4.2.2 through 4.2.5 and one of the following:

a. Section 5, "*Building Envelope*"; Section 6, "Heating, Ventilating, and Air Conditioning"; Section 7, "*Service Water Heating*"; Section 8, "Power"; Section 9, "Lighting"; and Section 10, "Other *Equipment*," or
b. Section 11, "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 11 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 Buildings

Alterations of *existing buildings* shall comply with the provisions of Sections 4.2.2 through 4.2.5 and one of the following:

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

in accordance with Section 4.2.1.1.

Exception 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.

4.2.2 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.

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*.

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 Note

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, 11.2(d), and G1.2.1(c). 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 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.

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, 11.2(d), and G1.2.1(c). *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 Option 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
   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

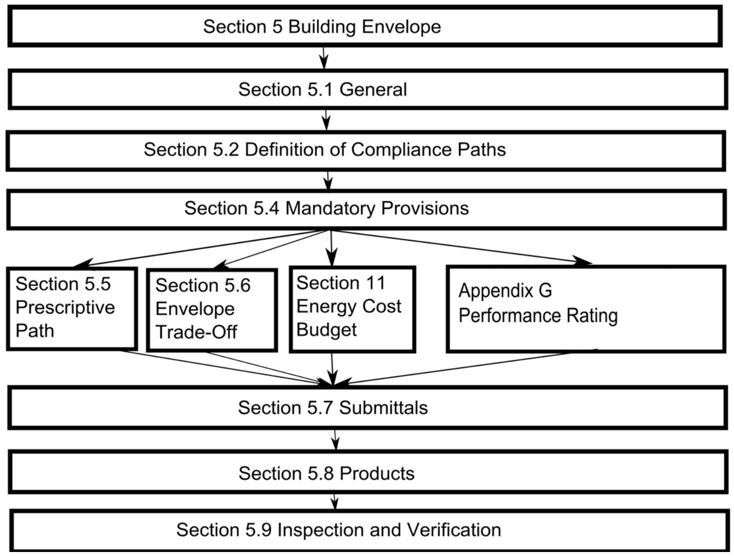
Before issuance of a certificate of occupancy, the *V&T providers* or *commissioning provider* shall complete the following activities:

a. Verification and *FPT* of the *systems* specified in Section 4.2.5.1.1 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*



5 Building Envelope

5.1 General

5.1.1 Scope

Section 5 specifies requirements for the *building envelope*.

5.1.2 Space Conditioning Categories

5.1.2.1

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

5.1.2.2

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

5.1.2.3

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

Exception to 5.1.2.3

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

5.1.3 Envelope Alterations

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

Exceptions to 5.1.3

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. Removal and replacement of a *roof* membrane where there is existing *roof* insulation integral to or below the *roof* deck.
7. 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.
8. 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 Climate

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

5.1.4.1 United States Locations

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 5.1.4.1

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."

5.1.4.2 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."

5.2 Compliance Paths

The *building envelope* shall comply with Section 5.1.2 and Section 5.2.2.

5.2.1 Requirements for All Compliance Paths

The *building envelope* shall comply with Section 5.1, "General"; Section 5.4, "Mandatory Provisions"; Section 5.7, "Submittals"; Section 5.8, "Product Information and Installation Requirements"; and Section 5.9, "Verification, Testing, Commissioning, and Inspection."

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."

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

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.

5.4.3.1 Continuous Air Barrier

The *exterior building envelope* and the *semiexterior building envelope* shall have a *continuous air barrier* complying with Sections 5.4.3.1.1 and 5.4.3.1.2.

Exceptions to 5.4.3.1

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.

5.4.3.1.1 Whole-Building Air Leakage

Whole-building pressurization testing shall be conducted in accordance with ASTM E779 or ASTM E1827 by an independent third party. The measured air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft^2 under a pressure differential of 0.3 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.*

Where a *building* contains both *conditioned space* and *semiheated space*, compliance shall be shown

a. 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*; or
b. 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*.

Reporting shall be in compliance with Section 4.2.5.1.2.

Exceptions to 5.4.3.1.1

1. For *buildings* having over 50,000 ft^2 of *gross conditioned floor area*, air leakage testing shall be permitted to be conducted on less than the whole *building*, provided the following portions of the *building* are tested and their measured air leakage is area-weighted by the surface areas of the *building envelope*:

a. The entire *floor* area of all *stories* that have any *spaces* directly under a *roof.*
b. The entire *floor* area of all *stories* that have a *building entrance* or loading dock.
c. Representative *above-grade wall* sections of the *building* totaling at least 25% of the *wall* area enclosing the remaining *conditioned space*. Floor area tested per (a) and (b) shall not be included in the 25%.

2. Where the measured air leakage rate exceeds 0.40 cfm/ft^2 but does not exceed 0.60 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. 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.
3. *Continuous air barrier* design and installation verification program in accordance with Section 5.9.1.2.

5.4.3.1.2 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.
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, and between *walls* and *roofs*
   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

5.4.3.2 Loading Dock Weatherseals

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

5.4.3.3 Vestibules and Revolving Doors

Vestibules and revolving doors shall be installed in accordance with this section.

5.4.3.3.1 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)

5.4.3.3.2 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*.

5.4.3.3.3 Vestibule Envelope

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

Exceptions to 5.4.3.3

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.*
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 complying with Section 10.4.5.
10. Self-closing *doors* in *buildings* 15 stories or less in Climate Zones 5 through 8 that have an air curtain complying with Section 10.4.5.

5.4.3.3.4 Vestibules for Large Spaces

Where vestibules are required under Section 5.4.3.3, 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 Areas

For all *opaque* surfaces except *doors*, compliance shall be demonstrated by one of the following two methods:

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

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

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.039	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*.

Table 5.5-1 *Building Envelope* Requirements for Climate Zone 1 (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-0.048	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	*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	0.50	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*.

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

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.039	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*.

Table 5.5-3 *Building Envelope* Requirements for Climate Zone 3 (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-0.039	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	*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	0.42	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).

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).

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*.

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*.

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

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-0.028	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	*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	0.29	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).

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

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-0.028	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	*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	0.26	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).

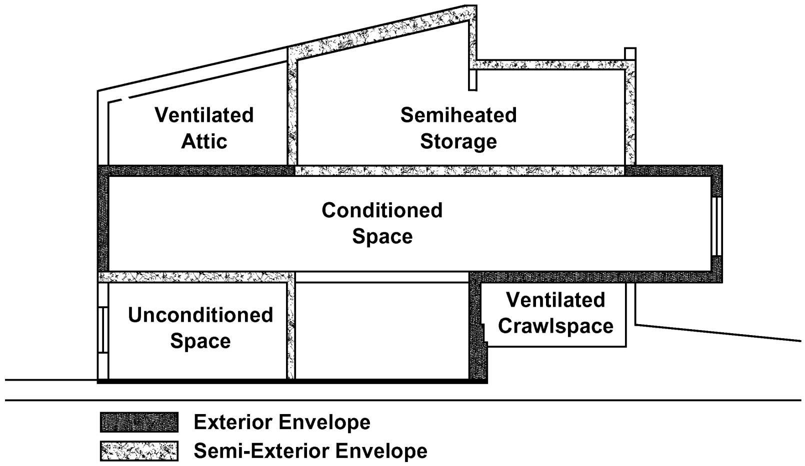


Figure 5.5.2 Exterior and *semiexterior building envelope.*

Table 5.5.3.1.1 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		

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

Exceptions to 5.5.3

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

5.5.3.1 Roof Insulation

All *roofs* shall comply with the insulation values specified in Tables 5.5-0 through 5.5-8. *Skylight* curbs shall be insulated to the level of *roofs* with insulation entirely above deck or R-5.0, whichever is less.

5.5.3.1.1 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 5.5.3.1.1.

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 5.5.3.1.1

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.

5.5.3.2 Above-Grade Wall Insulation

All *above-grade walls* shall comply with the insulation values specified in Tables 5.5-0 through 5.5-8.

Exception to 5.5.3.2

Alternatively, 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," ASTM C90 concrete block *walls*, ungrouted or partially grouted at 32 in. or less on center vertically and 48 in.or less on center horizontally, shall have ungrouted cores filled with material having a maximum thermal conductivity of 0.44 Btu·in./h·ft^2·°F. Other *mass walls* with integral insulation shall meet the criteria when their *U-factors* are equal to or less than those for the appropriate thickness and density in the "Partly Grouted, Cells Insulated" column of Table A3.1-3.

When a *wall* consists of both *above-grade* and *below-grade* portions, the entire *wall* for that story shall be insulated on either the exterior or the interior or be integral.

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.

In addition, for Climate Zone 0, *above-grade walls* shall comply with one of the following:

a. For east and west *walls*, a minimum of 75% of the *opaque wall* area shall have a minimum SRI of 29. For the portion of the *opaque wall* that is glass spandrel area, a minimum solar *reflectance* of 29% determined in accordance with NFRC 300 or ISO 9050 shall be permitted. Each *wall* is allowed to be considered separately.
b. For east and west *walls*, a minimum of 30% of the *above-grade wall* area shall be shaded through the use of shade-providing plants, man-made structures, *existing buildings*, hillsides, permanent *building* projections, *on-site renewable energy systems*, or a combination of these. Shade coverage shall be calculated at 10 a.m. for the east *walls* and 3 p.m. for the west *walls* on the summer solstice.

The *building* is allowed to be rotated up to 45 degrees to the nearest cardinal *orientation* for purposes of calculations and showing compliance.

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 Floor Insulation

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

5.5.3.5 Slab-on-Grade Floor Insulation

All *slab-on-grade floors*, including *heated slab-on-grade floors* and *unheated slab-on-grade floors*, shall comply with the insulation values specified in 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*.
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 Exception 3 to Section 5.5.4.4.1.

5.5.4.2.2 Maximum Skylight Fenestration Area

The total *skylight* area shall not be greater than that specified in 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 Exception (1) to Section 5.5.4.4.2 and the total *daylight area under skylights* is a minimum of half the floor area of the *space*.

5.5.4.2.3 Minimum Skylight Fenestration Area

In any *enclosed space* in a *building* that is

a. 2500 ft^2 and greater;
b. directly under a *roof* with ceiling heights greater than 15 ft; and
c. one of the following *space* types: office, lobby, atrium, concourse, corridor, storage (including nonrefrigerated warehouse), gymnasium, fitness/exercise area, playing area, gymnasium seating area, convention exhibit/event space, courtroom, automotive service, fire station engine room, manufacturing corridor/transition and bay areas, retail, library reading and stack areas, distribution/sorting area, transportation baggage and seating areas, or workshop,

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

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

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

Exceptions to Section 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).

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 $Btu/h \cdot ft^2 \cdot °F$ in Climate Zones 0 through 3 and 0.75 $Btu/h \cdot ft^2 \cdot °F$ in Climate Zones 4 through 8, provided the *skylights* meet all of the criteria in Exception (1) to Section 5.5.4.4.2.

Table 5.5.4.4.1 *SHGC* Multipliers for Permanent Projections

Projection Factor	*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

5.5.4.4 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 Section 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.

   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-, and west-oriented *vertical fenestration* before any reductions made for permanent projections in Exceptions 1 and 2 of Section 5.5.4.4.1.

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 Section 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* (oriented within 45 degrees of true west to the south and within 22.5 degrees of true west to the north in the northern hemisphere; oriented within 45 degrees of true west to the north and within 22.5 degrees of true west to the south in the southern hemisphere)

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

A_T = total *vertical fenestration area*

$SHGC_C$ = *SHGC* criteria in Tables 5.5-0 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 Section 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 façades, 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 Section 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 determined in accordance with NFRC 300 and NFRC 301, determined by an independent laboratory or included in a database published by a government agency, and certified by the *manufacturer*.
2. *Fenestration* not covered in the scope of the NFRC 200.
3. *Enclosed spaces* where the *daylight area under 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.

5.6 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 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.

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; and air leakage details in accordance with Section 5.4.3. 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*.

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 air leakage verification of the *building envelope* in accordance with Section 5.9.1.
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.

Exception 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 *manufacturers*' 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 A9.4.5.

5.8.1.3 Loose-Fill Insulation Limitation

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

5.8.1.4 Baffles

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

5.8.1.5 Substantial Contact

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

Exception 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 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 Section 5.8.2.3

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

5.8.2.4 Solar Heat Gain Coefficient

SHGC for the overall *fenestration area* shall be determined in accordance with NFRC 200.

Exceptions to Section 5.8.2.4

1. *Shading coefficient* (*SC*) of the center-of-glass multiplied by 0.86 shall be an acceptable alternative for determining compliance with the *SHGC* requirements for the overall *fenestration area*. *SC* shall be determined using a spectral data file determined in accordance with NFRC 300. *SC* shall be verified and certified by the *manufacturer*.
2. *SHGC* of the center-of-glass shall be an acceptable alternative for determining compliance with the *SHGC* requirements for the overall *fenestration area*. *SHGC* shall be determined using a spectral data file determined in accordance with NFRC 300. *SHGC* shall be verified and certified by the *manufacturer*.
3. *SHGC* from Section A8.1 shall be an acceptable alternative for determining compliance with the *SHGC* criteria for *skylights*. Where credit is being taken for a low-emissivity coating, the emissivity of the coating shall be determined in accordance with NFRC 300. Emissivity shall be verified and certified by the *manufacturer*.
4. *SHGC* from Section A8.2 shall be an acceptable alternative for determining compliance with the *SHGC* criteria for *vertical fenestration*.

5.8.2.5 Visible Transmittance

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

Exceptions to 5.8.2.5

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 using Exception 3 of Section 5.4.3.1.1. 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. 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 Zone 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 5.4.3.1.1 without using Exception 3.

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

5.9 Verification, Testing, Commissioning, and Inspection

5.9.1 Verification and Testing

5.9.1.1 Building Envelope Performance Verification

The *energy* performance of the *building envelope* shall be verified in accordance with this section and Section 4.2.5.1.

5.9.1.2 Verification of the Design and Installation of the Continuous Air Barrier

Verification of the design and installation of the *continuous air barrier* shall be determined in accordance with the following by an independent third party when using Exception 3 of Section 5.4.3.1.1:

a. A design review shall be conducted to verify and document compliance with the requirements in Sections 5.4.3 and 5.8.3.2.
b. 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 Sections 5.4.3.1.2 and 5.8.3.
c. Reporting shall comply with Section 4.2.5.1.2.

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 Appendices E and H for commissioning references and guidance.

5.9.3 Inspections

In addition to the requirements of Section 4.2.4, *building envelope* components and assemblies shall be inspected in accordance with Sections 5.9.3.1 through 5.9.3.4.

Informative Note

See Informative Appendices E and H for commissioning references and guidance.

5.9.3.1 Inspection of Fenestration and Door Requirements

Fenestration and *doors* shall be inspected to verify compliance with the requirements of Sections 5.4.3.2, 5.8.2.1, 5.8.2.2, and 5.8.2.3. Where testing is required to demonstrate compliance with the air leakage requirements, it shall be conducted by an independent third party. Operation of the *door* and closer or operating mechanism shall be inspected for conformance with the *manufacturer*'s instructions, and that the seals or gaskets are installed and in accordance with the *manufacturer*'s instructions.

5.9.3.2 Inspection of Loading Dock Weatherseals

Where there is a loading dock, weatherseals shall be inspected for proper installation and to verify that the seals are in good condition.

5.9.3.3 Inspection of Opaque Building Envelope Air Tightness Requirements

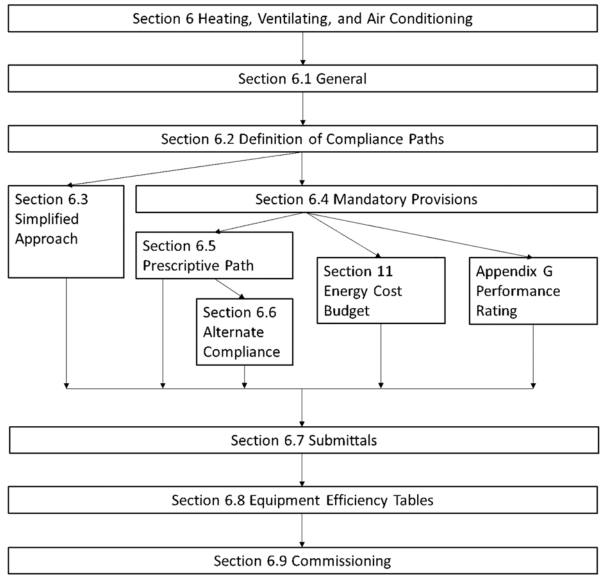
Opaque roof, *above-grade walls* and *below-grade walls*, and *floors*, shall be subject to the following inspections during *construction*:

a. Use of compliant materials and assemblies as indicated in Section 5.8.3.1.
b. Integration with adjoining *fenestration* and *continuous air barrier* elements.

5.9.3.4 Fenestration Inspections

Fenestration shall be subject to the following inspections during *construction*:

a. *Skylights* size and location in relation to the designed *primary sidelighted area* and *secondary sidelighted area* below.
b. *Roof monitor* size and location in relation to the designed *primary sidelighted area* and *secondary sidelighted area* below.
c. *Dynamic glazing* compliance with *SHGC* and *U-factor* in accordance with Sections 5.5.4.4.1 and 5.5.4.4.2, and testing of the operation for conformance with the *manufacturer*'s instructions.
d. Permanent *fenestration* projections installation and performance in accordance with Section 5.5.4.4.1 and the *construction documents*.



6 Heating, Ventilating, and Air Conditioning

6.1 General

6.1.1 Scope

6.1.1.1 New Buildings

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

6.1.1.2 Additions to Existing Buildings

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

Exception to 6.1.1.2

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

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

6.1.1.3.1

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

a. 6.3, "Simplified Approach Option 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"
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*"
o. 6.5.3.2.1, "Supply Fan Airflow *Control*"
p. 6.5.3.6, "Fractional HorsepowerKilowatt 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*"

6.1.1.3.2

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

6.1.1.3.3

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

6.1.1.3.4

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

6.1.1.3.5

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

Exceptions to 6.1.1.3

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.

6.1.2 Climate

Climate zones shall be determined in accordance with Section 5.1.4.

6.2 Compliance Paths

Mechanical equipment and systems providing heating, cooling, ventilating, or refrigeration shall comply with Section 6.2.1 and Section 6.2.2.

6.2.1 Requirements for all Compliance Paths

Mechanical equipment and systems shall comply with Section 6.1, "General"; Section 6.4, "Mandatory Provisions"; Section 6.7, "Submittals"; and Section 6.8, "Minimum *Equipment Efficiency* Tables."

6.2.2 Additional Requirements to Comply with Section 6

Mechanical equipment and systems shall comply with one of the following:

a. Section 6.3, "Simplified Approach Building Compliance Path for *HVAC Systems*"

Exception to 6.2.2(a)

When compliance is shown using Section 6.2.2(a), compliance with Section 6.4 is not required.

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b. Section 6.5, "Prescriptive Compliance Path"

Exception to 6.2.2(b)

HVAC systems only serving the heating, cooling, or ventilating needs of a *computer room* with IT *equipment* load greater than 10 kW shall be permitted to comply with Section 6.4, "Mandatory Provisions" and Section 6.6, "Alternative Compliance Path."

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.
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.
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*).
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.

Exception 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.

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i. The *system controls* shall not permit *reheat* or any other form of simultaneous heating and cooling for humidity *control*.
j. *Systems* serving *spaces* other than hotel/motel guest rooms, and other than those requiring continuous operation, which have both a cooling or heating capacity greater than 15,000 Btu/h and a supply fan motor power greater than 0.75 hp, shall be provided with a time clock that (1) can start and stop the *system* under different schedules for seven different day types per week, (2) is capable of retaining programming and time setting during a loss of power for a period of at least ten hours, (3) includes an accessible *manual* override that allows temporary operation of the *system* for up to two hours, (4) is capable of and configured with temperature *setback* down to 55°F during off hours, and (5) is capable of capable of and configured with temperature setup to 90°F during off hours.
k. *Systems* serving hotel/motel guest rooms shall comply with Section 6.4.3.3.5.
l. 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.
m. *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.
n. *Construction documents* shall require a ducted *system* to be air balanced in accordance with industry accepted procedures.
o. *Outdoor air* intake and exhaust *systems* shall meet the requirements of Section 6.4.3.4.
p. Where separate heating and cooling *equipment* serves the same temperature zone, *thermostats* shall be interlocked to prevent simultaneous heating and cooling.
q. *Systems* with a design supply air capacity greater than 10,000 cfm shall have *optimum start controls*.
r. The *system* shall comply with the *demand control ventilation* requirements in Section 6.4.3.8, occupied-standby controls in Section 6.5.3.8, and the *ventilation* design requirements in Section 6.5.3.7.
s. 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 6.8.1-20 shall have a minimum performance at the specified rating conditions when tested in accordance with the specified test procedure. Where multiple rating conditions or performance requirements are provided, the *equipment* shall satisfy all stated requirements unless otherwise exempted by footnotes in the table. *Equipment* covered under the Federal *Energy* Policy Act of 1992 (EPACT) shall have no minimum *efficiency* requirements for operation at minimum capacity or other than standard rating conditions. *Equipment* used to provide *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, "Water-Chilling Packages—Minimum *Efficiency* Requirements" (See Section 6.4.1.2 for water-cooled centrifugal water-chilling packages that are designed to operate at nonstandard conditions.)
d. Table 6.8.1-4, "Electrically Operated *Packaged Terminal Air Conditioners*, *Packaged Terminal Heat Pumps*, *Single-Package Vertical Air Conditioners*, *Single-Package Vertical Heat Pumps*, *Room Air Conditioners*, and *Room Air Conditioner* Heat Pumps—Minimum *Efficiency* Requirements"
e. Table 6.8.1-5, "Warm-Air Furnaces 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*"
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 Chiller 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"

6.4.1.2 Minimum Equipment Efficiencies—Listed Equipment—Nonstandard Conditions

6.4.1.2.1 Water-Cooled Centrifugal Chilling Packages

Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44.00°F leaving and 54.00°F entering chilled-fluid temperatures, and with 85.00°F entering and 94.30°F leaving condenser-fluid temperatures, shall have maximum full-load *kW*/ton (FL) and part-load rating requirements adjusted using the following equations:

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

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

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

where

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

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

- 36.00°F ≤ LvgEvap ≤ 60.00°F
- LvgCond ≤ 115.00°F
- 20.00°F ≤ LIFT ≤ 80.00°F

Manufacturers shall calculate the FL_{adj} and PLV_{adj} before determining whether to label the chiller per Section 6.4.1.5. Compliance with 90.1-2007, 2010, 2013, 2016 or combinations thereof, shall be *labeled* on chillers within the scope of the standard.

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

Example (Section 6.4.1.2.1)

Path A 600-ton centrifugal chiller Table 6.8.1-3:

FL	=	0.5600 *kW*/ton
IPLV.IP	=	0.5000 *kW*/ton
LvgCond	=	91.16°F
LvgEvap	=	42.00°F
LIFT	=	91.16 – 42 = 49.16°F
A	=	$0.00000014592 \times (49.16)^4 - 0.0000346496\times (49.16)^3 + 0.00314196 \text{ x } (49.16)^2 - 0.147199\times (49.16) + 3.93073 = 1.02331$
B	=	$0.0015 \times 42.00 + 0.934 = 0.99700$
K_{adj}	=	$1.02331 \times 0.99700 = 1.02024$
FL_{adj}	=	0.5600/1.02024 = 0.5489 *kW*/ton
PLV_{adj}	=	0.5000/1.02024 = 0.4901 *kW*/ton

6.4.1.2.2 Positive Displacement (Air- and Water-Cooled) Chilling Packages

Equipment with an evaporator leaving fluid temperature higher than 32.00°F and water-cooled positive displacement chilling packages with a condenser leaving fluid temperature below 115.00°F shall show compliance with Table 6.8.1-3 when tested or certified with water at standard rating conditions, per the referenced test procedure.

6.4.1.3 Ceiling Fans

Large-diameter ceiling fans shall be rated in accordance with 10 CFR 430 Appendix U or AMCA 230. The following data shall be provided:

a. Blade span (blade tip diameter)
b. Rated airflow and power consumption at the maximum speed

Informative Note:

See Informative Appendix F for the U.S. Department of Energy requirements for U.S. applications.

6.4.1.3.1

The data provided shall meet one of the following requirements:

a. It is determined by an independent laboratory.
b. It is included in a database published by USDOE.
c. It is certified under a program meeting the requirements of Section 6.4.1.5.

Exception to 6.4.1.3.1

Ceiling fans not covered in the scope of 10 CFR Part 430.

6.4.1.4 Equipment not Listed

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

6.4.1.5 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.

6.4.1.6 Labeling

6.4.1.6.1 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.

6.4.1.6.2 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.

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* having a design heating capacity and cooling capacity less than 15,000 Btu/h that are equipped with *readily accessible manual* on/off *controls.*

6.4.3.3.1 Automatic Shutdown

HVAC systems shall be equipped with at least one of the following:

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

b. An *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.

Exception to 6.4.3.3.1

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

6.4.3.3.2 Setback Controls

Heating *systems* shall be equipped with *controls* 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* 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 high *space* humidity levels.

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.

6.4.3.3.4 Zone Isolation

HVAC systems serving zones that are intended to operate or be occupied nonsimultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 25,000 ft^2 of *conditioned floor area* nor include more than one *floor*. Each isolation area shall be equipped with *isolation devices* capable of 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 Section 6.4.3.3.1. For central *systems* and plants, *controls* and devices shall be provided to allow stable *system* and *equipment* operation for any length of time while serving only the smallest isolation area served by the *system* or plant.

Exceptions 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.

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 subsection.

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. Cooling for humidity *control* shall be permitted during rented and unoccupied or unrented and unoccupied 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.

6.4.3.3.5.3 Automatic Control

Card key card controls shall be permitted to be used to indicate occupancy.

6.4.3.4 Ventilation System Controls

6.4.3.4.1 Stair and Shaft Vents

Stair and elevator shaft vents shall be equipped with motorized dampers that are capable of and configured to *automatically* close during normal *building* operation and are interlocked to open as required by fire and smoke detection *systems*.

6.4.3.4.2 Shutoff Damper Controls

All *outdoor air* intake and exhaust *systems* shall be equipped with motorized dampers that will *automatically* shut when the *systems* or *spaces* served are not in use. *Outdoor air* and exhaust/relief dampers shall be capable of and configured to *automatically* shut off during

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

Climate Zone	Outdoor Air Intake		Exhaust/Relief	
	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.

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 back draft) 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.

6.4.3.4.5 Enclosed Parking Garage Ventilation

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

Exceptions to 6.4.3.4.5

1. Garages less than 30,000 ft^2 with *ventilation systems* that do not use *mechanical cooling* or mechanical heating.

2. Garages that have a garage area to *ventilation system motor nameplate horsepower* ratio that exceeds 1500 ft^2/hp and do not use *mechanical cooling* or mechanical heating.
3. Where not permitted by the *authority having jurisdiction*.

6.4.3.5 Heat-Pump Auxiliary Heat Control

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

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

Exception to 6.4.3.6.1, 6.4.3.6.2, and 6.4.3.4.3

Systems serving zones where humidity levels are required to be maintained with precision of not more than ±5% relative humidity 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 500 ft^2 and with a design occupancy for *ventilation* of ≥25 people per 1000 ft^2 of floor area 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. *Systems* with exhaust air *energy* recovery complying with, and where required by, Section 6.5.6.1.
2. Multiple-zone *systems* without *DDC* of individual zones communicating with a central *control* panel.
3. *Systems* with a design outdoor airflow less than 750 cfm.
4. *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*.
5. *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.

6.4.3.9 Heated or Cooled Vestibules

Heating for vestibules and for air curtains 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

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 *system*s 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

6.4.3.10.3 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

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*.

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.
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 air leakage. Pressure-sensitive tape shall not be used as the primary sealant unless it has been certified to comply with UL-181A or UL-181B by an independent testing laboratory, and the tape is used in accordance with that certification. All connections shall be sealed, including but not limited to spin-ins, taps, other branch connections, access *doors*, access panels, and duct connections to *equipment*. Sealing that would void product listings is not required. Spiral lock seams need not be sealed. All duct pressure class ratings shall be designated in the design documents.

6.4.4.2.2 Duct Leakage Tests

Ductwork that is designed to operate at static pressures in excess of 3 in. 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.

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

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

Exception to 6.4.5(c)

Glazed portions of *doors* or structural members.

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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 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 to 6.4.5(g)

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 USDOE.

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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 to 6.4.5(h)

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 USDOE.

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

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

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

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

Exception 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 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.
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 Section 6.2.1 in Standard 62.1.
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

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
0A, 0B, 1A, 1B	No economizer requirement
2A, 2B, 3A, 4A, 5A, 6A, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	≥54,000 Btu/h

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

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 and *infiltration* loads, is less than or equal to transmission and *infiltration* losses at an outdoor temperature of 60°F.
8. *Systems* expected to operate fewer than 20 hours per week.
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*.

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

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[a] or T_{OA} > 75°F	*Outdoor air* enthalpy exceeds 28 Btu/lb[a] of dry air[a] or *outdoor air* temperature exceeds 75°F
Differential enthalpy with *fixed* dry-bulb temperature	All	$h_{OA} > h_{RA}$ or T_{OA} > 75°F	*Outdoor air* enthalpy exceeds return air enthalpy or *outdoor air* temperature exceeds 75°F

a. At altitudes substantially different than sea level, the *fixed* enthalpy limit shall be set to the enthalpy value at 75°F and 50% rh. As an example, at approximately 6000 ft elevation, the *fixed* enthalpy limit is approximately 30.7 Btu/lb.

b. Devices with selectable rather than adjustable *set points* shall be capable of being set to within 2°F and 2 Btu/lb of the *set point* listed.

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*).

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.

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

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

6.5.1.1.6 Sensor Accuracy

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

a. Dry-bulb and wet-bulb temperatures shall be accurate to ±2°F over the range of 40°F to 80°F.
b. Enthalpy and the value of a differential enthalpy sensor shall be accurate to ±3 Btu/lb over the range of 20 to 36 Btu/lb.
c. Relative humidity shall be accurate to ±5% over the range of 20% to 80% rh.

6.5.1.2 Fluid Economizers

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.

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.

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:
      (1) 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.
      (2) 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.
      (3) 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 *site-solar energy*.

6.5.2.1.1 Supply Air Temperature Reheat Limit

Where *reheating* is permitted by other parts of this standard, zones that have both supply and return/exhaust air openings greater than 6 ft above *floor* shall not supply heating air more than 20°F above the *space* temperature *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.

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 *site-solar energy* that provide *energy* equal to at least 75% of the annual *energy* for *reheating* or for providing warm air in mixing *systems*. This exception does not apply to *computer rooms*.
5. At least 90% of the annual *energy* for *reheating* or for providing warm air in mixing *systems* is provided from *site-recovered energy* (including condenser heat) or *site-solar 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.

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.

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 ≤ cfm_S × 0.0011	hp ≤ cfm_S × 0.0015
Option 2: Fan *system* bhp	Allowable fan *system* bhp	bhp ≤ cfm_S × 0.00094 + *A*	bhp ≤ cfm_S × 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 × 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

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 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 bhp.

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

The 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. 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. 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 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 that are intended to only operate 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 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.

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.

6.5.3.3 Multiple-Zone VAV System Ventilation Optimization Control

Multiple-zone *VAV systems* with *DDC* of individual zone boxes reporting to a central *control* panel shall include means to *automatically* reduce *outdoor air* intake flow below design rates in response to changes in *system ventilation efficiency* as defined by Appendix A of ASHRAE Standard 62.1.

Exceptions 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.

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.

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 to *outdoor air* temperature. The *controls* shall *reset* the supply air temperature at least 25% of the difference between the design supply air temperature and the design room air temperature. *Controls* that adjust the *reset* based on zone humidity are allowed 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.

Informative Note

HVAC zones that are expected to experience relatively constant loads typically include electronic equipment rooms and interior zones.

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 *site-solar energy*.

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 Table 10.8-4.

6.5.3.7 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 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.

6.5.3.8 Occupied-Standby 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 (5) 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 setup 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 6.5.3.8

Multiple zone systems without *automatic* zone flow control dampers.

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

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

than the larger of 25% of the design flow rate or the minimum flow required by the heating/cooling *equipment 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.

6.5.4.3 Chiller and Boiler Isolation

6.5.4.3.1

When a chilled-water plant includes more than one chiller, provisions shall be made so that all fluid flow through the chiller is *automatically* shut off when the chiller is shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller. Where constant-speed chilled-water or condenser water pumps are used to serve multiple chillers, the number of pumps shall be no less than the number of chillers and staged on and off with the chillers.

6.5.4.3.2

When a *boiler* plant includes more than one *boiler*, provisions shall be made so that the flow through the *boiler* is *automatically* shut off when the *boiler* is shut down. Where constant-speed hot-water pumps are used to serve multiple *boilers*, the number of pumps shall be no less than the number of *boilers* and staged on and off with the *boilers*.

6.5.4.4 Chilled- and Hot-Water Temperature Reset Controls

Chilled- and hot-water *systems* with a *design capacity* exceeding 300,000 Btu/h supplying chilled or heated water 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 *setpoint* 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.

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.

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

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

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.

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 cooling design condition and at least 60% at heating design condition. The *energy* recovery *system* shall provide the required *enthalpy 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 conditioned floor area in Climate Zone 0, 1, 2, 3, 4C, and 5C.
3. Enthalpy recovery ratio 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 6.5.6.1.2-1 shall be used for all *ventilation systems* that operate 8000 or more hours per year.

For spaces other than *nontransient dwelling units*, *energy* recovery *systems* shall result in an *enthalpy recovery ratio* of at least 50%. The *energy* recovery *system* shall provide the required *enthalpy recovery ratio* at both heating and cooling *design conditions*, unless one mode is not required for the climate zone by the exceptions below. Provision shall be made to bypass or *control* the *energy* recovery *system* to permit *air economizer* operation as required by Section 6.5.1.1.

Exceptions 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 *site-solar 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*,

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

Climate Zone	% *Outdoor Air* at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B,5C	NR	NR	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥28,000	≥26,500	≥11000	≥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

Climate Zone	% *Outdoor Air* at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3C	NR	NR	NR	NR	NR	NR	NR	NR
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.

6.5.6.2 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 *site-solar 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 condenser heat recovery *system* 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 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*.

Exceptions to 6.5.6.3

1. Buildings that provide ≥ 60% of their reheat energy from *on-site renewable energy* or *site-recovered energy.*
2. 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;

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

b. the *ventilation* rate required by the *authority having jurisdiction*, the facility Environmental Health and Safety department, or ASHRAE Standard 62.1; or
c. the mechanical exhaust flow minus the available *transfer air* from *conditioned spaces* or return air plenums on the same *floor*, 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 classified laboratories 3 or higher.
2. Vivarium *spaces*.
3. *Spaces* that are required by applicable codes and standards to be maintained at positive pressure relative to adjacent *spaces*. For *spaces* taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more *energy*.
4. *Spaces* where the *demand* for *transfer air* may exceed the available transfer airflow rate and where the *spaces* have a required negative pressure relationship. For *spaces* taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more *energy*.

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 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*.

Table 6.5.9 Hot-Gas Bypass Limitation

Rated Capacity	Maximum Hot-Gas Bypass, % of Total Capacity
≤240,000 Btu/h	15%
>240,000 Btu/h	10%

6.5.8 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 and single-zone *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.*
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 utilizing transcritical refrigeration cycle or ammonia refrigerant.

6.5.11.1 Condensers Serving Refrigeration Systems

Fan-powered condensers shall conform to the following requirements:

a. Design *saturated condensing temperatures* for air-cooled condensers shall be less than or equal to the design dry-bulb temperature plus 10°F for *low-temperature refrigeration systems* and less than or equal to the design dry-bulb temperature plus 15°F for *medium-temperature refrigeration systems*.
   1. *Saturated condensing temperature* for blend refrigerants shall be determined using the average of liquid and vapor temperatures as converted from the condenser drain pressure.

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

c. All condenser fans for air-cooled condensers, evaporatively cooled condensers, and air- or water-cooled fluid coolers or cooling towers shall incorporate one of the following continuous variable-speed fan *control* approaches and shall reduce fan motor *demand* to no more than 30% of design wattage at 50% of design air volume:
   1. Refrigeration *system* condenser *control* for air-cooled condensers shall use variable *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.

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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

HVAC systems only serving 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*.

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

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

6.9 Verification, Testing, and Commissioning

6.9.1 Verification and Testing

HVAC *control systems* shall be tested in accordance with this section and provisions of 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. Verification and *FTP* 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 Detailed instructions for *commissioning HVAC systems* shall be provided in the *construction documents*. *Commissioning* reporting shall comply with Section 4.2.5.2.2.

Informative Note

See Informative Appendix E for commissioning references.

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	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	≤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 12 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. Department of Energy 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.

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 12 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. Department of Energy 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.

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 12 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. Department of Energy 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.

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 12 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. Department of Energy 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.

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 12 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. Department of Energy 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.

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

Equipment Type	Size Category	Units	Path A	Path B	Test Procedure[c]
Air cooled chillers	<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 chillers without condenser must be rated with matching condensers and comply with air-cooled chiller *efficiency* requirements		AHRI 550/590
Water 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	
Water 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
Water 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 chillers shall be adjusted for nonstandard rating conditions per Section 6.4.1.2.1 and are only applicable for the range of conditions listed there. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and *IPLV*.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 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

d. NA means the requirements are not applicable for Path B, and only Path A can be used for compliance.

e. FL is the full-load performance requirements, and *IPLV*.IP is for the part-load performance requirements.

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

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency[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[a]	<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 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. Nonstandard size units must be factory *labeled* as follows: "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS." Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external *wall* opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.^{2}.

c. 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 USDOE 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.

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]
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 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Nonstandard size units must be factory *labeled* as follows: "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS." Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external *wall* opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.^{2}.
c. 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 USDOE 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.

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	Size Category (Input)	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure[a]
Warm-air furnace, gas fired for application outside the U.S. [g]	<225,000 Btu/h	Maximum capacity[c]	80% *AFUE* (nonweatherized) or 81% *AFUE* (weatherized) or 80% E_t[b,d]	10 CFR 430 Appendix N or Section 2.39, Thermal *Efficiency*, ANSI Z21.47
Warm-air furnace, gas fired	≥225,000 Btu/h	Maximum capacity[c]	80% E_t[b,d] before 1/1/2023 81% E_t[d] after 1/1/2023	Section 2.39, Thermal *Efficiency*, ANSI Z21.47
Warm-air furnace, oil fired for application outside the U.S. [g]	<225,000 Btu/h	Maximum capacity[c]	83% *AFUE* (nonweatherized) or 78% *AFUE* (weatherized) or 80% E_t[b,d]	10 CFR 430 Appendix N or Section 42, Combustion, UL 727
Warm-air furnace, oil fired	≥225,000 Btu/h	Maximum capacity[c]	81% E_t[d] before 1/1/2023 82% E_t[d] after 1/1/2023	Section 42, Combustion, UL 727
Electric furnaces for applications outside the U.S. [g]	<225,000 Btu/h	All	96% *AFUE*	10 CFR 430 Appendix N
Warm-air duct furnaces, gas fired	All capacities	Maximum capacity[c]	80% E_c[e]	Section 2.10, *Efficiency*, ANSI Z83.8
Warm-air unit heaters, gas fired	All capacities	Maximum capacity[c]	80% E_c[e,f]	Section 2.10, *Efficiency*, ANSI Z83.8
Warm-air unit heaters, oil fired	All capacities	Maximum capacity[c]	80% E_c[e,f]	Section 40, Combustion, UL 731

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Combination units (i.e., furnaces contained within the same cabinet as an air conditioner) not covered by 10 CFR 430 (i.e., three-phase power or with cooling capacity greater than or equal to 65,000 Btu/h) may comply with either rating. All other units greater than 225,000 Btu/h sold in the U.S. must meet the *AFUE* standards for consumer products and test using USDOE's *AFUE* test procedure at 10 CFR 430, Subpart B, Appendix N.
c. Compliance of multiple firing rate units shall be at the maximum firing rate.
d. E_t = thermal *efficiency*. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a *flue damper*. A *vent damper* is an acceptable alternative to a *flue damper* for those furnaces where combustion air is drawn from the *conditioned space*.
e. E_c = combustion *efficiency* (100% less flue losses). See test procedure for detailed discussion.
f. Units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an automatic flue damper.
g. For U.S. applications of federal covered <225,000 Btu/h products, see Informative Appendix F, Table F-4.

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[ad]	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[ad]	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[ad]	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[ad]	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[ad]	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 USDOE requirements for U.S. applications.

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 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

e. The efficiencies and test procedures for both open- and closed-circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of separate wet and dry heat exchange sections. The certification requirements do not apply to field-erected cooling towers.

f. All cooling towers shall comply with the minimum *efficiency* listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.

g. For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table, divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.

h. Requirements for evaporative condensers are listed with ammonia (R-717) and R-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.

Table 6.8.1-8 Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure
VRF air conditioners, air cooled	<65,000 Btu/h	All	*VRF* multisplit *system*	13.0 *SEER*	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	*Electric resistance* (or none)	*VRF* multisplit *system*	11.2 *EER* 15.5 *IEER*	
	≥135,000 Btu/h and <240,000 Btu/h	*Electric resistance* (or none)	*VRF* multisplit *system*	11.0 *EER* 14.9 *IEER*	
	≥240,000 Btu/h	*Electric resistance* (or none)	*VRF* multisplit *system*	10.0 *EER* 13.9 *IEER*	

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	All	*VRF* multisplit *system*	13.0 *SEER*	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	*Electric resistance* (or none)		11.0 *EER* 14.6 *IEER*	
			VRF multisplit *system* with heat recovery	10.8 *EER* 14.4 *IEER*	
	≥135,000 Btu/h and <240,000 Btu/h		*VRF* multisplit *system*	10.6 *EER* 13.9 *IEER*	
			VRF multisplit *system* with heat recovery	10.4 *EER* 13.7 *IEER*	
	≥240,000 Btu/h		*VRF* multisplit *system*	9.5 *EER* 12.7 *IEER*	
			VRF multisplit *system* with heat recovery	9.3 *EER* 12.5 *IEER*	
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
			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
			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
			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*	

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)		*VRF* multisplit *system*	7.7 *HSPF*	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 47°F db/43°F wb *outdoor air*	3.3 COP_H	
			17°F db/15°F wb *outdoor air*	2.25 COP_H	
	≥135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 47°F db/43°F wb *outdoor air*	3.2 COP_H	
			17°F db/15°F wb *outdoor air*	2.05 COP_H	
VRF water source (heating mode)	<65,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 68°F entering water	4.3 COP_H	AHRI 1230
	≥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
	≥135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 50°F entering water	3.3 COP_H	
VRF ground source (heating mode)	<135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 32°F entering water	3.1 COP_H	AHRI 1230
	≥135,000 Btu/h (cooling capacity)		*VRF* multisplit *system* 32°F entering water	2.8 COP_H	

Table 6.8.1-10 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		

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		

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		

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 Standard
Remote condensing commercial refrigerators and commercial freezers	Remote (RC)	Vertical open (VOP)	38 (M)	≥32	VOP.RC.M	0.64 × TDA + 4.07	AHRI 1200
			0 (L)	<32	VOP.RC.L	2.20 × TDA + 6.85	
		Semivertical open (SVO)	38 (M)	≥32	SVO.RC.M	0.66 × TDA + 3.18	
			0 (L)	<32	SVO.RC.L	2.20 × TDA + 6.85	
		Horizontal open (HZO)	38 (M)	≥32	HZO.RC.M	0.35 × TDA + 2.88	
			0 (L)	<32	HZO.RC.L	0.55 × TDA + 6.88	
		Vertical closed transparent (VCT)	38 (M)	≥32	VCT.RC.M	0.15 × TDA + 1.95	
			0 (L)	<32	VCT.RC.L	0.49 × TDA + 2.61	
		Horizontal closed Transparent (HCT)	38 (M)	≥32	HCT.RC.M	0.16 × TDA + 0.13	
			0 (L)	<32	HCT.RC.L	0.34 × TDA + 0.26	
		Vertical closed solid (VCS)	38 (M)	≥32	VCS.RC.M	0.10 × V + 0.26	
			0 (L)	<32	VCS.RC.L	0.21 × V + 0.54	
		Horizontal closed solid (HCS)	38 (M)	≥32	HCS.RC.M	0.10 × V + 0.26	
			0 (L)	<32	HCS.RC.L	0.21 × V + 0.54	
		Service over counter (SOC)	38 (M)	≥32	SOC.RC.M	0.44 × TDA + 0.11	
			0 (L)	<32	SOC.RC.L	0.93 × TDA + 0.22	
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.RC.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	
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 × V + 0.81	AHRI 1200

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.

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 Standard
Commercial ice-cream freezers	Remote (RC)	Vertical Open (VOP)	– 15 (I)	≤–5[b]	VOP.RC.I	2.79 × TDA + 8.70	AHRI 1200
		Semivertical Open (SVO)			SVO.RC.I	2.79 × TDA + 8.70	
		Horizontal Open (HZO)			HZO.RC.I	0.70 × TDA + 8.74	
		Vertical Closed Transparent (VCT)			VCT.RC.I	0.58 × TDA + 3.05	
		Horizontal Closed Transparent (HCT)			HCT.RC.I	0.40 × TDA + 0.31	
		Vertical Closed Solid (VCS)			VCS.RC.I	0.25 × V + 0.63	
		Horizontal Closed Solid (HCS)			HCS.RC.I	0.25 × V + 0.63	
		Service Over Counter (SOC)			SOC.RC.I	1.09 × TDA + 0.26	
	Self-contained (SC)	Vertical Open (VOP)			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.

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*	

Table 6.8.1-15 Electrically Operated Water-Source Heat Pumps—Minimum *Efficiency* Requirements

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-water, 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 12 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 <19 *kW* are regulated as consumer products by 10 CFR 430. $SCOP_C$, $SCOP2_C$, $SCOP_H$ and $SCOP2_H$ values for single-phase products are set by the USDOE.
Informative Note: See Informative Appendix F for the USDOE minimum.

Table 6.8.1-16 Heat-Pump and Heat Recovery Chiller Packages—Minimum *Efficiency* Requirements

Equipment Type	Size Category, ton$_R$	Cooling-Only Operation Cooling Efficiency[a] Air Source EER (FL/IPLV), Btu/W·h; Water Source Power Input per Capacity (FL/IPLV), kW/ton$_R$		Heating Operation									Test Procedure
				Heating Source Conditions (entering/leaving water) or OAT (db/wb), °F	Heat-Pump Heating Full-Load Efficiency (COP$_H$)[b], W/W				Heat Recovery Chiller Full-Load Efficiency (COP$_{HR}$)[b,c], W/W; Simultaneous Cooling and Heating Full-Load Efficiency (COP$_{SHC}$)[b], W/W				
					Leaving Heating Water Temperature				Leaving Heating Water Temperature				
					Low	Medium	High	Boost	Low	Medium	High	Boost	
		Path A	Path B		105°F	120°F	140°F	140°F	105°F	120°F	140°F	140°F	
Air source	All sizes	≥9.595 FL ≥13.02 IPLV.IP	≥9.215 FL ≥15.01 IPLV.IP	47 db 43 wb[d]	≥3.290	≥2.770	≥2.310	NA	NA	NA	NA	NA	AHRI 550/590
		≥9.595 FL ≥13.30 IPLV.IP	≥9.215 FL ≥15.30 IPLV.IP	17 db 15 wb[d]	≥2.230	≥1.950	≥1.630	NA	NA	NA	NA	NA	
Water source electrically operated positive displacement	<75	≤0.7885 FL ≤0.6316 IPLV.IP	≤0.7875 FL ≤0.5145 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	AHRI 550/590
				75/65[e]	NA	NA	NA	≥3.550	NA	NA	NA	6.150	
	≥75 and <150	≤0.7579 FL ≤0.5895 IPLV.IP	≤0.7140 FL ≤0.4620 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	
				75/65[e]	NA	NA	NA	≥3.550	NA	NA	NA	6.150	
	≥150 and <300	≤0.6947 FL ≤0.5684 IPLV.IP	≤0.7140 FL ≤0.4620 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	
				75/65[e]	NA	NA	NA	≥3.550	NA	NA	NA	6.150	
	≥300 and <600	≤0.6421 FL ≤0.5474 IPLV.IP	≤0.6563 FL ≤0.4305 IPLV.IP	54/44[e]	≥4.930	≥3.960	≥2.970	NA	≥8.900	≥6.980	≥5.000	NA	
				75/65[e]	NA	NA	NA	≥3.900	NA	NA	NA	6.850	
	≥600	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6143 FL ≤0.3990 IPLV.IP	54/44[e]	≥4.930	≥3.960	≥2.970	NA	≥8.900	≥6.980	≥5.000	NA	
				75/65[e]	NA	NA	NA	≥3.900	NA	NA	NA	6.850	

a. Cooling-only rating conditions are standard rating conditions defined in AHRI 550/590, Table 1.
b. Heating full-load rating conditions are at rating conditions defined in AHRI 550/590, Table 1.
c. For water-cooled heat recovery chillers that have capabilities for heat rejection to a heat recovery condenser and a tower condenser, the COP$_{HR}$ applies to operation at full load with 100% 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. Outdoor air entering dry-bulb (db) temperature and wet-bulb (wb) temperature.
e. Source-water entering and leaving water temperature.

Table 6.8.1-16 Heat-Pump and Heat Recovery Chiller Packages—Minimum *Efficiency* Requirements *(Continued)*

Equipment Type	Size Category, ton_R	Cooling-Only Operation Cooling Efficiency[a] Air Source EER (FL/IPLV), Btu/W·h Water Source Power Input per Capacity (FL/IPLV), kW/ton_R		Heating Operation									Test Procedure
				Heating Source Conditions (entering/leaving water) or OAT (db/wb), °F	Heat-Pump Heating Full-Load Efficiency (COP_H)[b], W/W				Heat Recovery Chiller Full-Load Efficiency (COP_{HR})[b,c], W/W Simultaneous Cooling and Heating Full-Load Efficiency (COP_{SHC})[b], W/W				
					Leaving Heating Water Temperature				Leaving Heating Water Temperature				
					Low	Medium	High	Boost	Low	Medium	High	Boost	
		Path A	Path B		105°F	120°F	140°F	140°F	105°F	120°F	140°F	140°F	
Water source electrically operated centrifugal	<75	≤0.6421 FL ≤0.5789 IPLV.IP	≤0.7316 FL ≤0.4632 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	AHRI 550/590
				75/65[e]	NA	NA	NA	≥3.550	NA	NA	NA	≥6.150	
	≥75 and <150	≤0.5895 FL ≤0.5474 IPLV.IP	≤0.6684 FL ≤0.4211 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	
				75/65[e]	NA	NA	NA	≥3.550	NA	NA	NA	≥6.150	
	≥150 and <300	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6263 FL ≤0.4105 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	
				75/65[e]	NA	NA	NA	≥3.550	NA	NA	NA	≥6.150	
	≥300 and <600	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6158 FL ≤0.4000 IPLV.IP	54/44[e]	≥4.930	≥3.960	≥2.970	NA	≥8.900	≥6.980	≥5.000	NA	
				75/65[e]	NA	NA	NA	≥3.900	NA	NA	NA	≥6.850	
	≥600	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6158 FL ≤0.4000 IPLV.IP	54/44[e]	≥4.930	≥3.960	≥2.970	NA	≥8.900	≥6.980	≥5.000	NA	
				75/65[e]	NA	NA	NA	≥3.900	NA	NA	NA	≥6.850	

a. Cooling-only rating conditions are standard rating conditions defined in AHRI 550/590, Table 1.
b. Heating full-load rating conditions are at rating conditions defined in AHRI 550/590, Table 1.
c. For water-cooled heat recovery chillers that have capabilities for heat rejection to a heat recovery condenser and a tower condenser, the COP_{HR} applies to operation at full load with 100% 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. Outdoor air entering dry-bulb (db) temperature and wet-bulb (wb) temperature.
e. Source-water entering and leaving water temperature.

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		

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, L	$0.04 \times A_{nd} + 1.9$	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.

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 Standard 1250.

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,e] (Steam, Steam Condensate, Hot-Water Heating and Domestic Water *Systems*)

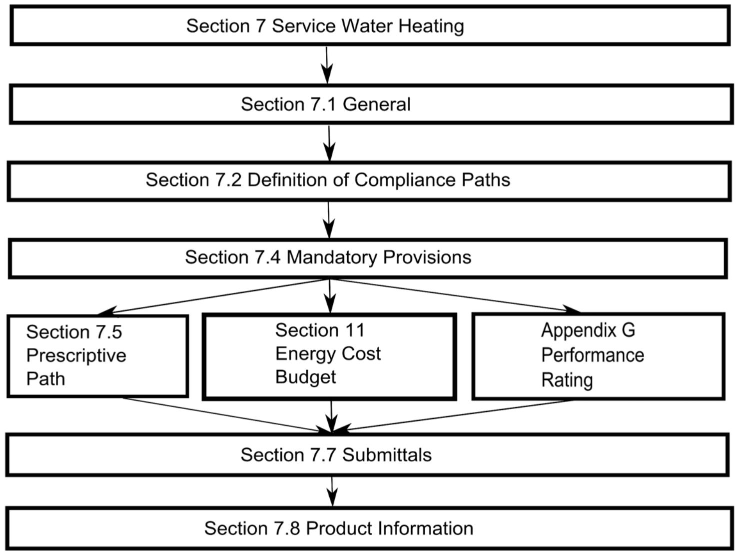
Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		≥Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in/h·ft^2·°F	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
>350	0.32 to 0.34	250	4.5	5.0	5.0	5.0	5.0
251 to 350	0.29 to 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

a. For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$,where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature [Btu·in/h·ft^2·°F]; and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.
b. These thicknesses are based on *energy efficiency* considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.
c. For *piping* smaller than 1.5 in. and located in partitions within *conditioned spaces*, reduction of these thicknesses by 1 in. shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 1 in.
d. For direct-buried heating and hot-water *system piping*, reduction of these thicknesses by 1.5 in. shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 1 in.
e. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having *thermal resistance* greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.

Table 6.8.3-2 Minimum *Piping* Insulation Thickness Cooling *Systems* (Chilled Water, Brine, and Refrigerant)[a,b,c,d]

Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in/h·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. For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$, where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature [Btu·in/h·ft2·°F]; and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.
b. These thicknesses are based on *energy efficiency* considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.
c. For direct-buried cooling *system piping*, insulation is not required.
d. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having *thermal resistance* greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.



7 Service Water Heating

7.1 General

7.1.1 Service Water-Heating Scope

7.1.1.1 New Buildings

Service water-heating systems and *equipment* shall comply with the requirements of this section as described in Section 7.2.

7.1.1.2 Additions to Existing Buildings

Service water-heating systems and *equipment* shall comply with the requirements of this section.

Exception to 7.1.1.2

When the *service water heating* to an *addition* is provided by existing *service water-heating systems* and *equipment*, such *systems* and *equipment* shall not be required to comply with this standard. However, any new *systems* or *equipment* installed must comply with specific requirements applicable to those *systems* and *equipment*.

7.1.1.3 Alterations to Existing Buildings

Building service water-heating equipment installed as a direct replacement for *existing building service water-heating equipment* shall comply with the requirements of Section 7 applicable to the *equipment* being replaced. New and replacement *piping* shall comply with Section 7.4.3.

Exception to 7.1.1.3

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 Section 7.2.1 and Section 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 *manufacturers*' published sizing guidelines or *generally accepted engineering standards* and handbooks acceptable to the *adopting authority* (e.g., *ASHRAE Handbook—HVAC Applications*).

7.4.2 Equipment Efficiency

All water-heating *equipment*, *hot-water supply boilers* used solely for heating potable water, *pool* heaters, and hot-water storage tanks shall meet the criteria listed in Table 7.8. Where multiple criteria are listed, all criteria shall be met. Omission of minimum performance requirements for certain classes of *equipment* does not preclude use of such *equipment* where appropriate. *Equipment* not listed in Table 7.8 has no minimum performance requirements.

Exceptions 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 7.8 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 Hot-Water Piping Insulation

The following *piping* shall be insulated to levels shown in Section 6, Table 6.8.1-3:

a. *Recirculating system piping*, including the supply and return *piping* of a circulating tank type *water heater*.
b. The first 8 ft of outlet *piping* for a constant-temperature nonrecirculating storage *system*.
c. The first 8 ft of branch *piping* connecting to recirculated, heat-traced, or impedance heated *piping*.
d. The inlet *piping* between the storage tank and a heat trap in a nonrecirculating storage *system*.
e. *Piping* that is externally heated (such as *heat trace* or impedance heating).

7.4.4 Service Water-Heating System Controls

7.4.4.1 Temperature Controls

Temperature *controls* shall be provided that allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use.

Exception 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 *site-solar 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 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 Buildings with High-Capacity Service Water-Heating Systems

New *buildings* with gas *service water-heating systems* with a total installed gas water-heating input capacity of 1,000,000 Btu/h or greater, shall have gas service water-heating *equipment* with a minimum thermal *efficiency* (E_t) of 90%. Multiple units of gas water-heating *equipment* are allowed to meet this requirement if the water-heating input provided by *equipment* with thermal *efficiency* (E_t) above and below 90% provides an input capacity-weighted average thermal *efficiency* of at least 90%.

Exception to 7.5.3

1. Where 25% of the annual *service water-heating* requirement is provided by *site-solar energy* or *site-recovered energy*.
2. *Water heaters* installed in individual *dwelling units*.
3. Individual gas *water heaters* with input capacity not greater than 100,000 Btu/h.

7.6 Alternative Compliance Path (Not Used)

7.7 Submittals

7.7.1 General

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.

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 provisions of 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 *FTP* 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.

Table 7.8 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*[e]	<4000 (Btu/h)/gal	SL ≤ 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 × V_r) Low DP: UEF = 0.5362 – (0.0012 × V_r) Medium DP: UEF = 0.6002 – (0.0011 × V_r) High DP: UEF = 0.6597 – (0.0009 × V_r)	10 CFR 430 Appendix E
	>105,000 Btu/h [d,f]	<4000 (Btu/h)/gal	80% E_t SL ≤ (Q/800 + 110 $\sqrt{V}$), Btu/h	10 CFR 431.106

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 12 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*.

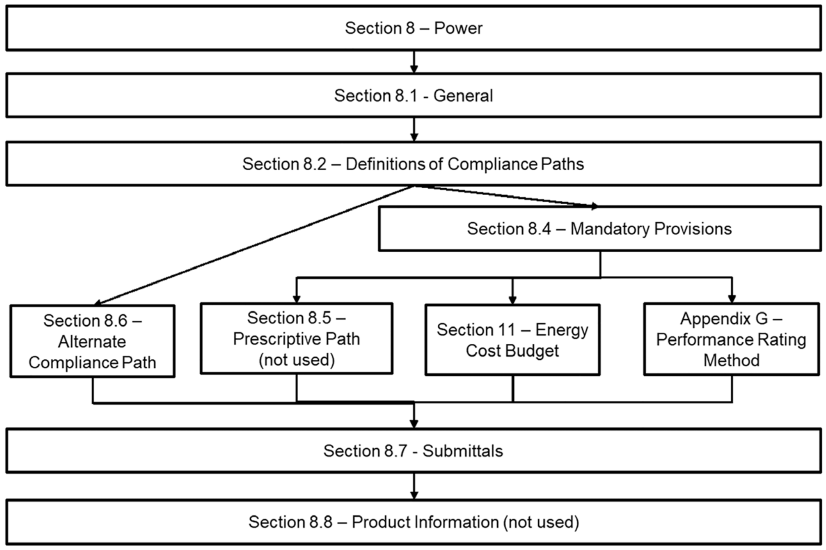
g. *Water heaters* or gas *pool* heaters in this category or subcategory are regulated as consumer products by the USDOE as defined in 10 CFR 430.

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 USDOE efficiency requirements shown in Appendix F, Table F-2.

Table 7.8 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]
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 ≤ $(Q/800 + 110\sqrt{V})$, Btu/h	
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 = $0.2932 - (0.0015 \times V_r)$ Low DP: UEF = $0.5596 - (0.0018 \times V_r)$ Medium DP: UEF = $0.6194 - (0.0016 \times V_r)$ High DP: UEF = $0.6740 - (0.0013 \times V_r)$	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 ≥ $0.59 - 0.0005 \times V$	10 CFR 430 Appendix E as it appeared as of 1/1/2014
	>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 12 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 USDOE 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 USDOE efficiency requirements shown in Appendix F, Table F-2.



8 Power

8.1 General

8.1.1 Scope

This section applies to all *building* power *distribution systems* and only to *equipment* described below.

8.1.2 New Buildings

Equipment installed in new *buildings* shall comply with the requirements of this section.

8.1.3 Addition to Existing Buildings

Equipment installed in addition to *existing buildings* shall comply with the requirements of this section.

8.1.4 Alterations to Existing Buildings

Exception 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* or *systems* shall comply with the requirements of this section applicable to those specific portions of the *building* and its *systems* that are being altered.

8.1.4.2

Any new *equipment* subject to the requirements of this section that is installed in conjunction with the *alterations* as a direct replacement of *existing equipment* shall comply with the specific requirements applicable to that *equipment*.

8.2 Compliance Paths

Power distribution systems and equipment shall comply with Section 8.2.1 and Section 8.2.2.

8.2.1 Requirements for All Compliance Paths

Power *distribution systems* and equipment only shall comply with Section 8.1, “General”; Section 8.4, “Mandatory Provisions”; and Section 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

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 Section 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

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

Up to 10% of the load for each of the categories (b) through (e) shall be allowed to be from other electrical loads.

Table 8.4.4 Minimum Nominal *Efficiency* Levels for Low-Voltage Dry-Type Distribution Transformers[a]

Single-Phase *Transformers*		Three-Phase *Transformers*	
kVA[b]	*Efficiency*,%[c]	kVA[b]	*Efficiency*,%[c]
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 distribution *transformer* is a *transformer* that is air-cooled, does not use oil as a coolant, has an input voltage ≤600 V, and is rated for operation at a frequency of 60 Hz.
b. *Kilovolt-ampere* rating.
c. Nominal efficiencies shall be established in accordance with the 10 CFR 431 test procedure for low-voltage *dry-type transformers*.

8.4.3.2 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 Sections 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 and *Equipment* branches of NEC Article 517.

8.4.4 Low-Voltage Dry-Type Distribution Transformers

Low-voltage *dry-type transformers* shall comply with the provisions of the Energy Policy Act of 2005, where applicable, as shown in Table 8.4.4. *Transformers* that are not included in the scope of the Energy Policy Act of 2005 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 of the Energy Policy Act of 2005 based on 10 CFR 431 definition:

1. Special purpose applications.
2. Not likely to be used in general purpose applications.
3. *Transformers* with multiple voltage taps, where the highest tap is at least 20% more than the lowest tap.
4. Drive *transformer*.
5. Rectifier *transformer*.
6. Auto-*transformer*.
7. Uninterruptible power *system transformer*.
8. Impedance *transformer*.
9. Regulating *transformer*.

10. Sealed and nonventilating *transformer*.
11. Machine tool *transformer*.
12. Welding *transformer*.
13. Grounding *transformer*.
14. Testing *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 *building* owner, including

a. a *single-line diagram* of the *building* electrical *distribution system* and
b. *floor* plans indicating location and area served for all distribution.

8.7.3.2 Manuals

Construction documents shall require that an operating manual and maintenance manual be provided to the *building* owner. The manuals shall include, at a minimum, the following:

a. Submittal data stating *equipment* rating and selected options for each piece of *equipment* requiring maintenance.
b. Operation manuals and maintenance manuals for each piece of *equipment* requiring maintenance. Required routine maintenance actions shall be clearly identified.
c. Names and addresses of at least one qualified *service agency*.
d. A complete narrative of how each *system* is intended to operate.

Enforcement agencies should only check to ensure that the *construction documents* require this information to be transmitted to the owner and should not expect copies of any of the materials.

8.8 Product Information (Not Used)

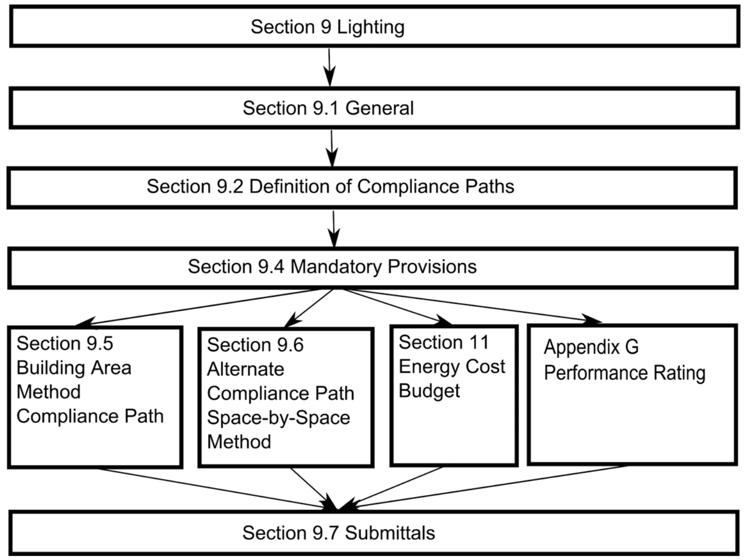
8.9 Verification, Testing, and Commissioning

8.9.1 Verification and Testing

Automatic receptacles controls (Section 8.4.2) and *energy* monitoring (Section 8.4.3) 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 Sections 8.4.2 and 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.



9 Lighting

9.1 General

9.1.1 Scope

This section shall apply to the following:

a. Interior *spaces* of *buildings*.

b. Exterior lighting that is powered through the *building*'s electrical *service*.

Exception to 9.1.1

1. Emergency lighting that is *automatically* off during normal *building* 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*.

9.1.2 Lighting Alterations

For the *alteration* of any *lighting system* in an interior *space*, that *space* shall comply with the *lighting power density* (*LPD*) allowances of Section 9.5.1 or 9.6.1 and the *control* requirements of Section 9.4.1.1 (a), (b), (c), (d), (g), (h), and (i), as applicable to that *space*.

For the *alteration* of any *lighting system* for the exterior of a *building* application, that *lighting system* shall comply with the *lighting power density* (*LPD*) allowances of Section 9.4.2 applicable to the area illuminated by that *lighting system* and the applicable *control* requirements of Sections 9.4.1.4 and 9.4.2.

Exception to 9.1.2

1. *Alterations* that involve 20% or less of the connected lighting load in a *space* or area need not comply with these requirements, provided that such *alterations* do not increase the installed lighting power.
2. Lighting *alterations* that only involve replacement of *lamps* plus *ballasts/drivers* or only involve one-for-one *luminaire* replacement need only comply with *LPD* requirement and Section 9.4.1.1(h) or 9.4.1.1(i).
3. Routine maintenance or *repair* situations.

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, 9.2.3.1, or 9.4.2.

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 changeable.

c. For 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*, the wattage shall be

   1. the specified wattage of the lighting *equipment* included in the *system* with a minimum of 30 W/lin ft,
   2. the wattage limit of the *system*'s *circuit breaker*, or
   3. the wattage limit of other permanent current-limiting 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 all other miscellaneous lighting *equipment* shall be the specified wattage of the lighting *equipment*.

9.1.5 Climate

Climate zones shall be determined in accordance with Section 5.1.4.

9.2 Compliance Paths

Lighting systems and *equipment* shall comply with Section 9.2.1 and Section 9.2.2.

9.2.1 Requirements for All Compliance Paths

Lighting systems and *equipment* shall comply with Section 9.1 "General"; Section 9.4, "Mandatory Provisions"; and Section 9.7, "Submittals."

Compliance with Section 9 shall be achieved by meeting all of the requirements of Section 9.1, "General"; Section 9.7, "Submittals"; and one of the following:

a. Section 9.3, "Simplified Building Method Compliance Path"
b. Section 9.4, "Mandatory Provisions", and Section 9.5, "Building Area Method"
c. Section 9.4, "Mandatory Provisions," and Section 9.6, "Space-by-Space 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).

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.

9.2.2 Additional Requirements to Comply with Section 9

Lighting systems and equipment shall comply with

a. Section 9.3, "Simplified Building Method Compliance Path,"
b. Section 9.5, "*Building* Area Method Compliance Path," or
c. Section 9.6, "Alternative Compliance Path: Space-by-Space Method."

Projects using the Energy Cost Budget Method (see Section 11 of this standard) must comply with Section 9.4, "Mandatory Provisions," as a portion of that compliance path.

Exception to 9.2.2

When compliance is shown using Section 9.2.2(a), compliance with Section 9.4 is not required.

9.2.3 Prescriptive Requirements

9.2.3.1 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, or the Space-by-Space Method described in Section 9.6.

Exception to 9.2.3.1

When using the compliance methods in Section 9.5 or 9.6 only, the lighting *equipment* and applications listed in Table 9.2.3.1 shall not be considered when determining the *interior lighting power allowance* developed in accordance with Section 9.5 or 9.6, nor shall the wattage for such lighting be included in the *installed interior lighting power* identified in accordance with Section 9.1.3. This exemption shall only apply when the lighting and controls are in compliance with the requirements of Table 9.2.3.1. Lighting controls noted in this table are the only required controls for this equipment and these applications.

9.2.3.2 Exterior Lighting Power Allowance

The *exterior lighting power allowance* for a *building*, or a separately metered or permitted portion of a *building*, 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 Building Lighting Power," when using Section 9.5 or Section 9.6 to determine the *interior lighting power allowance*.

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

Table 9.2.3.1 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	Lighting specifically designed for use only during medical or dental procedures	YES	9.4.1.1(a)—Local control
3	Lighting specifically designed for the life support of non-human life forms	YES	9.4.1.1(a)—Local control
4	Lighting for theatrical purposes, including performance, stage, broadcast studio, and film and video production	YES	9.4.1.1(a)—Local control
5	Lighting in sporting activity areas for television broadcasting	YES	9.4.1.1(a)—Local control
6	Lighting for photographic processes	YES	9.4.1.1(a)—Local control
7	Lighting that is an integral part of advertising or directional signage	YES	9.4.1.1(i)—Scheduled shutoff
8	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
9	Casino gaming areas	NO	9.4.1.1(h)—Automatic full OFF or 9.4.1.1(i)—Scheduled shutoff
10	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
11	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
12	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
13	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
14	Mirror lighting in dressing rooms	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
15	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
16	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
17	Furniture-mounted supplemental *task lighting*	YES	9.4.1.3(c)—Special Applications
18	Parking garage daylight transition lighting—lighting for covered vehicle entrances and exits from *buildings* and parking structures; each transition zone shall not exceed a depth of 66 ft inside the structure and a width of 50 ft.	YES	9.4.1.2(a) and (c)—Parking Garage Control

Table 9.3.1-1 Simplified Building Method for Office *Buildings*

Interior *Space* Type	Interior Lighting Power Allowance	*Controls* [a]
All *spaces* in office *buildings* other than parking garages, stairwells, and corridors	0.70 W/ft^2	All lighting shall be *automatically* controlled to turn off when the *building* is 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 *building* 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* less than or equal to 250 ft^2, classrooms, conference rooms, meeting rooms, training rooms, storage rooms, and break rooms	0.70 W/ft^2	These *spaces* shall also be controlled by *manual*-ON *occupant sensors*.
Office *spaces* greater than 250 ft^2 and restrooms	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors*.
Stairwells and corridors in office *buildings* and parking garages	0.70 W/ft^2	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 20 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be *automatically* controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by *occupant sensors*. *Controls* shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

than 25,000 ft^2. Interior and exterior wattage allowances shall be calculated and complied with separately.

Exception to 9.3

Alterations involving only *luminaire* and *lamp/ballast* replacements shall be permitted to comply by reducing the installed power by a minimum of 35% for existing T12 *systems*, 20% for existing T8 or T5 *systems*, 45% for existing HID *systems*, and 75% for existing incandescent *systems*.

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 Tables 9.3.1-1, 9.3.1-2, and 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 Tables 9.3.1-1, 9.3.1-2, and 9.3.1-3.

9.4 Mandatory Provisions

9.4.1 Lighting Control

Building lighting *controls* shall be installed to meet the provisions of Sections 9.4.1.1, 9.4.1.2, 9.4.1.3, and 9.4.1.4.

9.4.1.1 Interior Lighting Controls

For each *space* in the *building*, all of the lighting *control* functions indicated in Table 9.6.1, for the appropriate *space* type in 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 func-

Table 9.3.1-2 Simplified Building Method for Retail *Buildings*

Interior *Space* Type	Interior Lighting Power Allowance	*Controls* [a]
All *spaces* in retail *buildings* other than parking garages, stairwells, and corridors	1.00 W/ft^2	All lighting shall be *automatically* controlled to turn off when the *building* is 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 *building* 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	1.00 W/ft^2	These *spaces* shall also be 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 [b] in *spaces* with *toplighting*.
Stock rooms, dressing/fitting rooms, locker rooms, and restrooms	1.00 W/ft^2	These *spaces* shall also be controlled by; auto-ON or *manual*-ON *occupant sensors*, and *continuous daylight dimming* controls [b] in *spaces* with *toplighting*.
Office *spaces*, conference rooms, meeting rooms, training rooms, storage rooms, break rooms, and utility *spaces*	1.00 W/ft^2	These *spaces* shall also be controlled by; *manual*-ON *occupant sensors*, and *continuous daylight dimming* controls [b] in *spaces* with *toplighting*.
Stairwells and corridors in retail *buildings* and parking garages	1.00 W/ft^2	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 20 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be *automatically* controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by *occupant sensors*. *Controls* shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.
b. When the combined input power of the general lights completely or partially within the *daylight areas* is 150 W or greater.

tions 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 *controls* in the *space* that *controls* all of the lighting in the *space*. Each *control device* shall *control* an area (1) no larger than 2500 ft^2 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 light is clearly *labeled* to identify the controlled lighting.

Table 9.3.1-3 Simplified Building Method for School *Buildings*

Interior *Space* Type	Interior Lighting Power Allowance	*Controls* [a]
All *spaces* in school *buildings* other than parking garages, stairwells, and corridors	0.70 W/ft^2	All lighting shall be *automatically* controlled to turn off when the *building* is 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 *building* 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	0.70 W/ft^2	These *spaces* shall also be controlled by *manual*-ON *occupant sensors*.
Gymnasiums and cafeterias	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors*.
Restrooms	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors*.
Stairwells and corridors in school *buildings* and parking garages	0.70 W/ft^2	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 20 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be *automatically* controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by *occupant sensors*. *Controls* shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

Table 9.3.2 Simplified Building Method for *Building* Exteriors

Exterior Area Type	*Exterior Lighting Power Allowance* [a,b]	*Controls* [c]
Base allowance	200 W	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Façade lighting and special feature areas, walkways, plazas	0.10 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Landscape	0.04 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 foot	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Stairs and ramps	0.7 W/ft^2	No additional *controls* required.
Parking lots and drives	0.05 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 façade area by the allowed W/ft^2. Façade allowance shall not be traded with other exterior areas or between separate *façade areas*.
b. For *buildings* in Lighting Zone 2, as defined in Table 9.4.2-1, decrease exterior allowances by 20%. For *buildings* in Lighting Zone 4, as defined in Table 9.4.2-1, increase exterior allowances by 25%.
c. All exterior lighting shall be automatically controlled by either a photocell or an astronomical time switch to shut off the lighting when daylight is available.

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.

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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.

Exception to 9.4.1.1(c)

Lighting in open-plan office *spaces* shall be allowed to turn on *automatically* to more than 50%, provided the *control* zone is no larger than 600 ft^2.

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d. *Bilevel lighting control:* The *general lighting* in the *space* shall be controlled so as to provide at least one intermediate step in lighting power or continuous dimming in addition to full ON and full OFF. At least one intermediate step shall be between 30% and 70% (inclusive) of full lighting power.

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 150 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 300 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.
2. The photocontrol shall reduce electric lighting power in response to available daylight using continuous dimming to 20% or less and off.
3. When an automatic partial OFF control has reduced the lighting power to the unoccupied set point in accordance with Section 9.4.1(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.

Exception 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. Retail *spaces.*
4. *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).

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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 150 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 electric lighting power in response to available daylight using continuous dimming to 20% or less and off.
3. When an *automatic* partial OFF control has reduced the lighting power to the unoccupied set point in accordance with Section 9.4.1(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*.

Exception 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.

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g. *Automatic partial OFF (full OFF complies):* The *general lighting* power in the *space* shall be *automatically* reduced by at least 50% within 20 minutes of all occupants leaving the *space*.

Exception to 9.4.1.1(g)

This requirement does not have to be complied with in *spaces* that meet all four of the following requirements:

1. The *space* has an installed *LPD* of no more than 0.80 W/ft^2.
2. The *space* is lighted by *HID lamp*.
3. The *general lighting* power in the *space* is *automatically* reduced by at least 30% within 20 minutes of all occupants leaving the *space*.
4. Lighting load does not exceed 0.02 W/ft^2 multiplied by the *gross lighted floor area* of the *building*.

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h. *Automatic full OFF:* All lighting, 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.

Exception to 9.4.1.1(h)

The following lighting is not required to be *automatically* shut off:

1. *General lighting* and *task lighting* in shop and laboratory classrooms.
2. *General lighting* and *task lighting* in *spaces* where *automatic* shutoff would endanger the safety or security of room or *building* occupants.
3. Lighting required for 24/7 operation.
4. Lighting load not exceeding 0.02 W/ft^2 multiplied by the *gross lighted area* of the *building*.

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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* 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.

Exception to 9.4.1.1(i)

The following lighting is not required to be on scheduled shutoff:

1. Lighting in *spaces* where lighting is required for 24/7 continuous operation.
2. Lighting in *spaces* where patient care is rendered.
3. Lighting in *spaces* where *automatic* shutoff would endanger the safety or security of the room or *building* occupants.
4. Lighting load not exceeding 0.02 W/ft^2 multiplied by the *gross lighted floor area* of the *building*.

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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 lighting exempt per Section 9.2.3.1 shall be separately controlled to *automatically* reduce the lighting to no more than the general light level at night 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 lighting exempt per Section 9.2.3.1.
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 9.2.3.1. Lighting using additional interior lighting power applications shall be controlled in accordance with Section 9.6.2.

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 all switched receptacles in guestrooms and suites in hotels, motels, boarding houses, or similar *buildings* shall be *automatically* controlled such that the power to the lighting and switched receptacles in each *enclosed space* will be turned off within 20 minutes after all occupants leave that *space*.

Exception to 9.4.1.3(b)(1)

Enclosed spaces where the lighting and switched receptacles are controlled by card key *controls* and bathrooms are exempt.

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   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.

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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).

9.4.1.4 Exterior Lighting Control

Lighting for exterior applications not exempted in Section 9.1 shall meet the following requirements:

a. Lighting shall be controlled by a device that *automatically* turns off the lighting when sufficient daylight is available.
b. All *building* façade and landscape lighting shall be *automatically* shut off between midnight or business closing, whichever is later, and 6 a.m. or business opening, whichever comes first, or between times established by the *authority having jurisdiction*.
c. Lighting not specified in Section 9.4.1.4(b) and lighting for signage shall be controlled by a device that *automatically* reduces the connected lighting power by at least 50% for at least one of the following conditions:
   1. From 12 midnight or within one hour of the end of business operations, whichever is later, until 6 a.m. or business opening, whichever is earlier
   2. During any period when no activity has been detected for a time of no longer than 15 minutes
d. *Luminaires* serving outdoor parking areas and having a rated input wattage of greater than 78 W and a mounting height of 24 ft or less above the ground shall be controlled to *automatically* reduce the power of each *luminaire* by a minimum of 50% when no activity has been detected in the area illuminated by the controlled *luminaires* for a

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

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.

Exception to 9.4.1.4

1. Lighting for covered vehicle entrances or exits from *buildings* or parking structures where required for safety, security, or *eye adaptation*.
2. Lighting that is integral to signage and installed in the signage by the *manufacturer*.

9.4.2 Exterior Building Lighting Power

The total *exterior lighting power allowance* for all exterior *building* applications is the sum of the base site allowance plus the individual allowances for areas that are designed to be illuminated and are permitted in Table 9.4.2-2 for the applicable lighting zone 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 the *building* exterior is determined from Table 9.4.2-1 unless otherwise specified by the local jurisdiction.

Exception to 9.4.2

1. Lighting used for the following exterior applications is exempt when equipped with a *control device* that complies with the requirements of Section 9.4.1.4 and is independent of the *control* of the nonexempt lighting:
   a. Lighting that is integral to signage and installed in the signage by the *manufacturer*.
   b. Lighting for athletic playing areas.
   c. Lighting for industrial production, material handling, transportation sites, and associated storage areas.
   d. Theme elements in theme/amusement parks.
   e. Lighting used to highlight features of public monuments, public art displays, and registered *historic* landmark structures or *buildings*.
   f. Lighting for water features.
2. Lighting used for the following exterior applications is exempt when controlled separately:
   a. Specialized signal, directional, and marker lighting associated with transportation.
   b. Lighting integral to *equipment* or instrumentation and installed by its *manufacturer*.
   c. Lighting for theatrical purposes, including performance, stage, film production, and video production.
   d. Temporary lighting.
   e. Lighting for hazardous locations.
   f. Lighting for swimming *pools*.
   g. Searchlights.

Table 9.4.2-2 Individual Lighting Power Allowances for *Building* Exteriors

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance may be used in tradable or nontradable surfaces.)					
	No allowance	350 W	400 W	500 W	900 W
Tradable Surfaces (*LPD* allowances for uncovered parking areas, *building* grounds, *building entrances*, exits and loading docks, canopies and overhangs, and outdoor sales areas may be traded.)					
Uncovered Parking Areas					
Parking areas and drives	No allowance	0.03 W/ft^2	0.04 W/ft^2	0.06 W/ft^2	0.08 W/ft^2
***Building* Grounds**					
Walkways/ramps less than 10 ft wide	No allowance	0.5 W/linear foot	0.5 W/linear foot	0.6 W/linear foot	0.7 W/linear foot
Walkways/ramps 10 ft wide or greater Plaza areas Special feature areas	No allowance	0.10 W/ft^2	0.10 W/ft^2	0.11 W/ft^2	0.14 W/ft^2
Dining areas	No allowance	0.65 W/ft^2	0.65 W/ft^2	0.75 W/ft^2	0.95 W/ft^2
Stairways	No allowance	0.6 W/ft^2	0.7 W/ft^2	0.7 W/ft^2	0.7 W/ft^2
Pedestrian tunnels	No allowance	0.12 W/ft^2	0.12 W/ft^2	0.14 W/ft^2	0.21 W/ft^2
Landscaping	No allowance	0.03 W/ft^2	0.04 W/ft^2	0.04 W/ft^2	0.04 W/ft^2
***Building Entrances*, Exits, and Loading Docks**					
Pedestrian and vehicular entrances and exits	No allowance	14 W/lin ft of opening	14 W/lin ft of opening	21 W/lin ft of opening	21 W/lin ft of opening
Entry canopies	No allowance	0.20 W/ft^2	0.20 W/ft^2	0.20 W/ft^2	0.20 W/ft^2
Loading docks	No allowance	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2
Sales Canopies					
Free standing and attached	No allowance	0.4 W/ft^2	0.4 W/ft^2	0.6 W/ft^2	0.7 W/ft^2
Outdoor Sales					
Open areas (including vehicle sales lots)	No allowance	0.2 W/ft^2	0.2 W/ft^2	0.20 W/ft^2	0.20 W/ft^2
Street frontage for vehicle sales lots in addition to “open area” allowance	No allowance	No allowance	7 W/linear foot	7 W/linear foot	21 W/linear foot
Nontradable Surfaces (*LPD* allowances for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “Tradable Surfaces” section of this table.)					
Building facades (The allowance for each illuminated facade *orientation* shall be calculated by multiplying the allowable value by the entire façade area or facade length for that *orientation*.)	No allowance	No allowance	0.1 W/ft^2 of *façade area* or 2.5 W/linear foot of façade length	0.15 W/ft^2 of *façade area* or 3.75 W/linear foot of façade length	0.2 W/ft^2 of *façade area* or 5.0 W/linear foot of façade length
Automated teller machines and night depositories	No allowance	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location

Table 9.4.2-2 Individual Lighting Power Allowances for *Building* Exteriors *(Continued)*

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Uncovered entrances and gatehouse inspection stations at guarded facilities	No allowance	0.5 W/ft^2	0.5 W/ft^2	0.5 W/ft^2	0.5 W/ft^2
Uncovered loading areas for law enforcement, fire, ambulance, and other emergency *service* vehicles	No allowance	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2
Drive-through windows/ *doors*	No allowance	200 W per drive-through	200 W per drive-through	200 W per drive-through	200 W per drive-through
Parking near 24-hour retail entrances	No allowance	400 W per main entry	400 W per main entry	400 W per main entry	400 W per main entry
Roadway/parking entry, trail head, and toilet facility, or other locations approved by the *authority having jurisdiction*.	A single *luminaire* of 25 W or less	No additional allowance	No additional allowance	No additional allowance	No additional allowance
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 Table 9.6.1 as modified by factors in this row.	No allowance	65% of the *interior lighting power allowance* value	65% of the *interior lighting power allowance* value	80% of the *interior lighting power allowance* value	100% of the *interior lighting power allowance* value

9.4.3 Dwelling Units

Not less than 75% of the *permanently installed* lighting *fixtures* shall use *lamps* with an *efficacy* of at least 55 lm/W or have a total *luminaire efficacy* of at least 45 lm/W. No other provisions of Section 9 apply to dwelling units.

Exception to 9.4.3:

1. Lighting that is controlled with *dimmers* or controlled in accordance with Section 9.4.1.1(h).
2. Hotel/motel guest rooms. The requirements for hotel/motel guest rooms are covered in Table 9.6.1 and Section 9.4.1.3(b).

9.5 Building Area Method Compliance Path

9.5.1 Building Area Method of Calculating Interior Lighting Power Allowance

Use the following steps to determine the *interior lighting power allowance* by the *Building* Area Method:

a. Determine the appropriate *building* area type from Table 9.5.1 and the 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*.
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*.

Table 9.5.1 *Lighting Power Density* Allowances Using the *Building* Area Method

Building Area Type[a]	*LPD*, W/ft^2
Automotive facility	0.75
Convention center	0.64
Courthouse	0.79
Dining: Bar lounge/leisure	0.80
Dining: Cafeteria/fast food	0.76
Dining: Family	0.71
Dormitory	0.53
Exercise center	0.72
Fire station	0.56
Gymnasium	0.76
Health-care clinic	0.81
Hospital	0.96
Hotel/motel	0.56
Library	0.83
Manufacturing facility	0.82
Motion picture theater	0.44
Multifamily	0.45
Museum	0.55
Office	0.64
Parking garage	0.18
Penitentiary	0.69
Performing arts theater	0.84
Police station	0.66
Post office	0.65
Religious facility	0.67
Retail	0.84
School/university	0.72
Sports arena	0.76
Town hall	0.69
Transportation	0.50
Warehouse	0.45
Workshop	0.91

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.

9.6 Alternative Compliance Path: Space-by-Space Method

9.6.1 Space-by-Space Method of Calculating Interior Lighting Power Allowance

Use the following steps to determine the *interior lighting power allowance* by the Space-by-Space Method:

a. For each *space* enclosed by partitions that are 80% of the ceiling height or taller, determine the appropriate *space* type and the corresponding *LPD* allowance from Table 9.6.1. If a *space* has multiple functions, where more than one *space* type is applicable, that *space* shall be broken up into smaller subspaces, each using its own *space* type from Table 9.6.1. Any of these subspaces that are smaller in floor area than 20% of the original *space* and less than 1000 ft^2 need not be broken out separately. Include the floor area of balconies and other projections in this calculation.

b. In calculating the area of each *space* and subspace, the limits of the area are defined by the centerline of interior walls, the dividing line between subspaces, and the outside surface of *exterior walls* 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 9.6.1(a). For *space* types not listed, selection of a reasonable equivalent category shall be permitted.

d. The *interior lighting power allowance* is the sum of lighting power allowances of all *spaces* and subspaces. Trade-offs among *spaces* and subspaces are permitted, provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

9.6.2 Additional Interior Lighting Power

When using the Space-by-Space Method, an increase in the *interior lighting power allowance* is allowed for specific lighting functions. Additional power shall be allowed only if the specified lighting is installed and controlled independently of the *general* lighting in accordance with Section 9.4.1.1(j). 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 9.6.2 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 specified to be installed in addition to the *general lighting* for the purpose of decorative appearance or for highlighting art or exhibits not exempted in Table 9.2.3.1, Item 11, provided that the additional lighting power shall not exceed 0.75 W/ft^2 of such *spaces.*

b. For lighting *equipment* installed in sales areas and specifically designed and directed to highlight merchandise, calculate the additional lighting power as follows:

$$\text{Additional } \textit{Interior Lighting Power Allowance} = \\ 1000 \text{ W} + (\text{Retail Area } 1 \times 0.45 \text{ W/ft}^2) + (\text{Retail Area } 2 \times 0.45 \text{ W/ft}^2) \\ + (\text{Retail Area } 3 \times 1.05 \text{ W/ft}^2) + (\text{Retail Area } 4 \times 1.88 \text{ W/ft}^2)$$

where

Table 9.6.1 *Lighting Power Density* Allowances Using the Space-by-Space Method and Minimum *Control* Requirements Using Either Method

Informative Note: This table is divided into two sections; this first section covers *space* types that can be commonly found in multiple *building* types. The second part of this table covers *space* types that are typically found in a single *building* type.			The *control* functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1 For each *space* type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.								
			Local *Control* (See Section 9.4.1.1[a])	Restricted to *Manual* ON (See Section 9.4.1.1[b])	Restricted to Partial *Automatic* ON (See Section 9.4.1.1[c])	Bilevel Lighting *Control* (See Section 9.4.1.1[d])	*Automatic* Daylight Responsive *Controls* for Sidelighting (See Section 9.4.1.1[e][6])	*Automatic* Daylight Responsive *Controls* for Toplighting (See Section 9.4.1.1[f][6])	*Automatic* Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	*Automatic* Full OFF (See Section 9.4.1.1[h])	Scheduled Shutoff (See Section 9.4.1.1[i])
Common *Space* Types[1]	*LPD* Allowances, W/ft^2	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Atrium											
<20 ft in height	0.39	NA	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
≥20 ft and ≤40 ft in height	0.48	NA	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
>40 ft in height	0.60	11	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Audience Seating Area											
Auditorium	0.61	6	REQ	ADD1	ADD1	REQ	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	REQ	REQ		ADD2	ADD2
Penitentiary	0.67	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Performing arts theater	1.16	8	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Religious facility	0.72	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Sports arena	0.33	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	0.61	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Breakroom (See Lounge/Breakroom)											
Classroom/Lecture Hall/Training Room											
Penitentiary	0.89	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
All other classrooms/lecture halls/training rooms	0.71	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	

1. In cases where both a common *space* type and a *building* area specific *space* type are listed, the *building* area specific *space* type shall apply
2. In corridors, the extra *lighting power density* allowance is permitted when the width of the corridor is less than 8 ft and is not based on the *RCR*.
3. A “Facility for the Visually Impaired” is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a “Picking Area.”
6. *Automatic* daylight responsive *controls* are mandatory only if the requirements of the specified sections are present.
7. An additional 0.52 W/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.43 W/ft^2. The additional 0.52 W/ft^2 allowance shall not be used for any other purpose.
8. Class of play as defined by IES RP-6.

Table 9.6.1 *Lighting Power Density* Allowances Using the Space-by-Space Method and Minimum *Control* Requirements Using Either Method *(Continued)*

Informative Note: This table is divided into two sections; this first section covers *space* types that can be commonly found in multiple *building* types. The second part of this table covers *space* types that are typically found in a single *building* type.			The *control* functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each *space* type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.								
			Local *Control* (See Section 9.4.1.1[a])	Restricted to *Manual* ON (See Section 9.4.1.1[b])	Restricted to Partial *Automatic* ON (See Section 9.4.1.1[c])	Bilevel Lighting *Control* (See Section 9.4.1.1[d])	*Automatic* Daylight Responsive *Controls* for Sidelighting (See Section 9.4.1.1[e][6])	*Automatic* Daylight Responsive *Controls* for *Toplighting* (See Section 9.4.1.1[f][6])	*Automatic* Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	*Automatic* Full OFF (See Section 9.4.1.1[h])	Scheduled Shutoff (See Section 9.4.1.1[i])
Common *Space* Types[1]	*LPD*, W/ft^2	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Conference/Meeting/Multipurpose Room	0.97	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Confinement Cells	0.70	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Copy/Print Room	0.31	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Corridor[2]											
Facility for the visually impaired (and not used primarily by the staff)[3]	0.71	width <8 ft	REQ				REQ	REQ	REQ	ADD2	ADD2
Hospital	0.71	width <8 ft	REQ				REQ	REQ	ADD2	ADD2	ADD2
All other corridors	0.41	width <8 ft	REQ				REQ	REQ	REQ	ADD2	ADD2
Courtroom	1.20	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Computer Room	0.94	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Dining Area											
Penitentiary	0.42	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Facility for the visually impaired (and not used primarily by staff)[3]	1.27	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Bar/lounge or leisure dining	0.86	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Cafeteria or fast food dining	0.40	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Family dining	0.60	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
All other dining areas	0.43	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2

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2. In corridors, the extra *lighting power density* allowance is permitted when the width of the corridor is less than 8 ft and is not based on the *RCR*.
3. A “Facility for the Visually Impaired” is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a “Picking Area.”
6. *Automatic* daylight responsive *controls* are mandatory only if the requirements of the specified sections are present.
7. An additional 0.52 W/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.43 W/ft^2. The additional 0.52 W/ft^2 allowance shall not be used for any other purpose.
8. Class of play as defined by IES RP-6.

Table 9.6.1 ***Lighting Power Density*** **Allowances Using the Space-by-Space Method and Minimum** ***Control*** **Requirements Using Either Method** ***(Continued)***

Informative Note: This table is divided into two sections; this first section covers *space* types that can be commonly found in multiple *building* types. The second part of this table covers *space* types that are typically found in a single *building* type.			The *control* functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each *space* type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.								
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Common *Space* Types[1]	*LPD*, W/ft^2	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Electrical/Mechanical Room[7]	0.43	6	REQ				REQ	REQ			
Emergency Vehicle Garage	0.52	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Food Preparation Area	1.09	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Guest Room	0.41	6	See Section 9.4.1.3(b).								
Laboratory											
In or as a classroom	1.11	6	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
All other laboratories	1.33	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Laundry/Washing Area	0.53	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Loading Dock, Interior	0.88	6	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Lobby											
Facility for the visually impaired (and not used primarily by the staff)[3]	1.69	4	REQ				REQ	REQ	REQ	ADD2	ADD2
Elevator	0.65	6	REQ				REQ	REQ		ADD2	ADD2
Hotel	0.51	4	REQ				REQ	REQ		ADD2	ADD2
Motion picture theater	0.23	4	REQ				REQ	REQ		ADD2	ADD2
Performing arts theater	1.25	6	REQ				REQ	REQ	REQ	ADD2	ADD2
All other lobbies	0.84	4	REQ				REQ	REQ	REQ	ADD2	ADD2
Locker Room	0.52	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Lounge/Breakroom											
Healthcare facility	0.42	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
All other lounges/breakrooms	0.59	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	

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4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. *Automatic* daylight responsive *controls* are mandatory only if the requirements of the specified sections are present.
7. An additional 0.52 W/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.43 W/ft^2. The additional 0.52 W/ft^2 allowance shall not be used for any other purpose.
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Table 9.6.1 ***Lighting Power Density*** **Allowances Using the Space-by-Space Method and Minimum** ***Control*** **Requirements Using Either Method** ***(Continued)***

Informative Note: This table is divided into two sections; this first section covers *space* types that can be commonly found in multiple *building* types. The second part of this table covers *space* types that are typically found in a single *building* type.			The *control* functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each *space* type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.								
			Local *Control* (See Section 9.4.1.1[a])	Restricted to *Manual* ON (See Section 9.4.1.1[b])	Restricted to Partial *Automatic* ON (See Section 9.4.1.1[c])	Bilevel Lighting *Control* (See Section 9.4.1.1[d])	*Automatic* Daylight Responsive *Controls* for Sidelighting (See Section 9.4.1.1[e][6])	*Automatic* Daylight Responsive *Controls* for *Toplighting* (See Section 9.4.1.1[f][6])	*Automatic* Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	*Automatic* Full OFF (See Section 9.4.1.1[h])	Scheduled Shutoff (See Section 9.4.1.1[i])
Common *Space* Types[1]	*LPD*, W/ft^2	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Office											
Enclosed and ≤250 ft^2	0.74	8	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Enclosed and >250 ft^2	0.66	8	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Open plan	0.61	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Parking Area, Interior	0.15	4	See Section 9.4.1.2.								
Pharmacy Area	1.66	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Restroom											
Facility for the visually impaired (and not used primarily by the staff)[3]	1.26	8					REQ	REQ		REQ	
All other restrooms	0.63	8					REQ	REQ		REQ	
Sales Area[4]	1.05	6	REQ	ADD1	ADD1	REQ		REQ		ADD2	ADD2
Seating Area, General	0.23	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Stairway	The *space* containing the stairway shall determine the *LPD* and *control* requirements for the stairway.										
Stairwell	0.49	10				REQ	REQ	REQ	REQ	ADD2	ADD2
Storage Room											
<50 ft^2	0.51	9	REQ							ADD2	ADD2
≥50 ft^2	0.38	6	REQ	ADD1	ADD1		REQ	REQ		REQ	
Vehicular Maintenance Area	0.60	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Workshop	1.26	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2

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Table 9.6.1 ***Lighting Power Density*** **Allowances Using the Space-by-Space Method and Minimum** ***Control*** **Requirements Using Either Method** ***(Continued)***

			The *control* functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each *space* type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.								
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Building Type Specific/*Space* Types[1]	*LPD* W/ft[2]	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Facility for the Visually Impaired[3]											
Chapel (used primarily by residents)	0.70	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Recreation room/common living room (and not used primarily by staff)	1.77	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Automotive (See "Vehicular Maintenance Area")											
Convention Center—Exhibit *Space*	0.61	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Dormitory—Living Quarters	0.50	8	REQ								
Fire Station—Sleeping Quarters	0.23	6	REQ								
Gymnasium/Fitness Center											
Exercise area	0.90	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Playing area	0.85	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Healthcare Facility											
Exam/treatment room	1.40	8	REQ			REQ	REQ	REQ		ADD2	ADD2
Imaging room	0.94	6	REQ			REQ				ADD2	ADD2
Medical supply room	0.62	6	(See "Storage Room" under "Common *Space* Types" for *control* requirements.)								
Nursery	0.92	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Nurse's station	1.17	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Operating room	2.26	6	REQ			REQ				ADD2	ADD2
Patient room	0.68	6	REQ			REQ	REQ	REQ		ADD2	ADD2

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Building Type Specific/*Space* Types[1]	*LPD* W/ft²	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Physical therapy room	0.91	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Recovery room	1.25	6	REQ			REQ	REQ	REQ		ADD2	ADD2
Library											
Reading area	0.96	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Stacks	1.18	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Manufacturing Facility											
Detailed manufacturing area	0.80	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Equipment room	0.76	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Extra high bay area (>50 ft *floor*-to-ceiling height)	1.42	8	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
High bay area (25 to 50 ft *floor*-to-ceiling height)	1.24	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Low bay area (<25 ft *floor*-to-ceiling height)	0.86	3	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Museum											
General exhibition area	0.31	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Restoration room	1.10	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Performing Arts Theater—Dressing Room	0.41	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Post Office—Sorting Area	0.76	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Religious Facility											
Fellowship hall	0.54	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Worship/pulpit/choir area	0.85	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2

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Building Type Specific/*Space* Types[1]	*LPD* W/ft^2	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Retail Facilities											
Dressing/fitting room	0.51	8	REQ	ADD1	ADD1	REQ		REQ		REQ	
Mall concourse	0.82	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Sports Arena—Playing Area[8]											
Class I facility	2.94	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Class II facility	2.01	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Class III facility	1.30	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Class IV facility	0.86	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Transportation Facility											
Baggage/carousel area	0.39	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Airport concourse	0.25	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Ticket counter	0.51	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Warehouse—Storage Area											
Medium to bulky, palletized items	0.33	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Smaller, hand-carried items[5]	0.69	6	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2

1. In cases where both a common *space* type and a *building* area specific *space* type are listed, the *building* area specific *space* type shall apply
2. In corridors, the extra *lighting power density* allowance is permitted when the width of the corridor is less than 8 ft and is not based on the *RCR*.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. *Automatic* daylight responsive *controls* are mandatory only if the requirements of the specified sections are present.
7. An additional 0.52 W/ft^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.43 W/ft^2. The additional 0.52 W/ft^2 allowance shall not be used for any other purpose.
8. Class of play as defined by IES RP-6.

Table 9.6.3 *Control* Factors Used in Calculating Additional *Interior Lighting Power Allowance*

Additional *Control* Method (in Addition to Mandatory Requirements)	*Space* Type				
	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
Manual, continuous dimming *control* or programmable multilevel dimming *control*	0.05	0.05	0.10	0.10	0
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.

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

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

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

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

Exception to 9.6.2

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*.

9.6.3 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 9.6.3 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 9.6.3 for the corresponding *space* type and *control* method

9.6.4 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 Table 9.6.1.

$$RCR = 2.5 \times \text{Room Cavity Height} \times \text{Room Perimeter Length/Room Area}$$

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 Table 9.6.1.

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 *building* owner or the designated representative of the *building* 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 *building* owner or the designated representative of the *building* owner within 90 days after the date of *system* acceptance. These manuals shall include, at a minimum, the following:

a. Submittal data indicating all selected options for each piece of lighting *equipment*, including but not limited to *lamps*, *ballasts*, *drivers*, and lighting *controls*.
b. Operation and maintenance manuals for each piece of lighting *equipment* and lighting *controls* with routine maintenance clearly identified including, as a minimum, a recommended relamping/cleaning program and a schedule for inspecting and recalibrating all lighting *controls*.
c. A complete narrative of how each lighting *control system* is intended to operate, including recommended settings.

9.7.3.3 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. When *occupancy sensors*, time switches, programmable schedule controls, or *photosensors* are installed, at a minimum, the following procedures shall be performed:

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.
      (a) For each sensor to be tested, verify the following:
         (1) Status indicator (as applicable) operates correctly.
         (2) *Controlled* lights turn off or down to the permitted level within the required time.
         (3) For auto-ON *occupancy sensors*, the lights turn on to the permitted level when someone enters the *space*.
         (4) For *manual*-ON sensors, the lights turn on only when *manually* activated.
         (5) The lights are not incorrectly turned on by movement in nearby areas or by HVAC operation.

b. *Automatic* Time Switches
   1. Confirm that the *automatic* time-switch *control* is programmed with weekday, weekend, and holiday (as applicable) schedules.
   2. Document for the owner *automatic* time-switch programming, including weekday, weekend, and holiday schedules, as well as all setup and preference program settings.
   3. Verify that correct time and date are properly set in the time switch.
   4. Verify that any battery backup (as applicable) is installed and energized.
   5. Verify that the override time limit is set to no more than two (2) hours.
   6. Simulate occupied condition. Verify and document the following:
      (a) All lights can be turned on and off by their respective area *control* switch.
      (b) The switch only operates lighting in the *enclosed space* in which the switch is located.
   7. Simulate unoccupied condition. Verify and document the following:
      (a) All nonexempt lighting turns off.
      (b) *Manual* override switch allows only the lights in the *enclosed space* where the override switch is located to turn on or remain on until the next scheduled shut off occurs.

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.

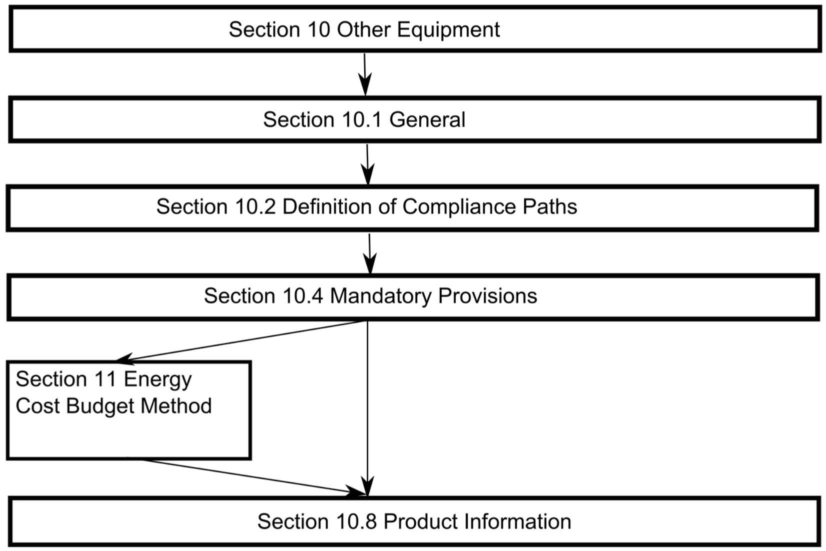
Verification and *FTP* documentation shall comply with Section 4.2.5.1.2.

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 Appendices E and H for commissioning references and guidance.



10 Other Equipment

10.1 General

10.1.1 Scope

This section applies only to the *equipment* described below.

10.1.1.1 New Buildings

Other *equipment* installed in new *buildings* shall comply with the requirements of this section.

10.1.1.2 Additions to Existing Buildings

Other *equipment* installed in additions to *existing buildings* shall comply with the requirements of this section.

10.1.1.3 Alterations to Existing Buildings

10.1.1.3.1

Alterations to other *building service equipment* or *systems* shall comply with the requirements of this section applicable to those specific portions of the *building* and its *systems* that are being altered.

10.1.1.3.2

Any new *equipment* subject to the requirements of this section that is installed in conjunction with the *alterations* as a direct replacement of *existing equipment* or *control devices* shall comply with the specific requirements applicable to that *equipment* or *control devices*.

Exception to 10.1.1.3.2

Compliance shall not be required for the relocation or reuse of *existing equipment*.

10.2 Compliance Paths

Other equipment shall comply with Section 10.2.1 and Section 10.2.2.

10.2.1 Requirements for All Compliance Paths

Other equipment shall comply with Section 10.1, “General”; Section 10.4, “Mandatory Provisions”; and Section 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*.

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 Lighting

For the *luminaires* in each elevator cab, not including signals and displays, the sum of the lumens divided by the sum of the watts (as described in Section 9.1.4) shall be no less than 35 lm/W.

10.4.3.2 Ventilation Power Limitation

Cab *ventilation* fans for elevators without air conditioning shall not consume over 0.33 W/cfm at maximum speed.

10.4.3.3 Standby Mode

When stopped and unoccupied with *doors* closed for over 15 minutes, cab interior lighting and *ventilation* shall be de-energized until required for operation.

10.4.3.4 Design Documents

Design documents shall list the following for new elevators:

a. Usage category as defined in ISO 25745-2 between 1 and 6.
b. *Energy efficiency* classes A through G 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 units shall be tested in accordance with ANSI/AMCA 220 or ISO 27327-1 and installed and commissioned in accordance with the manufacturer's instructions to ensure proper operation and shall have a jet velocity of not less than 6.6 ft/s at 6.0 in. above the floor and direction not less than 20 degrees towards the opening. Automatic controls shall be provided that will operate the air curtain with the opening and closing of the door.

10.4.6 Whole-Building Energy Monitoring

Measurement devices shall be installed at the *building* site to monitor the *energy* use of each new *building*.

10.4.6.1 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

10.4.6.2 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 10.4.6.1 and 10.4.6.2

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*.

10.4.7 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 10.4.7

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” (as amended); MIL-P-18472G, “Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, And Distilling Plant” (as amended).

Informative Note

Informative Appendix E, “Informative References,” 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 (Not Used)

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, and Commissioning

10.9.1 Verification and Testing

Service water pressure-booster *system* controls, elevator standby mode and whole-building *energy* monitoring shall be *commissioned* or verified and tested to verify that *control* elements and monitoring *systems* are configured and operating in accordance with Sections 10.4.2, 10.4.3.3, 10.4.5, and 4.2.5.2. *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.

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]

	Nominal Full-Load *Efficiency*, %							
	2-Pole		4-Pole		6-Pole		8-Pole	
Motor Horsepower, hp (kW)	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1 (0.75)	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5 (1.1)	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2 (1.5)	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3 (2.2)	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5 (3.7)	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5 (5.5)	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10 (7.5)	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15 (11)	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20 (15)	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25 (18.5)	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30 (22)	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40 (30)	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50 (37)	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60 (45)	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75 (55)	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100 (75)	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125 (90)	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150 (110)	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200 (150)	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1
250 (186)	95.8	95.0	96.2	95.8	95.8	95.8	95.0	95.0
300 (224)	95.8	95.4	96.2	95.8	95.8	95.8		
350 (261)	95.8	95.4	96.2	95.8	95.8	95.8		
400 (298)	95.8	95.8	96.2	95.8				
450 (336)	95.8	96.2	96.2	96.2				
500 (373)	95.8	96.2	96.2	96.2				

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 10.8-2 Minimum Nominal Full-Load *Efficiency* for NEMA Design C and *IEC Design H Motors* at 60 Hz[a,b]

Motor Horsepower, hp	Nominal Full-Load *Efficiency*, %					
	4-Pole		6-Pole		8-Pole	
	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.

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
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:

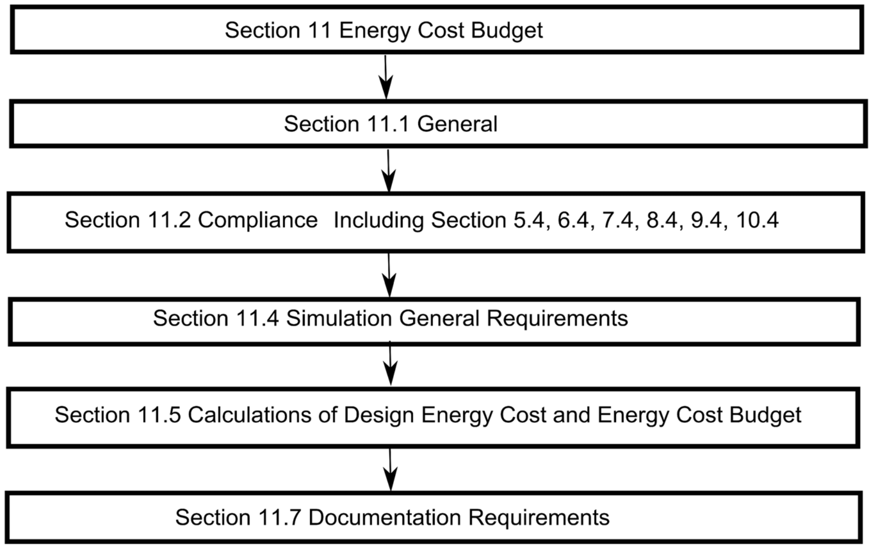
1. A horsepower at or above the midpoint between the two consecutive horsepowers shall be rounded up to the higher of the two horsepowers.
2. A horsepower below the midpoint between the two consecutive horsepowers shall be rounded down to the lower of the two horsepowers.
3. A *kilowatt* rating shall 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}.



11 Energy Cost Budget Method

11.1 General

11.1.1 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*.

11.1.2 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 either 9.5 or 9.6.

11.1.3 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.

11.2 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. A *design energy cost*, as calculated in Section 11.5, that does not exceed the *energy cost budget* as calculated by the *simulation program* described in Section 11.4.

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. Verification, testing, and commissioning requirements of Section 4.2.5 shall be met.

e. Proposed *building systems*, controls, or *building envelope* documented in Section 11.7(b) 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.

11.3 Simplified Option (Not Used)

11.4 Simulation General Requirements

11.4.1 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 11.4.5 shall be used.

Informative Note

ASHRAE Standing Standard Project Committee 90.1 recommends that the *simulation program* implement the rules of Section 11 that control simulation inputs and outputs be adopted for the purposes of easier use and simpler compliance.

11.4.1.1

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*, 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 11.5

11.4.1.2

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.

11.4.1.3

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*.

11.4.1.4

The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program 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 or for missing results.

Informative Note

There are no pass/fail criteria established by this requirement.

11.4.2 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*.

11.4.3 Renewable, Recovered, and Purchased Energy

11.4.3.1 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* shall be no more than 5% of the calculated *energy cost budget*.

11.4.3.2 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 used, 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*.

11.4.4 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*.

11.4.5 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 11.

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:

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.

11.5 Calculation of Design Energy Cost and Energy Cost Budget

11.5.1

The simulation model for calculating the *design energy cost* and the *energy cost budget* shall be developed in accordance with the requirements in Table 11.5.1.

Exception to 11.5.1

Energy used to recharge or refuel vehicles that are used for off-building site transportation purposes shall not be modeled for the *design energy cost* or the *energy cost budget*.

11.5.2 HVAC Systems

The *HVAC system* type and related performance parameters for the *budget building design* shall be determined from Figure 11.5.2, the *system* descriptions in Table 11.5.2-1 and accompanying notes, and the following rules:

a. **Budget *Building Systems* Not Listed.** Components and parameters not listed in Figure 11.5.2 and Table 11.5.2-2 or otherwise specifically addressed in this subsection shall be identical to those in the *proposed design*.

Exception to 11.5.2(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 and 7.4. Chillers shall use Path A efficiencies as shown in Table 6.8.1-3.

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 through 6.8.1-4. Where multiple *HVAC zones* are combined into a single *thermal block* in accordance with Table 11.5.1, the efficiencies for budget System Types 6, 8, and 10 taken from Tables 6.8.1-1 through 6.8.1-4 shall be based on 9000 Btu/h equipment capacity for *residential spaces*; otherwise, it shall be based on the capacity of the *thermal block* divided by the number of *HVAC zones*. Budget System Types 3, 4, 9, and 11 efficiencies taken from Tables 6.8.1-1 through 6.8.1-4 shall be based on the cooling equipment capacity of a single floor when grouping identical floors in accordance with Table 11.5.1. Where a full- and part-load *efficiency* rating is provided in Tables 6.8.1-1 through 6.8.1-4, the full-load equation below shall be used:

$$COP_{nfcooling} = 7.84\text{E-}8 \times EER \times Q + 0.338 \times EER$$

$$COP_{nfcooling} = -0.0076 \times \text{SEER}^2 + 0.3796 \times SEER$$

$$COP_{nfheating} = 1.48\text{E-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$$

(applies to Systems 6 and 9 heating *efficiency* only)

$$COP_{nfheating} = -0.0296 \times \text{HSPF}^2 + 0.7134 \times HSPF$$

$$COP_{nfcooling} = 0.3322 \times EER - 0.2145$$
(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.

EER, *SEER*, *COP*, and *HSPF* shall be at AHRI test conditions. Fan *energy* shall be modeled separately according to Section 11.5.2(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 11.5.2-1.

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 heat recovery shall be modeled for the *budget building design* in accordance with Section 6.5.6.1.

Exception to 11.5.2(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 6.5.3.7, the baseline building design shall be modeled to reflect the minimum amount required by Section 6.5.3.7.

e. **Economizers.** Budget *building systems* as listed in Table 11.5.2-1 shall have *air economizers* or *fluid economizers*, the same as in the *proposed design*, in accordance with Section 6.5.1. The high-limit shutoff shall be in accordance with Table 11.5.2-4.

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.

Exception to 11.5.2(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 (gr/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.

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*. *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 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 11.5.2 at "Water" if the *proposed design system* condenser is water or evaporatively cooled; enter Figure 11.5.2 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 11.5.2 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*.

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

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 11 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 11.5.1, “1. Design Model,” paragraph [a]).
j. The input and output reports from the *simulation program*, including 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). The output reports shall also show the amount of time any loads are not met by the *HVAC system* for both the *proposed design* and *budget building design*.
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 11.4.1.4.

11.7.3 Completion Requirements

Completion requirements shall be in compliance with Section 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)

Table 11.5.1 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 9.6.1. 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 11.4.1.1(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*.	Same as *proposed design*.

Table 11.5.1 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)	
Temperature and Humidity Schedules. Temperature and humidity *control set points* and schedules, as well as *temperature control throttling range*, shall be the same for *proposed design* and *baseline building design*. **HVAC Fan Schedules.** Schedules for HVAC fans that provide *outdoor air* for *ventilation* shall run continuously whenever *spaces* are occupied and shall be cycled ON and OFF to meet heating and cooling loads during unoccupied hours. **Exceptions:** 1. Where no heating and/or cooling *system* is to be installed, and a heating or cooling *system* is being simulated only to meet the requirements described in this table, heating and/or cooling *system* fans shall not be simulated as running continuously during occupied hours but shall be cycled ON and OFF to meet heating and cooling loads during all hours. 2. HVAC fans shall remain on during occupied and unoccupied hours in *spaces* that have health- and safety-mandated minimum *ventilation* requirements during unoccupied hours. 3. Dedicated outdoor air supply fans shall stay off during unoccupied hours. HVAC fans shall remain on during occupied and unoccupied hours in *systems* primarily serving *computer rooms*.	Same as *proposed design*.
5. *Building Envelope*	
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*. **Exceptions:** The following *building* elements are permitted to differ from architectural drawings. 1. Any *building envelope* assembly that covers less than 5% of the total area of that assembly type (e.g., *exterior walls*) need not be separately described. If not separately described, the area of a *building envelope* assembly must be added to the area of the adjacent assembly of that same type. 2. 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. 3. The exterior *roof* surface shall be modeled using the aged solar *reflectance* and thermal *emittance* determined in accordance with Section 5.5.3.1.1(a). Where aged test data are unavailable, the *roof* surface shall be modeled with a solar *reflectance* of 0.30 and a thermal *emittance* of 0.90. 4. 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.	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 5.1.3 for *alterations*. b. The exterior *roof* surfaces shall be modeled with a solar *reflectance* and thermal *emittance* as required in Section 5.5.3.1.1(a). All other *roofs*, including *roofs* exempted from the requirements in Section 5.5.3.1.1, shall be modeled the same as the *proposed design*. c. 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(c). The *VT* shall be equal to that determined in accordance with Section C3.6(c). The *fenestration* model for *building envelope alterations* shall reflect the limitations on area, *U-factor*, and *SHGC* as described in Section 5.1.3.

Table 11.5.1 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)**
5. *Building Envelope* (continued)	
	d. *Skylights* shall be included in each *thermal block* when required by Section 5.5.4.2.3. **Exceptions:** 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.
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, 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 for the applicable *space* type multiplied by 0.25. 2. *Automatic* lighting *controls* listed in Table 9.6.3 shall be modeled using the sum of the applicable control factors (CF). Apply control factors (CF) 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 9.6.3 and Table 9.6.3.	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 Section 9.6.3 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*.
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*. **Exceptions:** 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.	Same as *proposed design*.

Table 11.5.1 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)**
7. *Thermal Blocks—HVAC Zones* Designed (continued)	
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*.
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 11.5.2 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.	The *HVAC system* type and related performance parameters for the *budget building design* shall be determined from Figure 11.5.2, the *system* descriptions in Table 11.5.2-1 and accompanying notes, and in accord with rules specified in Section 11.5.2(a) through 11.5.2(k).

Table 11.5.1 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)**
10. *HVAC Systems* (continued)	
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*.	
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 7.8, 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. 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 *building* shall be modeled, unless specifically excluded by Section 13 of Table 11.5.1, including but not limited to exhaust fans, parking garage *ventilation* fans, exterior *building* lighting, swimming *pool* heaters and pumps, elevators and escalators, and cooking *equipment*.	Same as *proposed design*.

Table 11.5.1 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)**
12. Miscellaneous Loads (continued)	
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.	
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 Sections 1 through 12 of Table 11.5.1. **Exceptions:** 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 either 9.5 or 9.6 applying to the excluded components are met.	None.

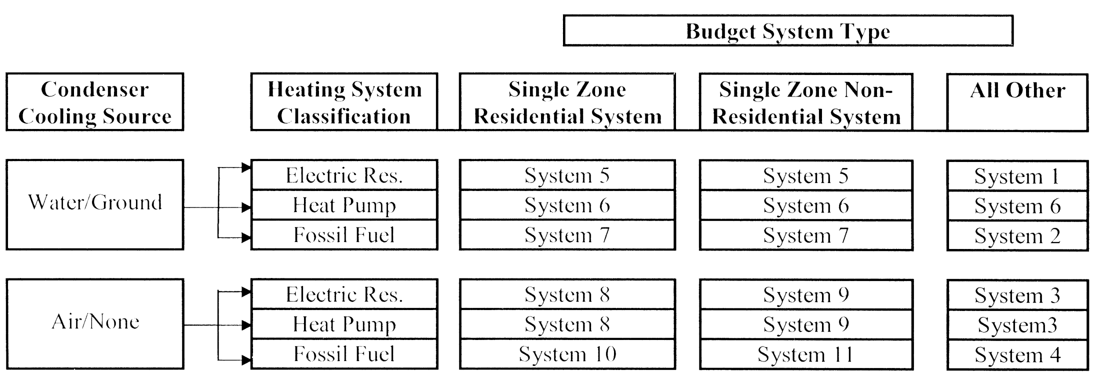


Figure 11.5.2 *HVAC systems* map.

Table 11.5.2-1 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 Exception 1(b) to Section 6.5.2.1. Supply air temperature *set point* shall be constant at the *design condition* (see Section 11.5.2[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 G3.1.3.15. 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 11.4.3. Otherwise, the *budget building design*'s chiller plant shall be modeled with chillers having the number as indicated in Table 11.5.2-2 as a function of *budget building design* chiller plant load and type as indicated in Table 11.5.2-3 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:

$\text{Approach}_{10°F Range} = 25.72 - (0.24 \times WB)$
where WB is the 0.4% *evaporation design wet-bulb temperature* in °F, valid for wet bulbs from 55°F to 90°F.

Except during economizer operation, the tower shall be controlled to maintain a cooling tower leaving water temperature, where weather permits, per Table 11.5.2-5, 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. 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 an 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*.

Table 11.5.2-2 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 11.5.2-3 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 11.5.2-4 Economizer High-Limit Shutoff

Economizer Type	High-Limit Shutoff
Air	Table 6.5.1.1.3
Fluid (integrated)	When its operation will no longer reduce *HVAC system energy*

Table 11.5.2-5 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

12 Normative References

Reference	Title
Air Conditioning, Heating and Refrigeration Institute (AHRI) 2311 Wilson Blvd., Arlington, VA 22201	
AHRI 210/240-2017	Unitary Air Conditioning and Air-Source Heat Pump Equipment (applicable before 1/1/2023)
AHRI 210/240-2023	Unitary Air Conditioning and Air-Source Heat Pump Equipment (applicable on or after 1/1/2023)
AHRI 310/380-2017	Packaged Terminal Air-Conditioners and Heat Pumps
AHRI 340/360-2019	Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
AHRI 365-2009	Commercial and Industrial Unitary Air-Conditioning Condensing Units
ANSI/AHRI 390-2003	Performance Rating of Single Packaged Vertical Air-Conditioners and Heat Pumps
ANSI/AHRI 400-2015	Performance Rating of Liquid-to-Liquid Heat Exchangers
ANSI/AHRI 460-2005	Remote Mechanical Draft Air Cooled Refrigerant Condensers
AHRI 550/590-2018	Performance Rating of Water-Chilling and Heat-Pump Water-Heating Packages Using the Vapor Compression Cycle
AHRI 560-2018	Absorption Water Chilling and Water Heating Packages
ANSI/AHRI Standard 910-2014	Performance Rating of Indoor Pool Dehumidifiers
ANSI/AHRI Standard 920-2015	Performance Rating of DX-Dedicated Outdoor Air System Units
ANSI/AHRI 1160-2014	Performance Rating of Heat Pump Pool Heaters
ANSI/AHRI 1200-2013	Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets
ANSI/AHRI 1230-2014 with Addendum 1	Performance Rating of Variable Refrigerant Flow (VRF) Multi-split Air-Conditioning and Heat Pump Equipment
AHRI Standard 1250-2014	Performance Rating of Walk-In Coolers and Freezers
AHRI Standard 1360-2017	Performance Rating of Computer and Data Processing Room Air Conditioners
BTS 2000 rEV 06.07	Testing Standard Method to Determine Efficiency of Commercial Space Heating Boilers
Air Movement and Control Association International (AMCA) 30 West University Drive, Arlington Heights, IL 60004-1806	
ANSI/AMCA 208-18	Calculation of the Fan Energy Index
ANSI/AMCA Standard 230-15	Laboratory Methods of Testing Air Circulating Fans for Rating and Certification
ANSI/AMCA Standard 500-D-18	Laboratory Methods of Testing Dampers for Rating
American Architectural Manufacturers Association (AAMA) 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

Reference	Title
American National Standards Institute (ANSI) 1899 L Street, NW, 11th Floor, Washington, DC 20036	
ANSI Z21.10.3-2017/CSA 4.3-2017	Gas-Fired Water Heaters, Volume III, Storage Water Heaters with Input Ratings Above 75,000 Btu Per Hour, Circulating and Instantaneous
ANSI Z21.47-2016/CSA 2.3-2016	Gas-Fired Central Furnaces
ANSI Z83.8-2016/CSA 2.6-2016	Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters And Gas-Fired Duct Furnaces
American Society of Mechanical Engineers (ASME) Two Park Avenue, New York, NY 10016-5990	
ASME A17.1-2016/CSA B44-16	Safety Code for Elevators and Escalators
ASHRAE 1791 Tullie Circle, NE, Atlanta, GA 30329	
ANSI/ASHRAE Standard 55-2017	Thermal Environmental Conditions for Human Occupancy
ANSI/ASHRAE Standard 62.1-2016 (with Addenda b, c, d, e, f, g, h, j, k, o, q, r, u, v, w, z)	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE/IESNA Standard 90.1-2007	Energy Standard for Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE/IESNA Standard 90.1-2010	Energy Standard for Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE/IESNA Standard 90.1-2013	Energy Standard for Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE Standard 127-2012	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners
ANSI/ASHRAE Standard 140-2017	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
ANSI/ASHRAE Standard 154-2016	Ventilation for Commercial Cooking Operations
ANSI/ASHRAE Standard 169-2013	Climatic Data for Building Design Standards
ANSI/ASHRAE/ASHE Standard 170-2017	Ventilation of Health Care Facilities
ANSI/ASHRAE/ACCA Standard 183-2007 (RA 2017)	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings
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
ANSI/AHAM RAC-1-R2015	Room Air Conditioners
ASTM International 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959	
ASTM C90-16A	Standard Specification for Loadbearing Concrete Masonry Units
ASTM C177-13	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM C272/C272M-18	Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions
ASTM C518-17	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus
ASTM C835-06 (2013) e1	Standard Test Method for Total Hemispherical Emittance of Surfaces up to 1400°C
ASTM C1224-15	Standard Specification for Reflective Insulation for Building Applications

Reference	Title
ASTM C1363-11	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM D1003-13	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
ASTM E283-04 (2012)	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
ASTM E779-2018	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
ASTM E972-96 (2013)	Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight
ASTM E1677-11	Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls
ASTM E1680-16	Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems
ASTM E1827-2017	Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
ASTM E1980-11	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low Sloped Opaque Surfaces
ASTM E2178-13	Standard Test Method for Air Permeance of Building Materials
ASTM E2357-18	Standard Test Method for Determining Air Leakage of Air Barrier Assemblies
Cool Roof Rating Council (CRRC) 2435 N. Lombard St. Portland, OR 97217 United States	
ANSI/CRRC S100-2016	Standard Test Methods for Determining Radiative Properties of Materials
Cooling Technology Institute (CTI) 3845 Cypress Creek Parkway, Suite 420, Houston, TX 77068; P.O. Box 681807	
CTI ATC-105 (19)	Acceptance Test Code for Water Cooling Towers
CTI ATC-105DS (18)	Acceptance Test Code for Dry Fluid Coolers
CTI ATC-105S (11)	Acceptance Test Code for Closed-Circuit Cooling Towers
CTI ATC-106 (11)	Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers
CTI STD-201 RS (17)	Performance Rating of Evaporative Heat Rejection Equipment
Door and Access Systems Manufacturers Association (DASMA) 1300 Sumner Avenue, Cleveland, OH 44115-2851	
ANSI/DASMA 105-2017	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors
Illuminating Engineering Society (IES) 120 Wall street, Floor 17, New York, NY 10005-4001	
ANSI/IES RP-28-2016	Lighting and the Visual Environment for Senior Living
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
ANSI/AHRI/ASHRAE/ISO 13256-1:1998 (R2015)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps
ANSI/AHRI/ASHRAE/ISO 13256-2:1998 (R2015)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 2: Water-to-Water and Brine-to-Water Heat Pumps

Reference	Title
ISO 25745-2:2015	Energy Performance of Lifts, Escalators and Moving Walks—Part 2: Energy Calculation and Classification for Lifts (Elevators)
National Electrical Manufacturers Association (NEMA) 1300 N. 17th Street, Suite 900, Arlington, VA 22209	
ANSI/NEMA MG 1-2016	Motors and Generators
National Fenestration Rating Council (NFRC) 6305 Ivy Lane, Suite 140, Greenbelt, MD 20770-6323	
ANSI/NFRC 100-2017	Procedure for Determining Fenestration Product U-Factors
ANSI/NFRC 200-2017	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence
NFRC 203-2017	Procedure for Determining Visible Transmittance of Tubular Daylighting Devices
NFRC 300-2017	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems
NFRC 301-2017	Test Method for Emittance of Specular Surfaces Using Spectrometric Measurements
ANSI/NFRC 400-2017	Procedure for Determining Fenestration Product Air Leakage
National Fire Protection Association (NFPA) 1 Battery March Park, P.O. Box 9101, Quincy, MA 02269-9101	
NFPA 70-2014	National Electric Code
NFPA 96-2017	Ventilation Control and Fire Protection of Commercial Cooking Operations
Telecommunications Industry Association (TIA) 1320 North Courthouse Road, Suite 200	
ANSI/TIA-942-REV A, July 12, 2017	Telecommunication Infrastructure Standard for Data Centers
Underwriters Laboratories, Inc. (UL) 333 Pfingsten Rd., Northbrook, IL 60062	
UL 181A-2013	Closure Systems for Use with Rigid Air Ducts and Air Connectors
UL 181B-2013	Closure Systems for Use with Flexible Air Ducts and Air Connectors
UL 727-2018	UL Standard for Safety—Oil Fired Central Furnaces
UL 731-2018	UL Standard for Safety—Oil-Fired Unit Heaters
U.S. Department of Defense 3010 Defense Pentagon, Washington, DC 20301	
MIL-P-17639F (1996)	Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use
MIL-P-17840C (1986)	Pumps, Centrifugal, Close-Coupled, Navy Standard (For Surface Ship Application)
MIL-P-17881D (1972)	Pumps, Centrifugal, Boiler Feed (Multi-Stage)
MIL-P-18472 (1989)	Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, and Distilling Plant
MIL-P-18682D	Pump, Centrifugal, Main Condenser Circulating, Naval Shipboard
U.S. Department of Energy (DOE) 1000 Independence Avenue, SW, Washington, DC 20585	
10 CFR Part 430, App N	Uniform Test Method for Measuring the Energy Consumption of Furnaces
10 CFR Part 431.304	Uniform Test Method for the Measurement of Energy Consumption of Walk-In Coolers and Walk-In Freezers

Reference	Title
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
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
U.S. Nuclear Regulatory Commission One White Flint North 11555 Rockville Pike Rockville, MD 20852-2738	
10 CFR Part 50	Domestic Licensing of Production and Utilization Facilities

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

A1.1 Precalculated Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities

The *U-factors*, *C-factors*, *F-factors*, and *heat capacities* for typical *construction* assemblies are included in Sections A2 through A8. These values shall be used for all calculations unless otherwise allowed by Section A1.2. Interpolation between values in a particular table in Normative Appendix A is allowed for rated *R-values* of insulation, including insulated sheathing. Extrapolation beyond values in a table in Normative Appendix A is not allowed.

A1.2 Applicant-Determined Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities

If the *building official* determines that the proposed *construction* assembly is not adequately represented in Sections A2 through A8, the applicant shall determine appropriate values for the assembly using the assumptions in Section A9. An assembly is deemed to be adequately represented if

a. the interior structure, hereafter referred to as the base assembly, for the *class of construction* is the same as described in Sections A2 through A8 and
b. changes in exterior or interior surface *building materials* added to the base assembly do not increase or decrease the *R-value* by more than 2 from that indicated in the descriptions in Sections A2 through A8.

Insulation, including insulated sheathing, is not considered a *building material*.

A2 ROOFS

A2.1 General

The buffering effect of suspended ceilings or attic *spaces* shall not be included in *U-factor* calculations.

A2.2 Roofs with Insulation Entirely Above Deck

A2.2.1 General

For the purpose of Section A1.2, the base assembly is *continuous insulation* over a structural deck. The *U-factor* includes R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. Added insulation is continuous and uninterrupted by framing. The framing factor is zero.

A2.2.2 Rated R-Value of Insulation

For *roofs with insulation entirely above deck*, the *rated R-value of insulation* is for *continuous insulation*.

Exception 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 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 A2.2.3 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 A2.2.3 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*.

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

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.

Table A2.4.2 *Single-Rafter Roofs*

Climate Zone	Minimum Insulation *R-Value* or Maximum Assembly *U-Factor*		
	Wood Rafter Depth, *d* (Actual)		
	$d \leq 8$ in.	$8 < d \leq 10$ in.	$10 < d \leq 12$ in.
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

Table A2.5.2 Assembly *U-Factors* for Attic *Roofs* with *Steel Joists* (4.0 ft on Center)

Rated *R-Value* of Insulation Alone	Overall *U-Factor* for Entire Assembly
R-0	U-1.282
R-4	U-0.215
R-5	U-0.179
R-8	U-0.120
R-10	U-0.100
R-11	U-0.093
R-12	U-0.086
R-13	U-0.080
R-15	U-0.072
R-16	U-0.068
R-19	U-0.058
R-20	U-0.056
R-21	U-0.054
R-24	U-0.049
R-25	U-0.048
R-30	U-0.041
R-35	U-0.037
R-38	U-0.035
R-40	U-0.033
R-45	U-0.031
R-50	U-0.028
R-55	U-0.027

A3 ABOVE-GRADE WALLS

A3.1 Mass Wall

A3.1.1 General

For the purpose of Section A1.2, the base assembly is a masonry or concrete *wall*. *Continuous insulation* is installed on the interior or exterior or within the masonry units, or it is installed on the interior or exterior of the concrete. The brick cavity *wall* has *continuous insulation* between the brick and the concrete or masonry. The *U-factors* include R-0.17 for exterior air film and R-0.68 for interior air film, vertical surfaces. For insulated *walls*, the *U-factor* also includes R-0.45 for 0.5 in. gypsum board. For the cavity *wall*, the *U-factor* includes R-0.74 for brick. *U-factors* are provided for the following configurations:

a. Concrete *wall*: 8 in. normal weight concrete *wall* with a density of 145 lb/ft^3.
b. Solid grouted concrete block *wall*: 8 in. medium weight ASTM C90 concrete block with a density of 115 lb/ft^3 and solid grouted cores.
c. Partially grouted concrete block *wall*: 8 in. medium weight ASTM C90 concrete block with a density of 115 lb/ft^3 having reinforcing steel every 32 in. vertically and every 48 in. horizontally, with cores grouted in those areas only. Other cores are filled with insulating material only if there is no other insulation.

A3.1.2 Mass Wall Rated R-Value of Insulation

A3.1.2.1

Mass wall HC shall be determined from Table A3.1-2 or A3.1-3.

A3.1.2.2

The *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing other than 20 gage 1 in. metal clips spaced no closer than 24 in. on center horizontally and 16 in. on center vertically.

A3.1.2.3

Where other framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly *U-factor*.

A3.1.2.4

Where *rated R-value of insulation* is used for concrete sandwich panels, the insulation shall be continuous throughout the entire panel.

A3.1.3 Mass Wall U-Factor

A3.1.3.1

U-factors for *mass walls* shall be taken from Table A3.1-1 or determined by the procedure in this subsection. It is acceptable to use the *U-factors* in Table A3.1-1 for all *mass walls*, provided that the grouting is equal to or less than that specified. *HC* for *mass walls* shall be taken from Table A3.1-2 or A3.1-3.

A3.1.3.2 Determination of Mass Wall U-Factors

If not taken from Table A3.1-1, *mass wall U-factors* shall be determined from Tables A3.1-2, A3.1-3, or A3.1-4 using the following procedure:

a. If the *mass wall* is uninsulated or only the cells are insulated:
   1. For concrete *walls*, determine the *U-factor* from Table A3.1-2 based on the concrete density and *wall* thickness.
   2. For concrete block *walls*, determine the *U-factor* from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.
b. If the *mass wall* has additional insulation:
   1. For concrete *walls*, determine the R_u from Table A3.1-2 based on the concrete density and *wall* thickness. Next, determine the effective *R-value* for the insulation/framing layer from Table A3.1-4 based on the *rated R-value of*

insulation installed, the thickness of the insulation, and whether it is installed between wood or *metal framing* or with no framing. Then, determine the *U-factor* by adding the R_u and the effective *R-value* together and taking the inverse of the total.

2. For concrete block *walls*, determine the R_u from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated. Next, determine the effective *R-value* for the insulation/framing layer from Table A3.1-4 based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or *metal framing* or with no framing. Then, determine the *U-factor* by adding the R_u and the effective *R-value* together and taking the inverse of the total.

A3.2 Metal Building Walls

A3.2.1 General

For the purpose of Section A1.2, the base assembly is a *wall* 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.

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 steel stud framing but where there is not a metal exterior surface-spanning member. The steel stud framing is a minimum uncoated thickness of 0.043 in. for 18 gage or 0.054 in. for 16 gage. The *U-factors* include R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625 in. gypsum board on the exterior, R-0.56 for 0.625 in. gypsum board on the interior, and R-0.68 for interior vertical surfaces air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2-2. Additional assemblies include *continuous insulation* uncompressed and uninterrupted by framing. *U-factors* are provided for the following configurations:

a. Standard framing: Steel stud framing at 16 in. on center with cavities filled with 16 in. wide insulation for both 3.5 in. deep and 6.0 in. deep *wall* cavities.

b. Advanced framing: Steel stud framing at 24 in. on center with cavities filled with 24 in. wide insulation for both 3.5 in.deep and 6.0 in. deep *wall* cavities.

A3.3.2 Rated R-Value of Insulation for Steel-Framed Walls

A3.3.2.1

The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between steel studs. It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing.

A3.3.2.2

If there are two values, the second *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.3.2.3

Opaque mullions in spandrel glass shall be covered with insulation complying with the *steel-framed wall* requirements.

A3.3.3 U-Factors for Steel-Framed Walls

A3.3.3.1

U-factors for *steel-framed walls* shall be taken from Table A3.3.3.1.

A3.3.3.2

For *steel-framed walls* with framing at less than 24 in. on center, use the standard framing values as described in Section A3.3.1(a).

A3.3.3.3

For *steel-framed walls* with framing from 24 to 32 in. on center, use the advanced framing values as described in Section A3.3.1(b).

A3.3.3.4

For *steel-framed walls* with framing greater than 32 in. on center, use the *metal building wall* values in Table A3.2.3.

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.

b. Advanced framing: Wood framing at 24 in. on center with cavities filled with 22.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep *wall* cavities. Double headers leave uninsulated cavities. Weighting factors are 78% insulated cavity, 18% studs, plates, and sills, and 4% headers.

c. Advanced framing with insulated headers: Wood framing at 24 in. on center with cavities filled with 22.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep *wall* cavities. Double header cavities are insulated. Weighting factors are 78% insulated cavity, 18% studs, plates, and sills, and 4% headers.

A3.4.2 Rated R-value of Insulation for Wood-Framed and Other Walls

A3.4.2.1

The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between wood studs. It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing.

A3.4.2.2

If there are two values, the second *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.4.3 U-Factors for Wood-Framed Walls

A3.4.3.1

U-factors for wood-framed *walls* shall be taken from Table A3.4.3.1.

A3.4.3.2

For wood-framed *walls* with framing at less than 24 in. on center, use the standard framing values as described in Section A3.4.1(a).

A3.4.3.3

For wood-framed *walls* with framing from 24 to 32 in. on center, use the advanced framing values as described in Section A3.4.1(b) if the headers are uninsulated, or the advanced framing with insulated header values as described in Section A3.4.1(c) if the headers are insulated.

A3.4.3.4

For wood-framed *walls* with framing greater than 32 in. on center, *U-factors* shall be determined in accordance with Section A9.

Table A3.1-1 Assembly *U-Factors* for Above-*Grade* Concrete *Walls* and Masonry *Walls*

Framing Type and Depth	Rated *R-Value* of Insulation Alone	Assembly *U-Factors* for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete *Walls*	Assembly *U-Factors* for 8 in. Medium Weight 115 lb/ft^3 Concrete Block *Walls*: Solid Grouted	Assembly *U-Factors* for 8 in. Medium Weight 115 lb/ft^3 Concrete Block *Walls*: Partially Grouted (Cores Uninsulated Except 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

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
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

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
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

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
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

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
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

The *U-factors* and R_u include standard air film resistances.
The *C-factors* and R_c are for the same assembly without air film resistances.
Note that the following assemblies do not qualify as a *mass wall* or *mass floor*: 3 in. thick concrete with densities of 85, 95, 125, and 135 lb/ft^3.

Table A3.1-2 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
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.

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

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

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

Table A3.1-4 Effective *R-Values* for Insulation/Framing Layers Added to Above-*Grade Mass Walls* and *Below-Grade Walls*

Depth, in.	Framing Type	*Rated R-Value of Insulation*																									
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Effective *R-value* if *Continuous Insulation* Uninterrupted by Framing (Includes Gypsum Board)																											
	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5
Effective *R-value* if Insulation is Installed in Cavity between Framing (Includes Gypsum Board)																											
0.5	Wood	1.3	1.3	1.9	2.4	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.9	0.9	1.1	1.1	1.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0.75	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.0	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.5	Wood	1.3	1.5	2.4	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.5	6.8	7.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.1	1.2	1.6	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.0	Wood	1.4	1.5	2.5	3.3	4.0	4.7	5.3	5.9	6.4	6.9	7.3	7.7	8.1	8.4	8.7	9.0	9.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	1.1	1.2	1.7	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.3	3.4	3.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.5	Wood	1.4	1.5	2.5	3.4	4.2	4.9	5.6	6.3	6.8	7.4	7.9	8.4	8.8	9.2	9.6	10.0	10.3	10.6	10.9	11.2	11.5	NA	NA	NA	NA	NA
	Metal	1.2	1.3	1.8	2.3	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	NA	NA	NA	NA	NA
3.0	Wood	1.4	1.5	2.5	3.5	4.3	5.1	5.8	6.5	7.2	7.8	8.3	8.9	9.4	9.9	10.3	10.7	11.1	11.5	11.9	12.2	12.5	12.9	NA	NA	NA	NA
	Metal	1.2	1.3	1.9	2.4	2.8	3.1	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8	NA	NA	NA	NA
3.5	Wood	1.4	1.5	2.6	3.5	4.4	5.2	6.0	6.7	7.4	8.1	8.7	9.3	9.8	10.4	10.9	11.3	11.8	12.2	12.6	13.0	13.4	13.8	14.1	14.5	14.8	15.1
	Metal	1.2	1.3	2.0	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.2	5.3	5.4	5.4	5.4	5.5
4.0	Wood	1.4	1.6	2.6	3.6	4.5	5.3	6.1	6.9	7.6	8.3	9.0	9.6	10.2	10.8	11.3	11.9	12.4	12.8	13.3	13.7	14.2	14.6	14.9	15.3	15.7	16.0
	Metal	1.2	1.3	2.0	2.6	3.0	3.4	3.7	4.0	4.2	4.5	4.6	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8	5.9	5.9	6.0	6.0
4.5	Wood	1.4	1.6	2.6	3.6	4.5	5.4	6.2	7.1	7.8	8.5	9.2	9.9	10.5	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.2	15.7	16.1	16.5	16.9
	Metal	1.2	1.3	2.1	2.6	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.4	6.5	6.6
5.0	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.3	7.2	8.0	8.7	9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.3	15.8	16.3	16.7	17.2	17.6
	Metal	1.2	1.4	2.1	2.7	3.2	3.7	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.7	6.8	6.8	6.9	7.0	7.1
5.5	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.4	7.3	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.7	15.3	15.8	16.3	16.8	17.3	17.8	18.2
	Metal	1.3	1.4	2.1	2.8	3.3	3.8	4.2	4.6	4.9	5.2	5.4	5.7	5.9	6.1	6.3	6.4	6.6	6.7	6.8	7.0	7.1	7.2	7.3	7.4	7.5	7.6

Table A3.2.3 Assembly *U-Factors* for *Metal Building Walls*

Insulation *System*	Rated *R-Value* of Insulation	Overall *U-Factor* for Entire Base *Wall* Assembly	Overall *U-Factor* for Assembly of Base *Wall* Plus *Continuous Insulation* (Uninterrupted by Framing)								
			R-6.5	R-9.8	R-13	R-15.8	R-19	R-22.1	R-25	R-32	R-38
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.

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

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

A4 BELOW-GRADE WALLS

A4.1 General

For the purpose of Section A1.2, the base assembly is 8 in. medium-weight concrete block with a density of 115 lb/ft^3 and solid grouted cores. *Continuous insulation* is installed on the interior or exterior. In contrast to the *U-factor* for *above-grade walls*, the *C-factor* for *below-grade walls* does not include *R-values* for exterior or interior air films or for soil. For insulated *walls*, the *C-factor* does include R-0.45 for 0.5 in. gypsum board.

A4.2 C-Factors for Below-Grade Walls

A4.2.1

C-factors for *below-grade walls* shall be taken from Table A4.2.1 or determined by the procedure described in this subsection.

A4.2.2

It is acceptable to use the *C-factors* in Table A4.2.1 for all *below-grade walls*.

A4.2.3

If not taken from Table A4.2.1, *below-grade wall C-factors* shall be determined from Tables A3.1-2, A3.1-3, or A3.1-4 using the following procedure:

a. If the *below-grade wall* is uninsulated or only the cells are insulated:
   1. For concrete *walls*, determine the *C-factor* from Table A3.1-2 based on the concrete density and *wall* thickness.
   2. For concrete block *walls*, determine the *C-factor* from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.

b. If the *mass wall* has additional insulation:
   1. For concrete *walls*, determine the R_c from Table A3.1-2 based on the concrete density and *wall* thickness. Next, determine the effective *R-value* for the insulation/framing layer from Table A3.1-4 based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or *metal framing* or with no framing. Then determine the *C-factor* by adding the R_c and the effective *R-value* together and taking the inverse of the total.
   2. For concrete block *walls*, determine the R_c from Table A3.1-3 based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated. Next, determine the effective *R-value* for the insulation/framing layer from Table A3.1-4 based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or *metal framing* or with no framing. Then determine the *C-factor* by adding the R_c and the effective *R-value* together and taking the inverse of the total.

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 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

A5.4.2.1

The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between wood joists.

A5.4.2.2

It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing. All *continuous insulation* shall be installed either on the interior above the *floor* structure or below a framing cavity completely filled with insulation.

A5.4.3 U-Factors for Wood-Framed Floors

A5.4.3.1

The *U-factors* for wood-framed *floors* shall be taken from Table A5.4.3.1.

A5.4.3.2

It is not acceptable to use these *U-factors* if the framing is not wood.

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 climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10 in. thick.

A6.3 F-Factors for Slab-on-Grade Floors

A6.3.1

F-factors for *slab-on-grade floors* shall be taken from Table A6.3.1-1 or A6.3.1-2.

A6.3.2

These *F-factors* are acceptable for all *slab-on-grade floors*.

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

Table A5.2.3.1 Assembly *U-Factors* for *Mass Floors*

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation *R-Value*: Rated (Effective Installed)	Overall *U-Factor* for Entire Base *Floor* Assembly	Overall *U-Factor* for Assembly of Base *Floor* Plus *Continuous Insulation* (Uninterrupted by Framing)																			
			Rated *R-Value* of *Continuous Insulation*																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Concrete *Floor* with Rigid Foam																						
	None (0.0)	0.322	0.243	0.196	0.164	0.141	0.123	0.110	0.099	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.043	0.036	0.030	0.026	0.023
Concrete *Floor* with Pinned Boards																						
	R-4.2 (4.2)	0.137	0.121	0.108	0.097	0.089	0.081	0.075	0.070	0.065	0.061	0.058	0.055	0.052	0.049	0.047	0.045	0.037	0.031	0.027	0.024	0.021
	R-6.3 (6.3)	0.107	0.096	0.088	0.081	0.075	0.070	0.065	0.061	0.058	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.023	0.020
	R-8.3 (8.3)	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.032	0.027	0.024	0.022	0.019
	R-10.4(10.4)	0.074	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.021	0.019
	R-12.5 (12.5)	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.028	0.025	0.022	0.020	0.018
	R-14.6 (14.6)	0.056	0.053	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.033	0.032	0.031	0.027	0.023	0.021	0.019	0.017
	R-16.7 (16.7)	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.032	0.031	0.030	0.030	0.029	0.025	0.022	0.020	0.018	0.017
Concrete *Floor* with Spray-On Insulation																						
1 in.	R-4 (4.0)	0.141	0.123	0.110	0.099	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.037	0.031	0.027	0.024	0.021
2 in.	R-8 (8.0)	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.032	0.028	0.024	0.022	0.020
3 in.	R-12 (12.0)	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.028	0.025	0.022	0.020	0.018
4 in.	R-16 (16.0)	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.026	0.023	0.020	0.018	0.017
5 in.	R-20 (20.0)	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.023	0.021	0.019	0.017	0.016
6 in.	R-24 (24.0)	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.021	0.019	0.018	0.016	0.015

Table A5.3.3.1 Assembly *U-Factors* for *Steel-Joist Floors*

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation *R-Value*: Rated (Effective Installed [See Table A9.2-1])	Overall *U-Factor* for Entire Base *Floor* Assembly	Overall *U-Factor* for Assembly of Base *Floor* Plus *Continuous Insulation* (Uninterrupted by Framing)																			
			Rated *R-Value* of *Continuous Insulation*																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Steel-Joist Floor with Rigid Foam																						
	None (0.0)	0.350	0.259	0.206	0.171	0.146	0.127	0.113	0.101	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
Steel-Joist Floor with Spray-on Insulation																						
1 in.	R-4 (3.88)	0.148	0.129	0.114	0.103	0.093	0.085	0.078	0.073	0.068	0.064	0.060	0.056	0.053	0.051	0.048	0.046	0.037	0.032	0.027	0.024	0.021
2 in.	R-8 (7.52)	0.096	0.088	0.081	0.075	0.070	0.065	0.061	0.058	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.033	0.028	0.025	0.022	0.020
3 in.	R-12 (10.80)	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.021	0.019
4 in.	R-16 (13.92)	0.060	0.056	0.053	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.032	0.031	0.027	0.024	0.021	0.019	0.018
5 in.	R-20 (17.00)	0.050	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.030	0.029	0.025	0.022	0.020	0.018	0.017
6 in.	R-24 (19.68)	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.024	0.021	0.019	0.017	0.016
Steel-Joist Floor with Batt Insulation																						
	None (0.0)	0.350	0.259	0.206	0.171	0.146	0.127	0.113	0.101	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (10.01)	0.078	0.072	0.067	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.030	0.026	0.023	0.021	0.019
	R-13 (11.70)	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.029	0.025	0.022	0.020	0.018
	R-15 (13.20)	0.062	0.059	0.055	0.052	0.050	0.047	0.045	0.043	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.028	0.024	0.022	0.020	0.018
	R-19 (16.34)	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.026	0.023	0.020	0.018	0.017
	R-21 (17.64)	0.049	0.047	0.044	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.025	0.022	0.020	0.018	0.017
	R-25 (20.25)	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.023	0.021	0.019	0.017	0.016
	R-30C (23.70)	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.025	0.024	0.021	0.019	0.018	0.016	0.015
	R-30 (23.70)	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.025	0.024	0.021	0.019	0.018	0.016	0.015
	R-38C (28.12)	0.032	0.031	0.030	0.029	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014
	R-38 (28.12)	0.032	0.031	0.030	0.029	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014

Table A5.4.3.1 Assembly *U-Factors* for Wood-Joist *Floors*

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation *R-Value*: Rated (Effective Installed)	Overall *U-Factor* for Entire Base *Floor* Assembly	Overall *U-Factor* for Assembly of Base *Floor* Plus *Continuous Insulation* (Uninterrupted by Framing)																			
			Rated *R-Value* of *Continuous Insulation*																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Wood-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

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

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: 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: 0.70.
d. Insulated metal *swinging doors*, including fire-rated *doors*, insulated *access hatches*, insulated smoke vents, and other insulated metal *nonswinging doors*: 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*: 0.50.
f. Any other wood *door*: 0.60.

A8 FENESTRATION

All *fenestration* with *U-factors*, *SHGC*, or *visible transmittance* determined, certified, and *labeled* in accordance with NFRC 100, 200, and 300, respectively, shall be assigned those values.

A8.1 Unlabeled Skylights

Unlabeled *skylights* shall be assigned the *U-factors* in Table A8.1-1 and are allowed to use the *SHGCs* and *VTs* in Table A8.1-2. The metal with thermal break frame category shall not be used unless all frame members have a thermal break equal to or greater than 0.25 in.

A8.2 Unlabeled Vertical Fenestration

Unlabeled *vertical fenestration*, both operable and fixed, shall be assigned the *U-factors*, *SHGCs*, and *VTs* in Table A8.2.

Table A8.1-1 Assembly *U-Factors* for Unlabeled *Skylights*

Product Type		Sloped Installation						
		Unlabeled *Skylight* with Curb (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)				Unlabeled *Skylight* without Curb (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type							
	Single Glazing							
1	1/8 in. glass	1.98	1.89	1.75	1.47	1.36	1.25	1.25
2	1/4 in. acrylic/ polycarb	1.82	1.73	1.60	1.31	1.21	1.10	1.10
3	1/8 in. acrylic/ polycarb	1.90	1.81	1.68	1.39	1.29	1.18	1.18
	Double Glazing							
4	1/4 in. 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

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

Table A8.1-2 Assembly *SHGCs* and Assembly Visible Transmittances (*VTs*) for Unlabeled *Skylights*

Glass Type	Glazing Type: Number of Glazing Layers Number and Emissivity of Coatings (Glazing is Glass Except where Noted)	Unlabeled *Skylights* (Includes Glass/Plastic, Flat/Domed, Fixed/Operable)						
		Frame:	Metal without Thermal Break		Metal with Thermal Break		Wood/Vinyl/ Fiberglass	
		Characteristic:	*SHGC*	*VT*	*SHGC*	*VT*	*SHGC*	*VT*
Clear	Single glazing, 1/8 in. glass		0.82	0.76	0.78	0.76	0.73	0.73
	Single glazing, 1/4 in. glass		0.78	0.75	0.74	0.75	0.69	0.72
	Single glazing, acrylic/polycarbonate		0.83	0.92	0.83	0.92	0.83	0.92
	Double glazing		0.68	0.66	0.64	0.66	0.59	0.64
	Double glazing, *e* = 0.40 on surface 2 or 3		0.71	0.65	0.67	0.65	0.62	0.63
	Double glazing, *e* = 0.20 on surface 2 or 3		0.66	0.61	0.62	0.61	0.57	0.59
	Double glazing, *e* = 0.10 on surface 2 or 3		0.59	0.63	0.55	0.63	0.51	0.61
	Double glazing, acrylic/polycarbonate		0.77	0.89	0.77	0.89	0.77	0.89
	Triple glazing		0.60	0.59	0.56	0.59	0.52	0.57
	Triple glazing, *e* = 0.40 on surface 2, 3, 4, or 5		0.64	0.60	0.60	0.60	0.56	0.57
	Triple glazing, *e* = 0.20 on surface 2, 3, 4, or 5		0.59	0.55	0.55	0.55	0.51	0.53
	Triple glazing, *e* = 0.10 on surface 2, 3, 4, or 5		0.54	0.56	0.50	0.56	0.46	0.54
	Triple glazing, *e* = 0.40 on surfaces 3 and 5		0.62	0.57	0.58	0.57	0.53	0.55
	Triple glazing, *e* = 0.20 on surfaces 3 and 5		0.56	0.51	0.52	0.51	0.48	0.49
	Triple glazing, *e* = 0.10 on surfaces 3 and 5		0.47	0.54	0.43	0.54	0.40	0.52
	Triple glazing, acrylic/polycarbonate		0.71	0.85	0.71	0.85	0.71	0.85
	Quadruple glazing, *e* = 0.10 on surfaces 3 and 5		0.41	0.48	0.37	0.48	0.33	0.46
	Quadruple glazing, acrylic/polycarbonate		0.65	0.81	0.65	0.81	0.65	0.81
Tinted	Single glazing, 1/8 in. glass		0.70	0.58	0.66	0.58	0.62	0.56
	Single glazing, 1/4 in. glass		0.61	0.45	0.56	0.45	0.52	0.44
	Single glazing, acrylic/polycarbonate		0.46	0.27	0.46	0.27	0.46	0.27
	Double glazing		0.50	0.40	0.46	0.40	0.42	0.39
	Double glazing, *e* = 0.40 on surface 2 or 3		0.59	0.50	0.55	0.50	0.50	0.48
	Double glazing, *e* = 0.20 on surface 2 or 3		0.47	0.37	0.43	0.37	0.39	0.36
	Double glazing, *e* = 0.10 on surface 2 or 3		0.43	0.38	0.39	0.38	0.35	0.37
	Double glazing, acrylic/polycarbonate		0.37	0.25	0.37	0.25	0.37	0.25
	Triple glazing		0.42	0.22	0.37	0.22	0.34	0.21
	Triple glazing, *e* = 0.40 on surface 2, 3, 4, or 5		0.53	0.45	0.49	0.45	0.45	0.44
	Triple glazing, *e* = 0.20 on surface 2, 3, 4, or 5		0.42	0.33	0.38	0.33	0.35	0.32
	Triple glazing, *e* = 0.10 on surface 2, 3, 4, or 5		0.39	0.34	0.35	0.34	0.31	0.33
	Triple glazing, *e* = 0.40 on surfaces 3 and 5		0.51	0.43	0.47	0.43	0.43	0.42
	Triple glazing, *e* = 0.20 on surfaces 3 and 5		0.40	0.31	0.36	0.31	0.32	0.29
	Triple glazing, *e* = 0.10 on surfaces 3 and 5		0.34	0.32	0.30	0.32	0.27	0.31
	Triple glazing, acrylic/polycarbonate		0.30	0.23	0.30	0.23	0.30	0.23
	Quadruple glazing, *e* = 0.10 on surfaces 3 and 5		0.30	0.29	0.26	0.29	0.23	0.28
	Quadruple glazing, acrylic/polycarbonate		0.27	0.25	0.27	0.25	0.27	0.25

Table A8.2 Assembly *U-Factors*, Assembly *SHGCs*, and Assembly Visible Transmittances (*VTs*) for Unlabeled *Vertical Fenestration*

		Unlabeled *Vertical Fenestration*					
		Clear Glass			*Tinted* Glass		
Frame Type	Glazing Type	*U-Factor*	*SHGC*	*VT*	*U-Factor*	*SHGC*	*VT*
All frame types	Single glazing	1.25	0.82	0.76	1.25	0.70	0.58
	Glass block	0.60	0.56	0.56	NA	NA	NA
Wood, vinyl, or fiberglass frames	Double glazing	0.60	0.59	0.64	0.60	0.42	0.39
	Triple glazing	0.45	0.52	0.57	0.45	0.34	0.21
Metal and other frame types	Double glazing	0.90	0.68	0.66	0.90	0.50	0.40
	Triple glazing	0.70	0.60	0.59	0.70	0.42	0.22

A9 DETERMINATION OF ALTERNATE ASSEMBLY U-FACTORS, C-FACTORS, F-FACTORS, OR HEAT CAPACITIES

A9.1 General

Component *U-factors* for other *opaque* assemblies shall be determined in accordance with Section A9 only if approved by the *building official* in accordance with Section A1.2. The procedures required for each *class of construction* are specified in Section A9.2. Testing shall be performed in accordance with Section A9.3. Calculations shall be performed in accordance with Section A9.4.

A9.2 Required Procedures

Two- or three-dimensional finite difference and finite volume computer models shall be an acceptable alternative method to calculating the thermal performance values for all assemblies and constructions listed below. The following procedures shall also be permitted to determine all alternative *U-factors*, *F-factors*, and *C-factors*:

a. Roofs
   1. *Roofs with insulation entirely above deck*: Testing or series calculation method.
   2. *Metal building roofs*: Testing, or for single-layer and double-layer *systems*, calculation method in Section A9.4.6.
   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*: Testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2-2 or the modified zone method.
   4. Wood-framed *walls*: Testing or parallel path calculation method.
   5. Other *walls*: Testing or two-dimensional calculation method.

c. Below-Grade Walls
   1. *Mass walls*: Testing or isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
   2. Other *walls*: Testing or two-dimensional calculation method.

d. Floors
   1. *Mass floors*: Testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
   2. *Steel-joist floors*: Testing or modified zone calculation method.
   3. *Wood-joist floors*: Testing or parallel path calculation method or isothermal planes calculation method.
   4. Other *floors*: Testing or two-dimensional calculation method.

e. Slab-on-Grade Floors
   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:

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, the appropriate assumptions listed in Sections A2 through A8, including framing factors, shall be used.

A9.4.1 Air Films

Prescribed *R-values* for air films shall be as follows:

R-Value	**Condition**
0.17	All exterior surfaces
0.46	All 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.

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 A9.4.4-2, 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*.

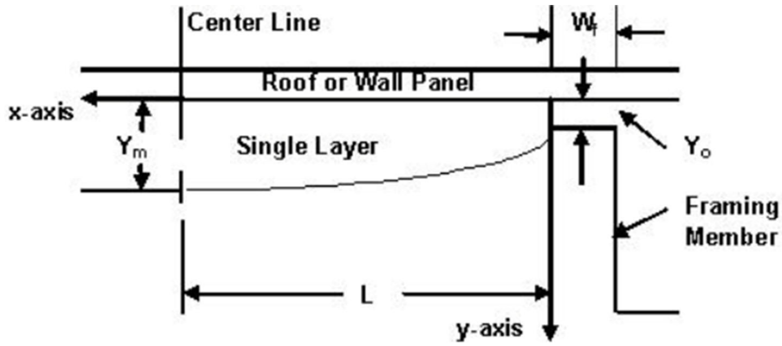


Figure A9.4.6.1 Geometry of single-layer fiberglass batt.

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

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:

$$k = A + B\rho + \frac{C}{\rho} \qquad \text{(A9.4-2)}$$

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:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{L}\right)\left(2 - \frac{X}{L}\right) \qquad \text{(A9.4-3)}$$

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 resistances of the interior (R_i) and exterior (R_e) air films to calculate the overall cavity *U-factor* (U_{co}) using Equation A9.4-5:

$$U_{co} = \frac{1}{\frac{1}{U_c} + R_i + R_e} \tag{A9.4-5}$$

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

Step 4: Determine the overall area-weighted *U-factor* for the entire *system* using Equation A9.4-9:

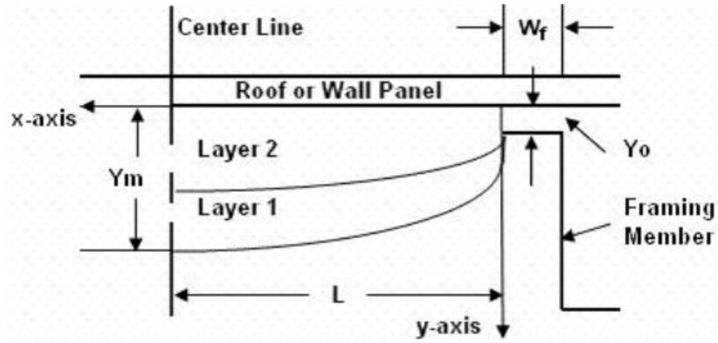


Figure A9.4.6.2-1 Geometry of double layers of fiberglass batts.

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

$$U_{es} = \frac{L \times U_{co} + (w_f/2) \times U_{fo}}{L + (w_f/2)} \tag{A9.4-9}$$

where

U_{es} = area-weighted *U-factor* for the entire *system*, Btu/h·ft²·°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:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \tag{A9.4-10}$$

where

U_{adj} = adjusted overall *U-factor* represented by correlation with the finite element modeling, Btu/h·ft²·°F

Step 6: If there is any *continuous insulation* present, calculate the overall *U-factor* using Equation A9.4-11:

$$U = \frac{1}{\frac{1}{U_{adj}} + R_{ci}} \tag{A9.4-11}$$

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.

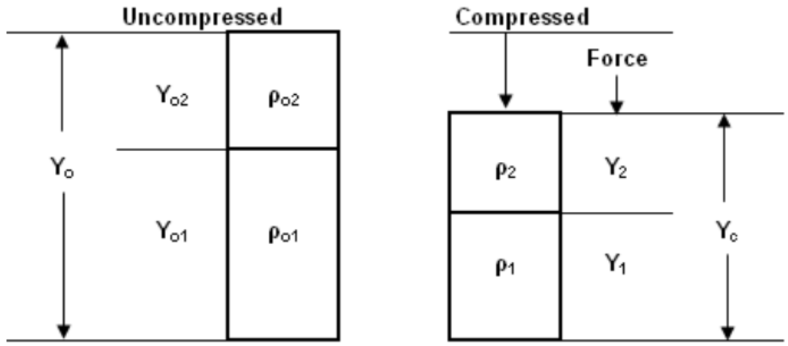


Figure A9.4.6.2-2 Compression of double layers of fiberglass insulation.

Step 1: The thermal conductivity of the fiberglass batt insulation is represented by a thermal curve of the form in Equation A9.4-12:

$$k = A + B\rho + \frac{C}{\rho} \quad \text{(A9.4-12)}$$

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:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{L}\right)\left(2 - \frac{X}{L}\right) \quad \text{(A9.4-13)}$$

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:

$$\left(\frac{Y_2}{Y_c}\right)^2 + \left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c/12)} - 1\right]\left(\frac{Y_2}{Y_c}\right) - \frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)Y_c/12} = 0 \quad \text{(A9.4-14)}$$

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 Equation A9.4-15a and A9.4-15b:

$$\frac{Y_{2,a}}{Y_c} = \left|\frac{-b + \sqrt{b^2 - 4ac}}{2a}\right| \quad \text{(A9.4-15a)}$$

$$\frac{Y_{2,b}}{Y_c} = \left|\frac{-b - \sqrt{b^2 - 4ac}}{2a}\right| \quad \text{(A9.4-15b)}$$

where

a = 1

$$b = \left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c/12)} - 1\right]$$

$$c = \left[\frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)Y_c/12}\right]$$

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:

$$\rho_c = \frac{\rho_o t_o}{t_c} \quad \text{(A9.4-16)}$$

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:

$$R_c = \frac{t_c}{A + B\rho_c + C/\rho_c} \quad \text{(A9.4-17)}$$

Determine the overall framing *U-factor* (U_{fo}) at the structural framing member, including the air film resistances, using Equation A9.4-18:

$$U_{fo} = \frac{1}{R_{TB} + R_c + R_i + R_e} \quad \text{(A9.4-18)}$$

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:

$$U_{es} = \frac{L \times U_{co} + (w_f/2) \times U_{fo}}{L + (w_f/2)} \quad \text{(A9.4-19)}$$

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:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \quad \text{(A9.4-20)}$$

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:

$$U_o = \frac{1}{\frac{1}{U_{adj}} + R_{ci}} \quad \text{(A9.4-21)}$$

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 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:

$$k = A + B\frac{\rho_o\delta_o}{y} + C\frac{y}{\rho_o\delta_o} \quad \text{(A9.4-22)}$$

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 = 0.00056897

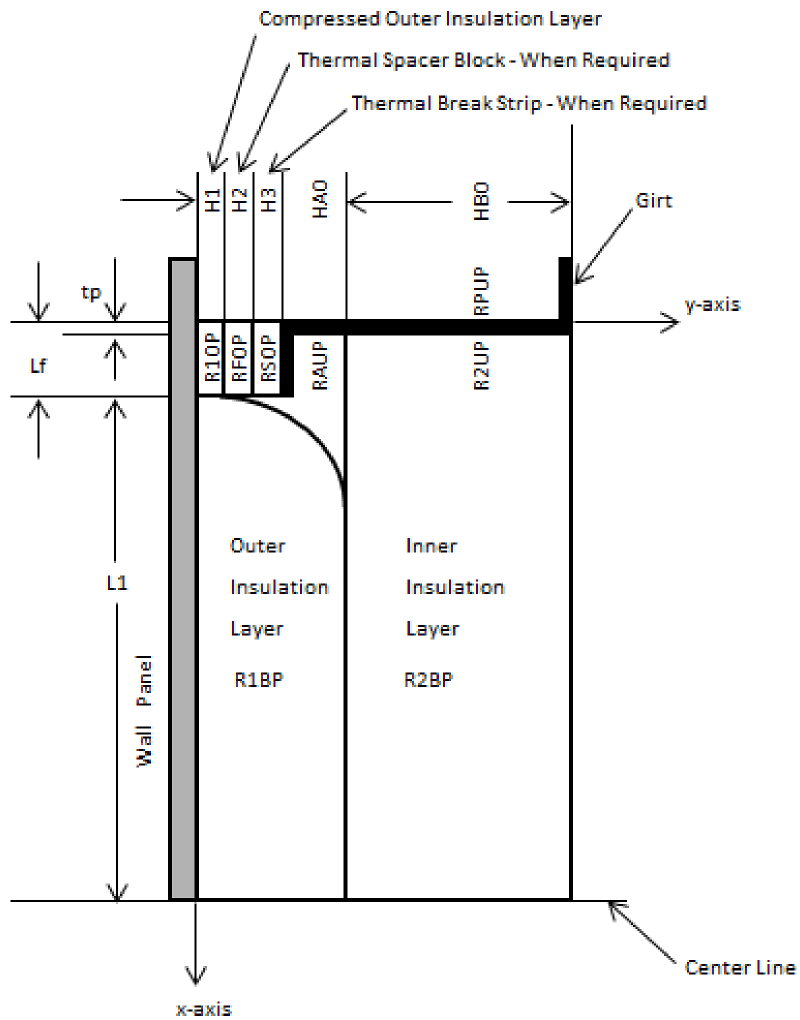


Figure A9.4.6.3 Geometry of single cavity layer or double-layer *wall*.

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:

$$\int_a^b f(x)\mathrm{d}x \approx \frac{1}{2}\sum_{k=1}^{N}(x_{k+1}-x_k)(y_k+y_{k+1}) \tag{A9.4-25}$$

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

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 9.4.25 can be simplified using the air space mean thickness (Y_a) to produce Equation A9.4-26:

$$R = \frac{Y_a}{K_a} + \frac{1}{X_a}\int_0^{x_a}\left(\frac{Y_m - y}{K}\right)\mathrm{d}x + \frac{Y_m}{K(Y_m)} \tag{A9.4-26}$$

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:

$$R_{BP} = R1BP + R2BP \tag{A9.4-27}$$

Add the air film resistances at the exterior (R_{AT}) and interior (R_{AB}), which are defined as Equation A9.4-28:

$$R_{AB} = \frac{1}{h_{AB}} \tag{A9.4-28}$$

where h_{AB} is the air film heat transfer coefficient at the exterior in Btu/h·ft^2·°F.

$$R_{AT} = \frac{1}{h_{AT}} \tag{A9.4-29}$$

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.

$$R_{BP+air} = R_{BP} + R_{AB} + R_{AT} \tag{A9.4-30}$$

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:

$$\mathrm{RAUP} = \frac{H3}{k_a} \tag{A9.4-31}$$

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.

$$\text{R2UP} = \frac{H4}{A + B\dfrac{\rho_o\delta_o}{H4} + C\dfrac{H4}{\rho_o\delta_o}} \quad \text{(A9.4-32)}$$

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:

$$\text{RPUP} = \frac{\text{Web Height}}{k_p} \quad \text{(A9.4-33)}$$

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:

$$\frac{L_f}{\text{RUP}} = \frac{L_f - t_p}{\text{RAUP} + \text{R2UP}} + \frac{t_p}{\text{RPUP}} \quad \text{(A9.4-34)}$$

Equation A9.4-34 can be rearranged and solved for RUP as presented in Equation A9.4-35:

$$\text{RUP} = \frac{(\text{RAUP} + \text{R2UP})\text{RPUP}}{(L_f - t_p)\text{RPUP} + t_p(\text{RAUP} + \text{R2UP})}L_f \quad \text{(A9.4-35)}$$

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:

$$\text{RUP} = \frac{(\text{RAUP} + \text{R2UP})\text{RPUP}}{L_f\text{RPUP} + t_p(\text{RAUP} + \text{R2UP})}L_f \quad \text{(A9.4-36)}$$

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.

$$R_{OPI} = \frac{H1}{k_f} + \frac{H2}{k_I} \quad \text{(A9.4-37)}$$

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

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:

$$R_{OP} = R_{OPI}\frac{1}{\left[1 + \frac{2(H1 + H2)}{\pi L_f}\right]} \quad \text{(A9.4-38)}$$

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:

$$R_{TP} = R_{UP} + R_{OP} \quad \text{(A9.4-39)}$$

The next calculation is to add the inside and outdoor air film coefficients using Equation A9.4-40:

$$R_{TP+air} = R_{TP} + R_{AB} + R_{AT} \quad \text{(A9.4-40)}$$

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:

$$R_{insul-sys} = \frac{(2L_1 + L_f)R_{BP+air}R_{TP+air}}{2L_1R_{TP+air} + L_fR_{BP+air}} \quad \text{(A9.4-41)}$$

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:

$$U_{adj} = \frac{1}{0.8627R_{insul-sys} + 1.132} \quad \text{(A9.4-42)}$$

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:

$$R_{BFci} = R_{ci}\frac{1}{\left[1 + \frac{2(h_{ci})}{\pi L_f}\right]} \quad \text{(A9.4-43)}$$

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:

$$R_{oci} = \frac{(2L_1 + L_f)R_{BPci}R_{ci}}{2L_1R_{BPci} + L_fR_{ci}} \quad \text{(A9.4-44)}$$

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:

$$U_o = \frac{1}{\frac{1}{U_{adj}} + R_{oci}} \quad \text{(A9.4-45)}$$

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 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
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.

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	Effective Emissivity of Air Space: 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

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

Table A9.4.6.1 Fiberglass Reference Properties

R-Value, h·ft^2·°F/Btu	Weight, lb/ft^2	Density, lb/ft^3	Thickness, ft
10	0.149	0.605	0.2458
11	0.168	0.630	0.2667
13	0.199	0.628	0.3167
16	0.243	0.634	0.3833
19	0.297	0.653	0.4542
25	0.427	0.742	0.5750
30	0.520	0.766	0.6792

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 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).

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.

C1.3 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.

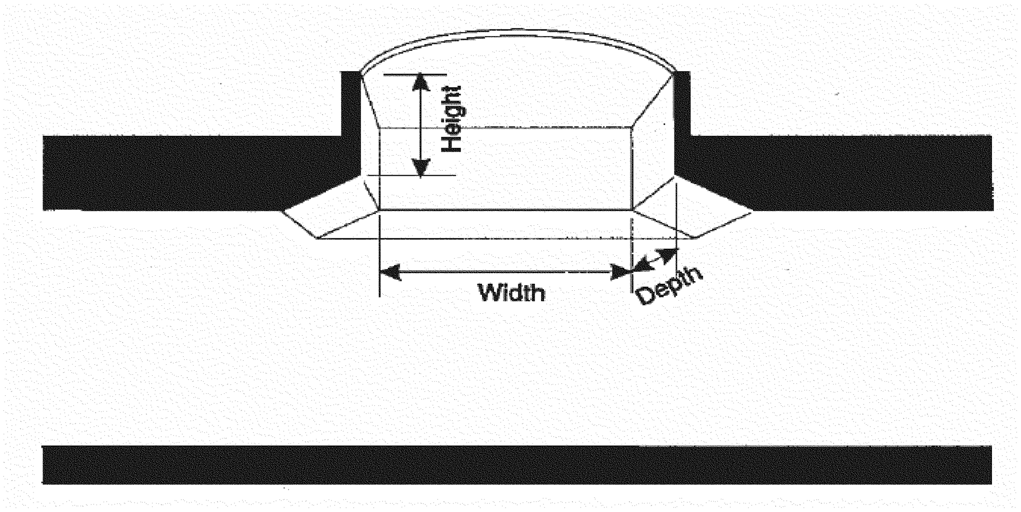


Figure C1.4 ***Skylight well*** **dimensions.**

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.

C2 OUTPUT REQUIREMENTS

Output reports shall contain the following information.

C2.1

Name and contact information of the entity executing the simulation, and date of report.

C2.2

Location of the *building*, including street address and climate zone.

C2.3

Location corresponding to the weather data used to perform the simulation.

C2.4

Simulation program used to perform the simulation.

C2.5

Tables summarizing the minimum information described in Section C1.

C2.6

All differences between the *proposed envelope performance factor* and the *base envelope performance factor*.

C2.7

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.

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 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

The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8, of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program 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 or for missing results.

Informative Note

There are no pass/fail criteria established by this requirement.

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.

C3.5.2 Model Geometry and Thermal Zones

The *building* model shall be divided into thermal zones described as follows:

a. Determine the ratio (R_c) of the *floor* area to the *gross wall area* for each unique combination of *space conditioning category* and *building* area type. The index "c" refers to a combination of *space conditioning category* and *building* area type as defined for each surface.
b. Create a perimeter zone for each unique combination of *building* area type, *above-grade-wall orientation*, and *space conditioning category*. If there is more than one *above-grade-wall* assembly for a *building* area type and *orientation*, each *above-grade-wall* assembly shall be placed end-to-end in the order it is defined. The area of each perimeter zone shall be the *gross wall area* of the zone times R_c or 1.25, whichever is smaller.
c. For each unique combination of *space conditioning category* and *building* area type with R_c greater than 1.25, interior zones shall be created and used in the trade-off procedure. The area of the interior zone shall be the total area for the unique combination of *space conditioning category* and *building* area type less

the area of the perimeter zones for that combination of *space conditioning category* and *building* area type.

d. Create a below-*grade* zone for each unique combination of *space conditioning category* and *building* area type associated with *below-grade walls*. If there is more than one *below-grade-wall* assembly for a *building* area type, each below-*grade-wall* assembly shall be placed end-to-end in the order it is defined. The area of each below-*grade* zone shall be the *gross wall area* of the zone times R_c or 1.25, whichever is smaller.

e. The *wall* height and the height of each thermal zone shall be 15 ft.

f. *Roof* area and *floor* area associated with each *building* area type shall be prorated among all zones of the corresponding *building* area type in proportion to the zone area of each zone. *Roof* area and *floor* area in each zone shall be centered in the horizontal plane of the zone with the same aspect ratio as the horizontal plane of the zone.

g. *Slab-on-grade floor* perimeter associated with each *building* area type shall be prorated among perimeter zones of the corresponding *building* area type in proportion to the area of each zone.

h. *Vertical fenestration area* shall be assigned to the associated surface as described in Section C1.4. *Vertical fenestration* shall be centered on the associated surface with the same aspect ratio as the associated surface. Windows with equivalent *U-factor*, *SHGC*, and *VT* that do not include fins may be combined into a single window on the associated surface.

i. *Skylight* area shall be assigned to the associated surface as described in Section C1.4, prorated among interior zones containing the *roof* area with which the *skylight* area is associated, in proportion to the associated *roof* area. If the total *skylight* area exceeds the associated *roof* area in interior zones, the remaining *skylight* area shall be prorated among perimeter zones containing the *roof* area with which the *skylight* area is associated, in proportion to the associated *roof* area.

j. Each zone shall be modeled as being fully enclosed. Zone boundaries not created as described above shall be modeled as adiabatic interior surfaces.

C3.5.3 Daylight Area and Photosensor Location

Daylight areas and *photosensors* shall not be modeled in *residential* zones. In each *nonresidential* zone, *daylight areas* and *photosensor* locations shall be modeled in accordance with the following:

a. For each *nonresidential* zone associated with *vertical fenestration*, the *daylight area* shall be modeled as directly adjacent to the *vertical fenestration* with a width equal to the width of the *vertical fenestration* and a depth equal to the head height of the *vertical fenestration*.

b. In each *nonresidential* zone associated with *skylights*, the *daylight area under skylights* shall be modeled as bounded, in each direction, by the edge of the *skylight* area plus 10 ft or the distance to the edge of the zone, whichever is less.

c. For each *daylight area* associated with *vertical fenestration*, a *photosensor* shall be modeled as located at the center of the width of the *daylight area*, at the depth of the *daylight area* and at a height of 3 ft.

d. For each *daylight area* associated with a *skylight*, a *photosensor* shall be modeled as located at the center of the horizontal plane of the *skylight* and at a height of 5 ft.

C3.5.4 Schedules

The schedule types listed in Section C3.1.1(c) shall be required input. The schedules shall be consistent with those in the *building envelope trade-off schedules and loads*[2] for the applicable *building* area type.

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 0.3 in. of water shall be 0.4 cfm/ft^2 of *building envelope* area. 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 0.3 in. of water, or 1.57 psf

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

2. Schedules and internal loads by *building* area type are found at http://sspc901.ashraepcs.org/documents.php.

C3.5.5.3.1 Infiltration Schedule

Infiltration shall be adjusted in accordance with the *infiltration* schedule in the *building envelope trade-off schedules and loads* for the applicable *building* area type.

C3.5.6 Interior Surfaces

Interior surfaces shall be modeled with visible light reflectances of 0.80 for ceilings, 0.50 for *walls*, and 0.20 for *floors*. Interior surfaces shall be modeled with a thermal *emittance* of 0.90.

C3.5.7 Lighting

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 11.5.2(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 maximum *U-factor* required in Section 5.5.3 for the appropriate *class of construction*, *space conditioning category*, and climate zone. *Mass walls* and *mass floors* shall be modeled with *HC* equal to 7.2 Btu/ft^2·°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. The exterior *roof* surfaces shall be modeled with a solar *reflectance* and thermal *emittance* as required in Section 5.5.3.1.1(a). All other *roofs*, including *roofs* exempted from the requirements in Section 5.5.3.1.1, shall be modeled the same as in the *proposed design*.

c. *Fenestration* shall be assumed to be flush with the *wall* or *roof*. If the *fenestration area* for new *buildings* or *additions* exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. If the *fenestration area* facing west or east of the *proposed 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, then averaging the results of the four simulations. *Fenestration U-factor* and *SHGC* shall be the maximum allowed for the appropriate *class of construction*, *space conditioning category*, and climate zone in accordance with Section 5.5.4. Where there is no *SHGC* requirement, the *SHGC* shall be equal to 0.40 for all *vertical fenestration* and 0.55 for *skylights*. The *VT* for *fenestration* in the base envelope design shall be equal to 1.10 times the *SHGC*.

d. Manually operated interior shades shall be modeled on all *vertical fenestration* as described in Section C3.5.5.1. Permanent shading devices, such as fins and overhangs, shall not be modeled.

e. *Daylight areas* and *photosensor* locations shall be modeled as described in Section C3.5.3 after reducing the *fenestration area* as described in Section C3.6(c).

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 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.

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

Informative Appendix E

Informative References

This appendix contains informative references for the convenience of users of Standard 90.1 and to acknowledge source documents when appropriate. Some documents are also included in Section 12, "Normative References," because there are other citations of those documents within the standard that are normative.

Address/Contact Information

Air Movement and Control Association (AMCA)
30 West University Drive
Arlington Heights, IL 60004

ASHRAE
1791 Tullie Circle
Atlanta, GA 30329-2305

(*After 10/30/2020*
180 Technology Parkway
Peachtree Corners, GA 30092)

Associated Air Balance Council (AABC)
220 19th Street NW, Suite 410
Washington, DC 20036

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
(973) 267-9700; pumps.org

LBNL Characterization and Survey of Automated Fault Detection and Diagnostics Tools
Lawrence Berkeley National Laboratory Building Technology and Urban Systems Division Energy Technologies Area
MS 90R3111
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Subsection No.	Reference	Title/Source
5.7.3.2	NIBS Guideline 3-2012	Building Enclosure Commissioning Process BECx, Annex O
5.7.3.2	ASTM E2947-16a	Standard Guide for Building Enclosure Commissioning, Section 9.4
5.9.1, H1	ASTM E2947-16a	Standard Guide for Building Enclosure Commissioning
5.9.1, H1	ASTM E2813-18	Standard Practice for Building Enclosure Commissioning
6.4.1	CTI STD-201 OM (19)	Operations Manual for Thermal Performance Certification of Evaporative Heat Rejection Equipment Cooling Technology Institute
6.4.2	2017 ASHRAE Handbook—Fundamentals	
6.4.3.1	ASHRAE Guideline 22-2012	Instrumentation for Monitoring Central Chilled-Water Plant Efficiency
6.4.4.1.1	MICA Insulation Standards, 7th Edition	National Commercial and Industrial Insulation Standards
6.4.4.2.1	SMACNA Duct Construction Standards (2005)	HVAC Duct Construction Standards, Metal and Flexible
6.4.4.2.2	SMACNA Duct Leakage Test Procedures (2012)	HVAC Air Duct Leakage Test Manual (Sections 3, 5, and 6)
6.7.3.2	ASHRAE Guideline 4-2008 (RA2013)	Preparation of Operating and Maintenance Documentation for Building Systems
6.7.3.3.1	AABC 2002	Associated Air Balance Council, National Standards for Total System Balance
6.7.3.3.1	ASHRAE Standard 111-2008	Measurement, Testing, Adjusting and Balancing of Building HVAC Systems
6.9.2, H1	ASHRAE Standard 202-2018	Commissioning Process for Buildings and Systems
6.9.2, H1	ASHRAE Guideline 0-2013	The Commissioning Process
6.9.2, H1	ASHRAE Guideline 1.1-2007	HVAC&R Technical Requirements for the Commissioning Process
6.9.2	NEBB Procedural Standards (2013)	Procedural Standards for Building Systems Commissioning
7.4.1, 7.5	2011 ASHRAE Handbook—HVAC Applications	Chapter 49, Service Water Heating/ASHRAE
8.4.2	LBNL-2001075	Characterization and Survey of Automated Fault Detection and Diagnostic Tools
8.4.2	Fault Detection and Diagnostics—Enabling Techno-Commissioning to Ease Building Operation and Improve Performance (Institute for Building Efficiency)	
8.4.2	HVAC&R Research, January 2005, Volume 11, Number 1	Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems—A Review, Part I
8.4.2	HVAC&R Research, April 2005, Volume 11, Number 2 (ASHRAE)	Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems—A Review, Part I
8.4.2	U.S. Department of Energy EERE; Better Buildings	Energy Management Information Systems (EMIS) Specification and Procurement Support Materials
9.6.1	IES RP-6 -15	Recommended Practice for Sports and Recreational Area Lighting
9.9.2	IES Design Guide 29-2011	The Commissioning Process Applied to Lighting and Control Systems

Subsection No.	Reference	Title/Source
10.4.3.4	ISO 25745-2:2015	Energy performance of lifts, escalators and moving walks—Part 2: Energy calculation and classification for lifts (elevators)
10.4.5	ISO 27327-1:209 (R2014)	Air Curtain Units—Part 1: Laboratory Methods of Testing for Aerodynamic Performance Rating
10.4.5	ANSI/AMCA Standard 220-05 (R2012)	Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating
10.4.7	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
11.4.2	CWEC	Canadian Weather for Energy Calculations
11.4.2	IWEC2	International Weather for Energy Calculations, Generation 2
11.4.2	TMY3	Typical Meteorological Year, Generation 3
A9.4.6	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	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
H1	ISO/IEC 17024:2012	Community Assessment—General Requirements for Bodies Operating Certification of Persons

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

Informative Appendix F

U.S. Department of Energy Minimum Energy Efficiency Requirements, Test Procedures, and Definitions

In the United States, the U.S. Department of Energy (USDOE) establishes *efficiency* standards for products that it defines as "residential covered products." Since these products are used in *buildings* covered by this standard, USDOE *efficiency* requirements are shown here for convenience. All USDOE *efficiency* requirements for *residential* products are found in the U.S. *Code of Federal Regulations*, 10 CFR 430.32.

USDOE also establishes definitions and test procedures for covered products. These are found in 10 CFR 430.2 and 10 CFR 430.23, respectively.

F1 USDOE 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 USDOE 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 USDOE Test Procedure and Definitions for Ceiling Fans

USDOE 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. USDOE 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.

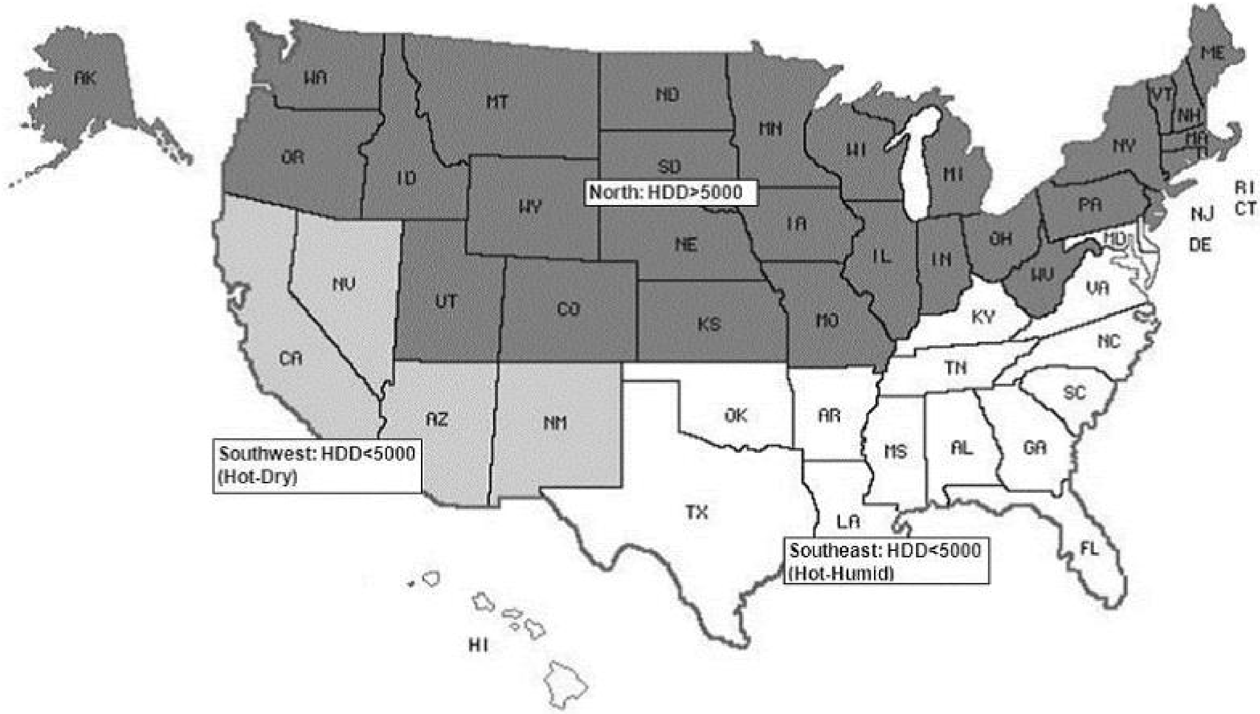

Figure F-1 Map of the regions for the analysis of central air conditioners and heat pumps.
(Source: *Federal Register* 76 FR 37431, June 7, 2018)

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*	before 1/1/2023 *SEER* = 13.0 $P_{W,OFF} \leq 30$ W after 1/1/2023 *SEER2* = 13.4 $P_{W,OFF} \leq 30$ W	before 1/1/2023 *SEER* = 14.0 $P_{W,OFF} \leq 30$ W after 1/1/2023 *SEER2* = 14.3 $P_{W,OFF} \leq 30$ W	before 1/1/2023 *SEER* = 14.0 *EER* = 12.2 $P_{W,OFF} \leq 30$ W after 1/1/2023 *SEER2* = 14.3 *EER2* = 11.7/9.8[d] $P_{W,OFF} \leq 30$ W	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*	before 1/1/2023 *SEER* = 13.0 $P_{W,OFF} \leq 30$ W after 1/1/2023 *SEER2* = 13.4 $P_{W,OFF} \leq 30$ W	before 1/1/2023 *SEER* = 14.0 $P_{W,OFF} \leq 30$ W after 1/1/2023 *SEER2* = 13.8 $P_{W,OFF} \leq 30$ W	before 1/1/2023 *SEER* = 14.0 *EER* = 11.7[d] $P_{W,OFF} \leq 30$ W after 1/1/2023 *SEER2* = 13.8 *EER2* = 11.2/9.8[e] $P_{W,OFF} \leq 30$ W	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; 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.
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 12 contains a complete specification of the referenced test procedures, including the referenced year version of the test procedure.

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*	before 1/1/2023 *SEER* = 14.0 *HSPF* = 8.2 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 14.3 *HSPF2* = 7.5 $P_{W,OFF} \le 33$ W	before 1/1/2023 *SEER* = 14.0 *HSPF* = 8.2 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 14.3 *HSPF2* = 7.5 $P_{W,OFF} \le 33$ W	before 1/1/2023 *SEER* = 14.0 *HSPF* = 8.2 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 14.3 *HSPF2* = 7.5 $P_{W,OFF} \le 33$ W	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*	before 1/1/2023 *SEER* = 14.0 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 13.4 $P_{W,OFF} \le 30$ W	before 1/1/2023 *SEER* = 14.0 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 13.4 $P_{W,OFF} \le 30$ W	before 1/1/2023 *SEER* = 14.0 *EER* = 11.0 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 13.4 *EER2* = 10.6 $P_{W,OFF} \le 30$ W	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*	before 1/1/2023 *SEER* = 14.0 *HSPF* = 8.0 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 13.4 *HSPF2* = 6.7 $P_{W,OFF} \le 33$ W	before 1/1/2023 *SEER* = 14.0 *HSPF* = 8.0 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 13.4 *HSPF2* = 6.7 $P_{W,OFF} \le 33$ W	before 1/1/2023 *SEER* = 14.0 *HSPF* = 8.0 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 13.4 *HSPF2* = 6.7 $P_{W,OFF} \le 33$ W	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*	before 1/1/2023 *SEER* = 12.0 *HSPF* = 7.2 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 12.0 *HSPF2* = 6.1 $P_{W,OFF} \le 30$ W	before 1/1/2023 *SEER* = 12.0 *HSPF* = 7.2 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 11.7 *HSPF2* = 6.1 $P_{W,OFF} \le 30$ W	before 1/1/2023 *SEER* = 12.0 *HSPF* = 7.2 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 12.0 *HSPF2* = 6.1 $P_{W,OFF} \le 30$ W	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*	before 1/1/2023 *SEER* = 12.0 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 11.7 $P_{W,OFF} \le 30$ W	before 1/1/2023 *SEER* = 12.0 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 11.7 $P_{W,OFF} \le 30$ W	before 1/1/2023 *SEER* = 12.0 $P_{W,OFF} \le 30$ W after 1/1/2023 *SEER2* = 11.7 $P_{W,OFF} \le 30$ W	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*	before 1/1/2023 *SEER* = 12.0 *HSPF* = 7.4 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 11.9 *HSPF2* = 6.3 $P_{W,OFF} \le 33$ W	before 1/1/2023 *SEER* = 12.0 *HSPF* = 7.4 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 11.9 *HSPF2* = 6.3 $P_{W,OFF} \le 33$ W	before 1/1/2023 *SEER* = 12.0 *HSPF* = 7.4 $P_{W,OFF} \le 33$ W after 1/1/2023 *SEER2* = 11.9 *HSPF2* = 6.3 $P_{W,OFF} \le 33$ W	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; 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.
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 12 contains a complete specification of the referenced test procedures, including the referenced year version of the test procedure.

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 ≤100 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 = 0.91	
		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.

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 12 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 $P_{W,SB} \le 11$ W $P_{W,OFF} \le 11$ W	10 CFR 430 Appendix N
		Nonweatherized mobile home	75% AFUE $P_{W,SB} \le 11$ W $P_{W,OFF} \le 11$ W	
		Weatherized	78% AFUE	
Electric furnace	<225,000 Btu/h	All	78% AFUE $P_{W,SB} \le 10$ W $P_{W,OFF} \le 10$ W	10 CFR 430 Appendix N

a. Section 12 contains a complete specification of the referenced test procedure.

Table F-5 Residential Boiler [a] Minimum Efficiency Requirements for U.S. Applications (see 10 CFR 430)

Product Class	Minimum Efficiency prior to January 15, 2021 [b]	Minimum Efficiency as of January 15, 2021 [b]	Standby Mode and Off-Mode Power Consumption as of January 15, 2021 [c]	Design Requirements
Gas-fired hot-water boiler	82% AFUE	84% AFUE	$P_{W,SB} \leq 9$ W $P_{W,OFF} \leq 9$ W	Constant burning pilot not permitted. Automatic means for adjusting water temperature required (except for boilers equipped with tankless domestic water heating coils).
Gas-fired steam boiler	80% AFUE	82% AFUE	$P_{W,SB} \leq 8$ W $P_{W,OFF} \leq 8$ W	Constant burning pilot not permitted.
Oil-fired hot-water boiler	84% AFUE	86% AFUE	$P_{W,SB} \leq 11$ W $P_{W,OFF} \leq 11$ W	Automatic means for adjusting temperature required (except for boilers equipped with tankless domestic water heating coils)[d].
Oil-fired steam boiler	82% AFUE	85% AFUE	$P_{W,SB} \leq 11$ W $P_{W,OFF} \leq 11$ W	None
Electric hot-water boiler	None	None	$P_{W,SB} \leq 8$ W $P_{W,OFF} \leq 8$ W	Automatic means for adjusting temperature required (except for boilers equipped with tankless domestic water heating coils)[d].
Electric steam boiler	None	None	$P_{W,SB} \leq 8$ W $P_{W,OFF} \leq 8$ 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 § 430.23(e)(2)(iv) for additional details regarding automatic means for adjusting water temperature.

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*."

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. Table G3.7 and the methodology described in Section 9.6.1, or
   2. Table G3.8 and the methodology described in Section 9.5.1.
c. Energy efficiency levels of installed components and *systems* that meet or exceed the efficiency levels used to calculate the *proposed building performance*.
d. Verification, testing, and *commissioning* requirements of Section 4.2.5 shall be met.
e. 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 *building* when calculating the Performance Cost Index.

Exception to G1.2.2

Energy used to recharge or refuel vehicles that are used for off-building site transportation purposes shall not be modeled in the *baseline building performance* or the *proposed building performance*.

Informative Note

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.

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.

G1.3.2 Application Documentation

Simulated performance shall be documented, and documentation shall be submitted to the *rating authority*. The information shall be submitted in a report and shall include the following:

a. A brief description of the project, the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10, the *simulation program* used, the version of the *simulation program*, and the results of the *energy* analysis. This summary shall contain the calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.

b. An overview of the project that includes the number of stories (above and below *grade*), the typical *floor* size, the uses in the *building* (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is *conditioned space*.

c. A list of the *energy*-related features that are included in the design and on which the performance rating is based. This list shall document all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.

d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, 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, 9.5, and 9.6 (prescriptive provisions).

f. A table with a summary by end use of the *energy* cost savings in the *proposed building performance*.

g. A site plan showing all adjacent *buildings* and topography that may shade the proposed *building* (with estimated height or number of stories).

h. *Building* elevations and *floor* plans (schematic is acceptable).

i. A diagram showing the *thermal blocks* used in the computer simulation.

j. An explanation of any significant modeling assumptions.

k. Backup calculations and material to support data inputs (e.g., *U-factors* for *building envelope* assemblies, NFRC ratings for *fenestration*, end-uses identified in Table G3.1, “1. Design Model,” paragraph [a]).

l. Input and output reports from the *simulation program* or compliance software, including a breakdown of *energy* use by at least the following components: lights, internal *equipment* loads, *service water-heating equipment*, *space*-heating *equipment*, *space*-cooling and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of *unmet load hours* for both the *proposed design* and *baseline building design*.

m. *Purchased energy rates* used in the simulations.

n. An explanation of any error messages noted in the *simulation program* output.

o. For any exceptional calculation methods employed, document the predicted *energy* savings by *energy* type, the *energy* cost savings, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.

p. The reduction in *proposed building performance* associated with *on-site renewable energy*.

q. 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.

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 *simulation program* shall include calculation methodologies for the *building* components being modeled. For components that cannot be modeled by the *simulation program*, the exceptional calculation methods requirements in Section G2.5 shall be used.

G2.2.1

The *simulation program* shall be approved by the *rating authority* and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year.
b. Hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat set points*, and *HVAC system* operation, defined separately for each day of the week and holidays.
c. Thermal mass effects.
d. Ten or more thermal zones.
e. Part-load performance curves for mechanical *equipment.*
f. Capacity and *efficiency* correction curves for *mechanical heating* and *mechanical cooling equipment*.
g. *Air economizers* with integrated *control*.
h. *Baseline building design* characteristics specified in Section G3.

G2.2.2

The *simulation program* shall have the ability to either 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 engine.

G2.2.3

The *simulation program* shall be capable of performing design load calculations to determine required HVAC *equipment* capacities and air and water flow rates in accordance with *generally accepted engineering standards* and handbooks (for example, *ASHRAE Handbook—Fundamentals*) for both the *proposed design* and *baseline building design*.

G2.2.4

The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program 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 or for missing results.

Informative Note

There are no pass/fail criteria established by this requirement.

G2.3 Climatic Data

The *simulation program* shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the *proposed design* is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the *construction* site. The selected weather data shall be approved by the *rating authority*.

G2.4 Renewable, Recovered, and Purchased Energy

G2.4.1 On-Site Renewable Energy and Site-Recovered Energy

Site-recovered energy shall not be considered *purchased energy* and shall be subtracted from the *proposed design energy* consumption prior to calculating the *proposed building performance*. *On-site renewable energy* shall be subtracted from the *proposed 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 USDOE'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. 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 (www.eia.gov).

G2.5 Exceptional Calculation Methods

When the *simulation program* does not model a design, material, or device of the *proposed design*, an exceptional calculation method shall be used as approved by the *rating authority*. Where there are multiple designs, materials, or devices that the *simulation program* does not model, each shall be calculated separately and exceptional savings determined for each. At no time shall the total exceptional savings constitute more than half of the difference between the *baseline building performance* and the *proposed building performance*. All applications for approval of an exceptional method shall include the following:

a. Step-by-step documentation of the exceptional calculation method performed, detailed enough to reproduce the results.
b. Copies of all spreadsheets used to perform the calculations.
c. A sensitivity analysis of *energy* consumption when each of the input parameters is varied from half to double the value assumed.
d. The calculations shall be performed on a time-step basis consistent with the *simulation program* used.
e. The performance rating calculated with and without the exceptional calculation method.

G3 CALCULATION OF THE PROPOSED DESIGN AND BASELINE BUILDING PERFORMANCE

G3.1 Building Performance Calculations

The simulation model for calculating the proposed and *baseline building performance* shall be developed in accordance with the requirements in Table G3.1.

G3.1.1 Baseline HVAC System Type and Description

HVAC systems in the *baseline building design* shall comply with the following:

a. *HVAC systems* in the *baseline building design* shall be determined in the following order of priority:
   1. The *building* type with the largest *conditioned floor area*.
   2. Number of *floors* (including *floors* above grade and below *grade* but not including *floors* solely devoted to parking).
   3. *Gross conditioned floor area*.
   4. Climate zone as specified in Table G3.1.1-3, which shall conform with the *system* descriptions in Table G3.1.1-4. For *Systems* 1, 2, 3, 4, 9, 10, 11, 12, and 13, each *thermal block* shall be modeled with its own *HVAC system*. For *Systems* 5, 6, 7, and 8, each *floor* shall be modeled with a separate *HVAC system*. *Floors* with identical *thermal blocks* can be grouped for modeling purposes.
b. Use additional *system* types for nonpredominant conditions (i.e., *residential*/*nonresidential*) if those conditions apply to more than 20,000 ft^2 of *conditioned floor area*.
c. If the baseline *HVAC system* type is 5, 6, 7, 8, 9, 10, 11, 12, or 13 use separate *single-zone systems* conforming with the requirements of *system* 3 or *system* 4 for any *HVAC zones* that have occupancy, internal gains, or schedules that differ significantly from the rest of the *HVAC zones* served by the *system*. The total peak internal gains that differ by 10 Btu/h·ft^2 or more from the average of other *HVAC zones* served by the *system*, or schedules that differ by more than 40 equivalent full-load hours per week from other *spaces* served by the *system,* are considered to differ significantly. Examples where this exception may be applicable include but are not limited to natatoriums and continually occupied security areas. This exception does not apply to *computer rooms*.
d. For laboratory *spaces* in a *building* having a total laboratory exhaust rate greater than 15,000 cfm, use a single *system* of type 5 or 7 serving only those *spaces*.

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance*

No.	*Proposed Building Performance*	*Baseline Building Performance*
1. Design Model		
	a. The simulation model of the *proposed design* shall be consistent with the design documents, including proper accounting of *fenestration* and *opaque building envelope* types and areas; interior lighting power and *controls*; *HVAC system* types, sizes, and *controls*; and *service water-heating systems* and *controls*. All end-use load components within and associated with the *building* shall be modeled, including but not limited to exhaust fans, parking garage *ventilation* fans, snow-melt and freeze-protection *equipment*, 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 *conditioned floor area* as the *proposed design*. The *baseline building design* shall be developed by modifying the *proposed design* as described in Section G3. Except as specifically instructed, all *building systems* and *equipment* shall be modeled identically in the *proposed design* and *baseline building design*. 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 9.6.1 **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.

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

<table>
<tr><th>No.</th><th>Proposed Building Performance</th><th>Baseline Building Performance</th></tr>
<tr><td colspan="3">4. Schedule</td></tr>
<tr><td colspan="2">
Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation shall be used. The schedules shall be typical of the proposed building type as determined by the designer and approved by the rating authority.

Temperature and Humidity Schedules. Temperature and humidity control set points and schedules as well as temperature control throttling range shall be the same for proposed design and baseline building design.

HVAC Fan Schedules. Schedules for HVAC fans that provide outdoor air for ventilation shall run continuously whenever spaces are occupied and shall be cycled ON and OFF to meet heating and cooling loads during unoccupied hours.

Exceptions:
1. Where no heating and/or cooling system is to be installed, and a heating or cooling system is being simulated only to meet the requirements described in this table, heating and/or cooling system fans shall not be simulated as running continuously during occupied hours but shall be cycled ON and OFF to meet heating and cooling loads during all hours.
2. HVAC fans shall remain on during occupied and unoccupied hours in spaces that have health- and safety-mandated minimum ventilation requirements during unoccupied hours.
3. HVAC fans shall remain on during occupied and unoccupied hours in systems primarily serving computer rooms.
</td><td>
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. Fan schedules may be allowed to differ when Section G3.1.1(c) applies.
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<tr><td colspan="3">5. Building Envelope</td></tr>
<tr><td colspan="2">
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.
Exceptions: The following building elements are permitted to differ from architectural drawings:
1. All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor stabs, concrete floor beams over parking garages, roof parapet) shall be separately modeled using either of the following techniques:
a. Separate model of each of these assemblies within the energy simulation model.
b. Separate calculation of the U-factor for each of these assemblies. The U-factors of these assemblies are then averaged with larger adjacent surfaces using an area-weighted average method. This average U-factor is modeled within the energy simulation model.
Any other building envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described, provided that 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.
2. Exterior surfaces whose azimuth orientation and tilt differ by less than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.
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Equivalent dimensions shall be assumed for each building envelope component type as in the proposed design; i.e., the total gross area of walls shall be the same in the proposed design and baseline building design. The same shall be true for the areas of roofs, floors, and doors, and the exposed perimeters of concrete slabs on grade shall also be the same in the proposed design and baseline building design. The following additional requirements shall apply to the modeling of the baseline building design:
a. Orientation. The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, and 270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself.
Exceptions:
1. If it can be demonstrated to the satisfaction of the rating authority that the building orientation is dictated by site considerations.
2. Buildings where the vertical fenestration area on each orientation varies by less than 5%.
b. Opaque Assemblies. Opaque assemblies used for new buildings, existing buildings, or additions shall conform with assemblies detailed in Normative Appendix A and shall match the appropriate assembly maximum U-factors in Tables G3.4-1 through G3.4-8:
• Roofs—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).
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Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

No.	*Proposed Building Performance*	*Baseline Building Performance*
5. *Building Envelope* (continued)		
	3. The exterior *roof* surface shall be modeled using the aged solar *reflectance* and thermal *emittance* determined in accordance with Section 5.5.3.1.1(a). Where aged test data are unavailable, the *roof* surface may be modeled with a *reflectance* of 0.30 and a thermal *emittance* of 0.90. 4. *Manual fenestration* shading devices, such as blinds or shades, shall be modeled or not modeled the same as in the *baseline building design*. *Automatically* controlled *fenestration* shades or blinds shall be modeled. Permanent shading devices, such as fins, overhangs, and light shelves shall be modeled. 5. *Automatically* controlled *dynamic glazing* may be modeled. Manually controlled *dynamic glazing* shall use the average of the minimum and maximum *SHGC* and *VT*. b. *Infiltration* shall be modeled using the same methodology and adjustments for weather and *building* operation in both the *proposed design* and the *baseline building design*. These adjustments shall be made for each simulation time step and must account for but not be limited to weather conditions and *HVAC system* operation, including strategies that are intended to positively pressurize the *building*. The air leakage rate of the *building envelope* (I_{75Pa}) at a fixed *building* pressure differential of 0.3 in. of water shall be 0.6 cfm/ft^2 for buildings providing verification in accordance with Section 5.9.1.2. The air leakage rate of the *building envelope* shall be converted to appropriate units for the *simulation program* using one of the methods in Section G3.1.1.4. **Exceptions:** When whole-*building* air leakage testing, in accordance with Section 5.4.3.1.1, is specified during design and completed after *construction*, the *proposed design* air leakage rate of the *building envelope* shall be as measured.	• *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). c. ***Vertical Fenestration Areas.*** For *building* area types included in Table G3.1.1-1, *vertical fenestration areas* for new *buildings* and additions shall equal that in Table G3.1.1-1 based on the area of gross *above-grade walls* that separate *conditioned spaces* and *semiheated spaces* from the exterior. Where a *building* has multiple *building* area types, each type shall use the values in the table. The *vertical fenestration* shall be distributed on each face of the *building* in the same proportion as in the *proposed design*. For *building* areas not shown in Table G3.1.1-1, *vertical fenestration areas* for new *buildings* and additions shall equal that in the *proposed design* or 40% of gross *above-grade wall* area, whichever is smaller, and shall be distributed on each face of the *building* in the same proportions in the *proposed design*. The *fenestration area* for an *existing building* shall equal the existing *fenestration area* prior to the proposed work and shall be distributed on each face of the *building* in the same proportions as the *existing building*. d. ***Vertical Fenestration* Assemblies.** *Fenestration* for new *buildings*, *existing buildings*, and additions shall comply with the following: • *Fenestration U-factors* shall match the appropriate requirements in 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. e. ***Skylights* and Glazed Smoke Vents.** *Skylight* area shall be equal to that in the *proposed design* or 3%, whichever is smaller. If the *skylight* area of the *proposed design* is greater than 3%, baseline *skylight* area shall be decreased by an identical percentage in all *roof* components in which *skylights* are located to reach 3%. *Skylight orientation* and tilt shall be the same as in the *proposed design*. *Skylight U-factor* and *SHGC* properties shall match the appropriate requirements in Tables G3.4-1 through G3.4-8 using the value and the applicable *skylight* percentage. f. ***Roof* Solar *Reflectance* and Thermal *Emittance.*** The exterior *roof* surfaces shall be modeled using a solar *reflectance* of 0.30 and a thermal *emittance* of 0.90. g. ***Roof* Albedo.** All *roof* surfaces shall be modeled with a reflectivity of 0.30. h. 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.
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.	Interior lighting power in the *baseline building design* shall be determined using the values in Table G3.7. Lighting shall be modeled having the automatic shutoff controls in buildings >5000 ft^2 and occupancy sensors in employee lunch and break rooms, conference/meeting rooms, and classrooms (not including shop classrooms, laboratory classrooms, and preschool through 12th-grade classrooms).

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance (Continued)*

No.	*Proposed Building Performance*	*Baseline Building Performance*
6. Lighting (continued)		
	c. Where lighting neither exists nor is submitted with design documents, lighting shall comply with but not exceed the requirements of Section 9. Lighting power shall be determined in accordance with the *Building* Area Method. d. *Lighting system* power shall include all *lighting system* components shown or provided for on the plans (including *lamps* and *ballasts* and task and furniture-mounted *fixtures*). 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 Table 9.6.1 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. Lighting power for parking garages and building façades 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 (g) and (h). 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 Table G3.7 for the applicable *space* type. This reduction shall be taken only for lighting controlled by the *occupancy sensors*. Credit for other programmable lighting *control* in *buildings* less than 5000 ft^2 can be taken by reducing the lighting schedule each hour by 10%.	These *controls* shall be reflected in the *baseline building design* lighting schedules. No additional *automatic* lighting *controls,* e.g., *automatic controls* for daylight utilization and *occupancy sensors* in *space* types not listed above, shall be modeled in the *baseline building design*. Exterior lighting in areas identified as “Tradable Surfaces” in Table G3.6 shall be modeled with the baseline lighting power shown in Table G3.6. Other exterior lighting shall be modeled the same in the *baseline building design* as in the *proposed design*.
7. *Thermal Blocks—HVAC Zones* Designed		
	Where *HVAC zones* are defined on HVAC design drawings, each *HVAC zone* shall be modeled as a separate *thermal block*. **Exceptions:** 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*.

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

No.	*Proposed Building Performance*	*Baseline Building Performance*
8. *Thermal Blocks*—*HVAC Zones* Not Designed		
	Where the *HVAC zones* and *systems* have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and *space* temperature schedules, and in combination with the following guidelines: a. Separate *thermal blocks* shall be assumed for interior and perimeter *spaces*. Interior *spaces* shall be those located greater than 15 ft from an *exterior wall* or *semiexterior wall*. Perimeter *spaces* shall be those located within 15 ft of an *exterior wall* or *semiexterior wall*. A separate thermal zone does not need to be modeled for areas adjacent to *semiexterior walls* that separate *semiheated space* from *conditioned space*. b. Separate *thermal blocks* shall be assumed for *spaces* adjacent to glazed *exterior walls* or glazed *semiexterior walls*; a separate zone shall be provided for each *orientation*, except that orientations that differ by less than 45 degrees may be considered to be the same *orientation*. Each zone shall include all *floor* area that is 15 ft or less from a glazed perimeter *wall*, except that *floor* area within 15 ft of glazed perimeter *walls* having more than one *orientation* shall be divided proportionately between zones. c. Separate *thermal blocks* shall be assumed for *spaces* having *floors* that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. d. Separate *thermal blocks* shall be assumed for *spaces* having exterior ceiling or *roof* assemblies from zones that do not share these features.	Same as *proposed design*.
9. *Thermal Blocks*—Multifamily *Residential Buildings*		
	Residential spaces shall be modeled using at least one *thermal block* per *dwelling unit*, except that those units facing the same orientations may be combined into one *thermal block*. Corner units and units with *roof* or *floor* loads shall only be combined with units sharing these features.	Same as *proposed design*.
10. *HVAC Systems*		
	The *HVAC system* type and all related performance parameters in the *proposed design*, such as *equipment* capacities and efficiencies, shall be determined as follows: a. Where a complete *HVAC system* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where an *HVAC system* has been designed and submitted with design documents, the HVAC model shall be consistent with design documents. Mechanical *equipment* efficiencies shall be adjusted from actual *design conditions* to the standard rating conditions specified in Section 6.4.1 if required by the simulation model. Where *efficiency* ratings include supply fan *energy*, the *efficiency* rating shall be adjusted to remove the supply fan *energy* from the *efficiency* rating in the *baseline building design*. The equations in Section G3.1.2.1 shall not be used in the *proposed design*. The *proposed design HVAC system* shall be modeled using *manufacturers*' full- and part-load data for the *HVAC system* without fan power. c. Where no heating *system* exists or no heating *system* has been submitted with design documents, the *system* type shall be the same *system* as modeled in the *baseline building design* and shall comply with but not exceed the requirements of Section 6. d. Where no cooling *system* exists or no cooling *system* has been submitted with design documents, the cooling *system* type shall be the same as modeled in the *baseline building design* and shall comply with the requirements of Section 6. **Exception:** *Spaces* using baseline *HVAC system* types 9 and 10.	The *HVAC systems* in the *baseline building design* shall be of the type and description specified in Section G3.1.1, shall meet the general *HVAC system* requirements specified in Section G3.1.2, and shall meet any *system*-specific requirements in Section G3.1.3 that are applicable to the baseline *HVAC system* types. If the *proposed design* includes humidification then the *baseline building design* shall use adiabatic humidification. **Exception:** If the proposed *building* humidification *system* complies with Section 6.5.2.4 then the *baseline building design* shall use nonadiabatic humidification. For *systems* serving *computer rooms*, the *baseline building design* shall not have *reheat* for the purpose of dehumidification. *Fossil fuel systems* shall be modeled using natural gas as their *fuel* source. **Exception:** For *fossil fuel systems* where natural gas is not available for the proposed *building* site as determined by the *rating authority*, the baseline *HVAC systems* shall be modeled using propane as their *fuel*.

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

No.	*Proposed Building Performance*	*Baseline Building Performance*
11. *Service Water-Heating Systems*		
	The *service water-heating system* type and all related performance parameters, such as *equipment* capacities and efficiencies, in the *proposed design* shall be determined as follows: 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. **Exceptions:** 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.

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

No.	*Proposed Building Performance*	*Baseline Building Performance*
11. *Service Water-Heating Systems* (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 to (h):** Where natural gas is not available for the proposed *building* site, as determined by the *rating authority*, gas storage *water heaters* shall be modeled using propane as their *fuel*. 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. **Exceptions:** 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, No. 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.	Same as *proposed design*.

Table G3.1 Modeling Requirements for Calculating Proposed and *Baseline Building Performance* (Continued)

No.	*Proposed Building Performance*	*Baseline Building Performance*
14. Exterior Conditions (continued)		
	b. **Ground Temperatures for *Below-Grade Wall* and Basement *Floor* Heat-Loss Calculations.** It is acceptable to use either an annual average ground temperature or monthly average ground temperatures for calculation of heat loss through *below-grade walls* and basement *floors*. c. **Water Main Temperatures for *Service Water-Heating* Calculations.** It is acceptable to use either an annual water main supply temperature or monthly average water main supply temperatures for calculating *service water heating*. If annual or monthly water main supply temperatures are not available from the local water utility, annual average ground temperatures may be used.	Same as *proposed design*.
15. Distribution *Transformers*		
	Low-voltage dry-type distribution *transformers* shall be modeled if the *transformers* in the *proposed design* exceed the *efficiency* required in Table 8.4.4.	Low-voltage dry-type distribution *transformers* shall be modeled only if the *proposed design transformers* exceed the *efficiency* requirements of Table 8.4.4. If modeled, the *efficiency* requirements from Table 8.4.4 shall be used. The ratio of the capacity to peak electrical load of the *transformer* shall be the same as the ratio in the *proposed design*.
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*.

The lab exhaust fan shall be modeled as constant horsepower reflecting constant-volume stack discharge with *outdoor air* bypass.

e. Thermal zones designed with heating-only *systems* in the *proposed design* serving storage rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the *proposed design* shall use *system* type 9 or 10 in the *baseline building design*.
f. If the baseline *HVAC system* type is 9 or 10, use additional *system* types for all *HVAC zones* that are mechanically cooled in the *proposed design*.
g. *Computer rooms* in *buildings* with a total *computer room* peak cooling load >3,000,000 Btu/h or a total *computer room* peak cooling load >600,000 Btu/h where the baseline *HVAC system* type is 7 or 8 shall use *System* 11. All other *computer rooms* shall use *System* 3 or 4.
h. For hospitals, depending on *building* type, use *System* 5 or 7 in all climate zones.

G3.1.1.1 Purchased Heat

For *systems* using purchased hot water or steam, the heating source shall be modeled as purchased hot water or steam in both the *proposed design* and *baseline building 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*.

G3.1.1.2 Purchased Chilled Water

For *systems* using purchased chilled water, the cooling source shall be modeled as purchased chilled water in both the *proposed design* and *baseline building 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*.

G3.1.1.3 Baseline HVAC System Requirements for Systems Utilizing Purchased Chilled Water and/or Purchased Heat

If the *proposed design* uses purchased chilled water and/or purchased heat, the following modifications to the baseline *HVAC system* types in Table G3.1.1-4 shall be used.

G3.1.1.3.1 Purchased Heat Only

If the *proposed design* uses purchased heat, but does not use purchased chilled water, then Tables G3.1.1-3 and G3.1.1-4 shall be used to select the baseline *HVAC system* type, and purchased heat shall be substituted for the heating type in Table G3.1.1-4. The same heating source shall be used in the *proposed design* and *baseline building design*.

G3.1.1.3.2 Purchased Chilled Water Only

If the *proposed design* uses purchased chilled water but does not use purchased heat, then Tables G3.1.1-3 and G3.1.1-4 shall be used to select the baseline *HVAC system* type, with the modifications listed below:

a. Purchased chilled water shall be substituted for the cooling types in Table G3.1.1-4.
b. *System* 1 and 2 shall be constant-volume fan-coil units with *fossil fuel boilers*.
c. *System* 3 and 4 shall be constant-volume single-zone air handlers with *fossil fuel* furnaces.
d. *System* 7 shall be used in place of *System* 5.
e. *System* 8 shall be used in place of *System* 6.

G3.1.1.3.3 Purchased Chilled Water and Purchased Heat

If the *proposed design* uses purchased chilled water and purchased heat, then Tables G3.1.1-3 and G3.1.1-4 shall be used to select the baseline *HVAC system* type, with the following modifications:

a. Purchased heat and purchased chilled water shall be substituted for the heating types and cooling types in Table G3.1.1-4.
b. *System* 1 shall be constant-volume fan-coil units.
c. *System* 3 shall be constant-volume single-zone air handlers.
d. *System* 7 shall be used in place of *System* 5.

G3.1.1.3.4 On-Site Distribution Pumps

All on-site distribution pumps shall be modeled in both the *proposed design* and *base building design*.

G3.1.1.4 Modeling Building Envelope Infiltration

The air leakage rate of the *building envelope* (I_{75Pa}) at a pressure differential of 0.3 in. of water shall be converted to appropriate units for the *simulation program* using one of the following formulas:

For methods describing air leakage as a function of *floor* area,

$$I_{FLR} = 0.112 \times I_{75Pa} \times S/A_{FLR}$$

For methods describing air leakage as a function of the area of *above-grade walls* that separate *conditioned spaces* and *semiheated spaces* from the exterior,

$$I_{AGW} = 0.112 \times I_{75Pa} \times S/A_{AGW}$$

When using the measured air leakage rate of the *building envelope* at a pressure differential of 0.3 in. of water for the *proposed design*, the air leakage rate shall be calculated as follows:

$$I_{75Pa} = Q/S$$

where

I_{75Pa}	=	air leakage rate of the *building envelope* (cfm/ft^2) at a fixed *building* pressure differential of 0.3 in. of water, or 1.57 psf
Q	=	volume of air in cfm flowing through the *building envelope* when subjected to a pressure differential of 0.3 in. of water, or 1.57 psf, in accordance with ASTM E 779
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

Exception to G3.1.1.4

A multizone airflow model alternative method to modeling *building envelope* air leakage may be used, provided the following criteria are met:

1. Where the calculations are made independently of the *energy simulation program*, the proposed method must comply with Section G2.5.
2. The method for converting the air leakage rate of the *building envelope* at 0.3 in. of water, or 1.57 psf, to the appropriate units for the *simulation program* is fully documented and submitted to the *rating authority* for approval.

G3.1.2 General Baseline HVAC System Requirements

HVAC systems in the *baseline building design* shall conform with the general provisions in this section.

G3.1.2.1 Equipment Efficiencies

All HVAC *equipment* in the *baseline building design* shall be modeled at the minimum *efficiency* levels, both part load and full load, in accordance with Tables G3.5.1 through G3.5.6. Where multiple *HVAC zones* or *residential spaces* are combined into a single *thermal block* in accordance with Table G3.1, the efficiencies (for baseline HVAC System Types 1, 2, 3, 4, 9, and 10) taken from Tables G3.5.1, G3.5.2, G3.5.4, and G3.5.5 shall be based on the equipment capacity of the *thermal block* divided by the number of *HVAC zones* or *residential spaces*. HVAC System Types 5 or 6 efficiencies taken from Table G3.5.1 shall be based on the cooling equipment capacity of a single floor when grouping identical floors in accordance with Section G3.1.1(a)(4).

$COP_{nfcooling}$ 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.

G3.1.2.2 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 G3.1.2.2.1, 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.

G3.1.2.2.1 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, 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 G3.1.2.2.1

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.

G3.1.2.3 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.

G3.1.2.4 Fan System Operation

Supply and return fans shall operate continuously whenever *HVAC zones* are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. Supply, return, and/or exhaust fans will remain on during occupied and unoccupied hours in *HVAC zones* that have health and safety mandated minimum *ventilation* requirements during unoccupied hours.

Exception to G3.1.2.4

For *Systems* 6 and 8, only the *terminal*-unit fan and *reheat* coil shall be energized to meet heating *set point* during unoccupied hours.

G3.1.2.5 Ventilation

Minimum *ventilation system outdoor air* intake flow shall be the same for the *proposed design* and *baseline building design*.

Exception to G3.1.2.5

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*.

G3.1.2.6 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 G3.1.2.6

Exception to G3.1.2.6

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 G3.1.2.6.1.

G3.1.2.6.1 Computer Room Economizers

Systems that serve *computer rooms* that are *HVAC System* 3 or 4 shall not have an economizer. *Systems* that serve *computer rooms* that are *HVAC System* 11 shall include an integrated *fluid economizer* meeting the requirements of Section 6.5.1.2 in the *baseline building design*.

G3.1.2.7 Economizer High-Limit Shutoff

The high-limit shutoff shall be a dry-bulb fixed switch with *set-point* temperatures in accordance with the values in Table G3.1.2.7.

G3.1.2.8 Design Airflow Rates

G3.1.2.8.1 Baseline All System Types Except System Types 9 and 10

System design supply airflow rates for the *baseline building design* shall be based on a supply-air-to-room temperature *set-point* difference of 20°F or the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. For *systems* with multiple zone *thermostat set points*, use the design *set point* that will result in the lowest supply air cooling *set point* or highest supply air heating *set point*. If return or relief fans are specified in the *proposed design*, the *baseline building design* shall also be modeled with fans serving the same functions and sized for the baseline *system* supply fan air quantity less the minimum *outdoor air*, or 90% of the supply fan air quantity, whichever is larger.

Exception to G3.1.2.8.1

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*.

G3.1.2.8.2 Baseline System Types 9 and 10

System design supply airflow rates for the *baseline building design* shall be based on the temperature difference between a supply air temperature *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*.

G3.1.2.9 System Fan Power

System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered *VAV* boxes) shall be calculated using the following formulas:

For *Systems* 1 and 2,

$$P_{fan} = \text{CFM}_s \times 0.3$$

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 G3.1.2.8.2),

$$P_{fan} = \text{CFM}_{nmc} \times 0.054$$

where

P_{fan}	=	electric power to fan motor, W
bhp	=	brake horsepower of baseline fan motor from Table G3.1.2.9

fan motor *efficiency*	=	the *efficiency* from Table G3.9.1 for the next motor size greater than the bhp
CFMs	=	the baseline *system* maximum design supply fan airflow rate, cfm
CFM_{nmc}	=	the baseline non-*mechanical cooling* fan airflow, cfm

G3.1.2.9.1

The calculated *system* fan power shall be distributed to supply, return, exhaust, and relief fans in the same proportion as the *proposed design*.

G3.1.2.10 Exhaust Air Energy Recovery

Individual fan *systems* that have both a design supply air capacity of 5000 cfm or greater and have a minimum design *outdoor air* supply of 70% or greater shall have an *energy* recovery *system* with at least 50% *enthalpy recovery ratio*. Fifty percent *enthalpy recovery ratio* shall mean a change in the enthalpy of the *outdoor air* supply equal to 50% of the difference between the *outdoor air* and return air at *design conditions*. Provision shall be made to bypass or *control* the heat recovery *system* to permit *air economizer* operation, where applicable.

Exception to G3.1.2.10

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.
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*.

G3.1.3 System-Specific Baseline HVAC System Requirements

Baseline *HVAC systems* shall conform with provisions in this section, where applicable, to the specified baseline *system* types, as indicated in section headings.

G3.1.3.1 Heat Pumps (Systems 2 and 4)

Electric air-source heat pumps shall be modeled with electric auxiliary heat and an *outdoor air thermostat*. The *systems* shall be controlled to energize auxiliary heat only when the *outdoor air* temperature is less than 40°F. The air-source heat pump shall be modeled to continue to operate while auxiliary heat is energized.

G3.1.3.2 Type and Number of Boilers (Systems 1, 5, 7, 11, and 12)

The *boiler* plant shall be natural draft, except as noted in Section G3.1.1.1. The *baseline building design boiler* plant shall be modeled as having a single *boiler* if the *baseline building design* plant serves a *conditioned floor area* of 15,000 ft^2 or less, and as having two equally sized *boilers* for plants serving more than 15,000 ft^2. *Boilers* shall be staged as required by the load.

G3.1.3.3 Hot-Water Supply Temperature (Systems 1, 5, 7, 11, and 12)

Hot-water design supply temperature shall be modeled as 180°F and design return temperature as 130°F.

G3.1.3.4 Hot-Water Supply Temperature Reset (Systems 1, 5, 7, 11, and 12)

Hot-water supply temperature shall be *reset* based on outdoor dry-bulb temperature using the following schedule: 180°F at 20°F and below, 150°F at 50°F and above, and ramped linearly between 180°F and 150°F at temperatures between 20°F and 50°F.

Exception to G3.1.3.4

Systems served by purchased heat.

G3.1.3.5 Hot-Water Pumps

The *baseline building design* hot-water pump power shall be 19 W/gpm. The pumping *system* shall be modeled as primary-only with continuous variable flow and a minimum of 25% of the design flow rate. Hot-water *systems* serving 120,000 ft^2or 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 G3.1.3.5

The pump power for *systems* using purchased heat shall be 14 W/gpm.

G3.1.3.6 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*.

G3.1.3.7 Type and Number of Chillers (Systems 7, 8, 11, 12, and 13)

Electric chillers shall be used in the *baseline building design* regardless of the cooling *energy* source, e.g. direct-fired absorption or absorption from purchased steam. The *baseline building design*'s chiller plant shall be modeled with chillers having the number and type as indicated in Table G3.1.3.7 as a function of *building* peak cooling load.

Exception to G3.1.3.7

Systems using purchased chilled water shall be modeled in accordance with Section G3.1.1.3.

G3.1.3.8 Chilled-Water Design Supply Temperature (Systems 7, 8, 11, 12, and 13)

Chilled-water design supply temperature shall be modeled at 44°F and return water temperature at 56°F.

G3.1.3.9 Chilled-Water Supply Temperature Reset (Systems 7, 8, 11, 12, and 13)

Chilled-water supply temperature shall be *reset* based on outdoor dry-bulb temperature using the following schedule: 44°F at 80°F and above, 54°F at 60°F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F.

Exception to G3.1.3.9

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.

G3.1.3.10 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. 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 G3.1.3.10

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.

G3.1.3.11 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 G3.1.3.11, floating up to the design leaving water temperature for the cooling tower. The *baseline building design* condenser-water pump power shall be 19 W/gpm and modeled as constant volume. For *computer room systems* using *System* 11 with an integrated *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.

G3.1.3.12 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.

G3.1.3.13 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 G3.1.3.13

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.

G3.1.3.14 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*.

G3.1.3.15 VAV Fan Part-Load Performance (Systems 5 through 8 and 11)

VAV system supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table G3.1.3.15.

G3.1.3.16 Computer Room Equipment Schedules

Computer room equipment schedules shall be modeled as a constant fraction of the peak design load per the following monthly schedule:

Month 1, 5, 9—25%

Month 2, 6, 10—50%

Month 3, 7, 11—75%

Month 4, 8, 12—100%

G3.1.3.17 System 11 Supply Air Temperature and Fan Control

Minimum volume *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 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.

G3.1.3.18 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.

G3.1.3.19 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 design room heating temperature *set point*.

Table G3.1.1-1 Baseline *Building Vertical Fenestration* Percentage of Gross *Above-Grade-Wall* Area

Building Area Types[a]	Baseline *Building* Gross *Above-Grade-Wall* Area
Grocery store	7%
Healthcare (outpatient)	21%
Hospital	27%
Hotel/motel (≤75 rooms)	24%
Hotel/motel (>75 rooms)	34%
Office (≤5000 ft^2)	19%
Office (5000 to 50,000 ft^2)	31%
Office (>50,000 ft^2)	40%
Restaurant (quick service)	34%
Restaurant (full service)	24%
Retail (stand alone)	11%
Retail (strip mall)	20%
School (primary)	22%
School (secondary and university)	22%
Warehouse (nonrefrigerated)	6%

Table G3.1.1-2 Baseline *Service Water-Heating System*

Building Area Type	Baseline Heating Method
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*

Table G3.1.1-3 Baseline *HVAC System* Types

Building Type, Number of *Floors*, and Gross Conditioned Floor Area	Climate Zones 3B, 3C, and 4 to 8	Climate Zones 0 to 3A
Residential	*System* 1—*PTAC*	*System* 2—*PTHP*
Public assembly <120,000 ft^2	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Public assembly ≥120,000 ft^2	*System* 12—SZ-CV-HW	*System* 13—SZ-CV-ER
Heated-only storage	*System* 9—Heating and *ventilation*	*System* 10—Heating and *ventilation*
Retail and 2 *floors* or fewer	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Other nonresidential and 3 *floors* or fewer and <25,000 ft^2	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Other nonresidential and 4 or 5 *floors* and <25,000 ft^2 or 5 *floors* or fewer and 25,000 ft^2 to 150,000 ft^2	*System* 5—Packaged *VAV* with *reheat*	*System* 6—Packaged *VAV* with PFP boxes
Other nonresidential and more than 5 *floors* or >150,000 ft^2	*System* 7—*VAV* with *reheat*	*System* 8—*VAV* with PFP boxes

Notes:
1. *Residential building* types include dormitory, hotel, motel, and multifamily. *Residential space* types include guest rooms, living quarters, private living *space*, and sleeping quarters. Other *building* and *space* types are considered *nonresidential*.
2. Where attributes make a *building* eligible for more than one baseline *system* type, use the predominant condition to determine the *system* type for the entire *building* except as noted in Section G3.1.1.
3. For laboratory *spaces* in a *building* having a total laboratory exhaust rate greater than 15,000 cfm, use a single *system* of type 5 or 7 serving only those *spaces*.
4. For hospitals, depending on *building* type, use *System* 5 or 7 in all climate zones.
5. Public assembly *building* types include houses of worship, auditoriums, movie theaters, performance theaters, concert halls, arenas, enclosed stadiums, ice rinks, gymnasiums, convention centers, exhibition centers, and natatoriums.

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 G3.1.1.3.
b. For Climate Zones 0 through 3A, the heating type shall be *electric resistance*. For all other climate zones the heating type shall be hot-water fossil-*fuel boiler*.

Table G3.1.2.6 Climate Conditions under which Economizers are Included for Comfort Cooling for Baseline *Systems* 3 through 8 and 11, 12, and 13

Climate Zone	Conditions
0A, 0B, 1A, 1B, 2A, 3A, 4A	NR
Others	Economizer Included

Note: NR means that there is no conditioned *building floor* area for which economizers are included for the type of zone and climate.

Table G3.1.2.7 Economizer High-Limit Shutoff Temperature

Climate Zone	Dry-Bulb Temperature *Set Point*
2B, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	75°F
5A, 6A	70°F

Table G3.1.2.9 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
$\text{CFM}_s \times 0.00094 + A$	$\text{CFM}_s \times 0.0013 + A$	$\text{CFM}_s \times 0.00062 + A$

Notes:
1. Where *A* is calculated according to Section 6.5.3.1.1 using the pressure-drop adjustment from the *proposed design* and the design flow rate of the baseline *building system*.
2. Do not include pressure-drop adjustments for evaporative coolers or heat recovery devices that are not required in the baseline *building system* by Section G3.1.2.10.

Table G3.1.3.7 Type and Number of Chillers

Building Peak Cooling Load	Number and Type of Chillers
≤300 tons	1 water-cooled screw chiller
>300 tons, <600 tons	2 water-cooled screw chillers sized equally
≥600 tons	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

Table G3.1.3.11 Heat-Rejection Leaving Water Temperature

Climate Zone	Leaving Water Temperature
5B, 5C, 6B, 8	65°F
0B, 1B, 2B, 3B, 3C, 4B, 4C, 5A, 6A, 7	70°F
3A,4A	75°F
0A, 1A, 2A	80°F

Table G3.1.3.15 Part-Load Performance for *VAV* Fan *Systems*

Method 1—Part-Load Fan Power Data	
Fan Part-Load Ratio	Fraction of Full-Load Power
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00

Method 2—Part-Load Fan Power Equation

$$P_{fan} = 0.0013 + 0.1470 \times \text{PLR}_{fan} + 0.9506 \times (\text{PLR}_{fan})^2 - 0.0998 \times (\text{PLR}_{fan})^3$$

where

P_{fan} = fraction of full-load fan power and
PLR_{fan} = fan part-load ratio (current cfm/design cfm).

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

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	**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	$SHGC_{all}$-0.39	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

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

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

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

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

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

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_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}1.22	$SHGC_{alr}$ 0.40	VT_{alr}0.44
10.1% to 20.0%	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}1.22	$SHGC_{alr}$ 0.40	VT_{alr}0.44
20.1% to 30.0%	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}1.22	$SHGC_{alr}$ 0.40	VT_{alr}0.44
30.1% to 40.0%	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}0.46	$SHGC_{alr}$ 0.40	VT_{alr}0.44	U_{alr}1.22	$SHGC_{alr}$ 0.40	VT_{alr}0.44
Skylight All, % of Roof									
0% to 2.0%	U_{alr}0.58	$SHGC_{alr}$ 0.55	VT_{alr}0.61	U_{alr}0.58	$SHGC_{alr}$ 0.55	VT_{alr}0.61	U_{alr}0.81	$SHGC_{alr}$ 0.55	VT_{alr}0.61
2.1%+	U_{alr}0.58	$SHGC_{alr}$ 0.55	VT_{alr}0.61	U_{alr}0.58	$SHGC_{alr}$ 0.55	VT_{alr}0.61	U_{alr}0.81	$SHGC_{alr}$ 0.55	VT_{alr}0.61

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 $COP_{nfheating}$	

Table G3.5.3 *Performance Rating Method* Water Chilling Packages—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure
Water-cooled, electrically operated, positive displacement (rotary screw and scroll)	<150 tons	*kW*/ton	0.790 FL 0.676 *IPLV*.IP	ARI 550/590
	≥150 tons and <300 tons		0.718 FL 0.629 *IPLV*.IP	
	≥300 tons		0.639 FL 0.572 *IPLV*.IP	
Water-cooled, electrically operated, centrifugal	<150 tons	*kW*/ton	0.703 FL 0.670 *IPLV*.IP	ARI 550/590
	≥150 tons and <300 tons		0.634 FL 0.596 *IPLV*.IP	
	≥300 tons		0.576 FL 0.549 *IPLV*.IP	

Table G3.5.4 *Performance Rating Method* Electrically Operated *Packaged Terminal Air Conditioners*, *Packaged Terminal Heat Pumps* (efficiency ratings excluding supply fan power)

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum *Efficiency* [a]	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

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 Plaza areas Special feature areas	0.2 W/ft^2
	Stairways	1.0 W/ft^2
	Building Entrances and Exits	
	Main entries	30 W/linear foot of *door* width
	Other *doors*	20 W/linear foot of *door* width
	Canopies and Overhangs	
	Canopies (free standing and attached and overhangs)	1.25 W/ft^2
	Outdoor Sales	
	Open areas (including vehicle sales lots)	0.5 W/ft^2
	Street frontage for vehicle sales lots in addition to open-area allowance	20 W/linear foot
Nontradable Surfaces (*Lighting power density* calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “Tradable Surfaces” section of this table.)	*Building* Façades	0.2 W/ft^2 for each illuminated wall or surface or 5.0 W/linear foot) for each illuminated wall or surface length
	Automated Teller Machines (ATMs) and Night Depositories	270 W per location plus 90 W per additional ATM per location
	Entrances and Gatehouse Inspection Stations at Guarded Facilities	1.25 W/ft^2 of uncovered area (covered areas are included in the “Canopies and Overhangs” section of “Tradable Surfaces”)
	Loading Areas for Law Enforcement, Fire, Ambulance and Other Emergency *Service* Vehicles	0.5 W/ft^2 of uncovered area (covered areas are included in the “Canopies and Overhangs” section of “Tradable Surfaces”)
	Drive-up Windows at Fast-Food Restaurants	400 W per drive-through
	Parking Near 24-Hour Retail Entrances	800 W per main entry

Table G3.7 *Performance Rating Method Lighting Power Density* Allowances and *Occupancy Sensor* Reductions Using the Space-by-Space Method

Common *Space* Types[a]	*Lighting Power Density*, W/ft²	*Occupancy Sensor* Reduction[b]
Audience Seating Area		
Auditorium	0.90	10%
Convention center	0.70	10%
Exercise center	0.30	10%
Gymnasium	0.40	10%
Motion picture theater	1.20	10%
Penitentiary	0.70	10%
Performing arts theater	2.60	10%
Religious facility	1.70	10%
In a sports arena	0.40	10%
Transportation facility	0.50	10%
All other audience seating area	0.90	10%
Atrium		
≤40 ft in height	0.0375 per foot in total height	10%
>40 ft in height	0.50 + 0.025 per foot in total height	10%
Banking Activity Area	1.50	10%
Breakroom (See Lounge/Breakroom)		
Classroom/Lecture Hall/Training Room		
Penitentiary	1.30	None
Preschool through 12th grade, laboratory, and shop classrooms	1.40	30%
All other classroom/lecture hall/training room	1.40	None
Conference/Meeting/Multipurpose Room	1.30	None
Confinement Cells	0.90	10%
Copy/Print Room	0.90	10%
Corridor		
Facility for the visually impaired (and used primarily by residents)	1.15	25%
Hospital	1.00	25%
Manufacturing facility	0.50	25%
A other corridor	0.50	25%
Courtroom	1.90	10%
Computer Room	2.14	35%
Dining Area		
Penitentiary	1.30	35%
Facility for the visually impaired (and used primarily by residents)	3.32	35%
Bar/lounge or leisure dining	1.40	35%
Cafeteria or fast food dining	0.90	35%
Family dining	2.10	35%
All other dining area	0.90	35%
Electrical/Mechanical Room	1.50	30%
Emergency Vehicle Garage	0.80	10%
Food Preparation Area	1.20	30%
Guest Room	1.14	45%
Judges Chambers	1.30	30%
Dwelling Unit	1.07	None

a. In cases where both a common *space* type and a *building* area specific *space* type are listed, the *building* area specific *space* type shall apply
b. For *manual*-ON or partial-auto-ON *occupancy sensors*, the *occupancy sensor* reduction factor shall be multiplied by 1.25.
c. For *occupancy sensors* controlling individual workstation lighting, *occupancy sensor* reduction factor shall be 30%.

Table G3.7 *Performance Rating Method Lighting Power Density* Allowances and *Occupancy Sensor* Reductions Using the Space-by-Space Method *(Continued)*

Common *Space* Types[a]	*Lighting Power Density*, W/ft^2	*Occupancy Sensor* Reduction[b]
Laboratory		
In or as a classroom	1.40	None
All other laboratory	1.40	10%
Laundry/Washing Area	0.60	10%
Loading Dock, Interior	0.59	10%
Lobby		
Facility for the visually impaired (and used primarily by residents)	2.26	25%
Elevator	0.80	25%
Hotel	1.10	25%
Motion picture theater	1.10	25%
Performing arts theater	3.30	25%
All other lobby	1.30	25%
Locker Room	0.60	25%
Lounge/Breakroom		
Healthcare facility	0.80	None
All other lounge/breakroom	1.20	None
Office		
Enclosed	1.10	30%
Open plan	1.10	15%[c]
Parking Area, Interior	0.20	15%
Pharmacy Area	1.20	10%
Restroom		
Facility for the visually impaired (and used primarily by residents)	1.52	45%
All other restroom	0.90	45%
Sales Area	1.70	15%
Seating Area, General	0.68	10%
Stairwell	0.60	75%
Storage Room		
Hospital	0.90	45%
≥50 ft^2	0.80	45%
<50 ft^2	0.80	45%
Vehicular Maintenance Area	0.70	10%
Workshop	1.90	10%
***Building* Type Specific *Space* Types [a]**	***Lighting Power Density*, W/ft^2**	***Occupancy Sensor* Reduction [b]**
Assisted Living Facility		
Chapel (used primarily by residents)	2.77	10%
Recreation room (used primarily by residents)	3.02	10%
Automotive (See “Vehicular Maintenance Area”)		10%
Convention Center—Exhibit *Space*	1.30	35%
Dormitory—Living Quarters	1.11	10%
Fire Station—Sleeping Quarters	0.30	10%
Gymnasium/Fitness Center		
Exercise area	0.90	35%
Playing area	1.40	35%

a. In cases where both a common *space* type and a *building* area specific *space* type are listed, the *building* area specific *space* type shall apply
b. For *manual*-ON or partial-auto-ON *occupancy sensors*, the *occupancy sensor* reduction factor shall be multiplied by 1.25.
c. For *occupancy sensors* controlling individual workstation lighting, *occupancy sensor* reduction factor shall be 30%.

Table G3.7 *Performance Rating Method Lighting Power Density* Allowances and *Occupancy Sensor* Reductions Using the Space-by-Space Method *(Continued)*

***Building* Type Specific *Space* Types [a]**	***Lighting Power Density*, W/ft^2**	***Occupancy Sensor* Reduction [b]**
Healthcare Facility		
Emergency room	2.70	10%
Exam/treatment room	1.50	10%
Medical supply room	1.40	45%
Nursery	0.60	10%
Nurse's station	1.00	10%
Operating room	2.20	10%
Patient room	0.70	10%
Physical therapy room	0.90	10%
Recovery room	0.80	10%
Library		
Reading area	1.20	15%
Stacks	1.70	15%
Manufacturing Facility		
Detailed manufacturing area	2.10	10%
Equipment room	1.20	10%
Extra-high bay area (>50 ft *floor*-to-ceiling height)	1.32	10%
High bay area (25 to 50 ft *floor*-to-ceiling height)	1.70	10%
Low bay area (<25 ft *floor*-to-ceiling height)	1.20	10%
Museum		
General exhibition area	1.00	10%
Restoration room	1.70	10%
Post Office—Sorting Area	1.20	10%
Religious Facility		
Fellowship hall	0.90	10%
Worship/pulpit/choir area	2.40	10%
Retail Facilities		
Dressing/fitting room	0.89	10%
Mall concourse	1.70	10%
Sports Arena—Playing Area		
Class I facility	4.61	10%
Class II facility	3.01	10%
Class III facility	2.26	10%
Class IV facility	1.50	10%
Transportation Facility		
Baggage/carousel area	1.00	10%
Airport concourse	0.60	10%
Ticket counter	1.50	10%
Warehouse—Storage Area		
Medium to bulky, palletized items	0.90	45%
Smaller, hand-carried items	1.40	45%

a. In cases where both a common *space* type and a *building* area specific *space* type are listed, the *building* area specific *space* type shall apply
b. For *manual*-ON or partial-auto-ON *occupancy sensors*, the *occupancy sensor* reduction factor shall be multiplied by 1.25.
c. For *occupancy sensors* controlling individual workstation lighting, *occupancy sensor* reduction factor shall be 30%.

Table G3.8 *Performance Rating Method Lighting Power Densities* Using the *Building* Area Method

***Building* Area Type**	***Lighting Power Density*, W/ft²**
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

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 G3.9.1

a. Use the *efficiency* for the next motor size greater than the calculated bhp.

Table G3.9.3 *Performance Rating Method* Hydraulic Elevator Motor *Efficiency*

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.

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.

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, 11.2(d), and G1.2.1(c) 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 nonenergy 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.
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 (US)
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. US 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 *commissioning provider* and the *FPT providers* 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).

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, 11.2(d), and G1.2.1(c).

b. Provisions are established in the construction documents for verification and *FPT*, and *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.

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*		×

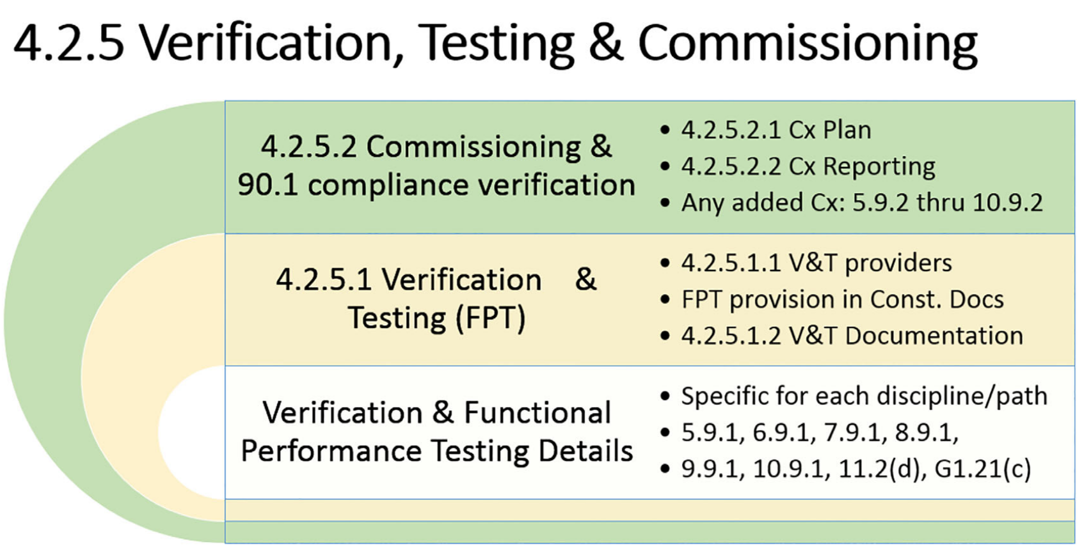

Figure H-1 Coordination of verification/FPT and commissioning requirements.

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 suggested 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, 11.2(d), and G1.2.1. 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.

Table H-2 Typical Commissioning Process Activities, Deliverables and Responsibilities

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 *commissioning* teams	Predesign
2	Basis of Design (BoD)	BoD document	NR	Design team	Design through construction
3	*Commissioning* plan	*Commissioning* 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*	NR	Cx provider	Construction
7	*Commission* designated systems, inspections, *FPT*	Installation, inspection, functional test reports, performance test reports*	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*	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*	NR	Contractors and manufacturers with review by *Cx provider*	Final
11	Preliminary Cx report	Preliminary Cx report	4.2.5.1.2, 4.2.5.2.2	Cx provider	Construction
12	Cx activities during occupancy	Additional information and updates to reports*	NR	*Cx provider* and building operations	Final
13	Final Cx report	Final Cx Report	4.2.5.2.2	Cx provider	Final

* Noted interim or partial deliverables are typically included in the preliminary and final *commissioning* reports.
NR = Not required by Standard 90.1; Cx = commissioning.

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:

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.	
5.4.3.1.2	Air barrier installation	Air barriers meet the following: • Continuity at all transitions within the exterior wall assemblies, including, but not limited to, terminations between opaque walls and fenestration and door assemblies; envelope penetrations; wall and floors; walls and roof; and joints, seams, connection between planes, and changes in air barrier material. • Surfaces of substrate or membrane are clean and free of dirt, debris, oil, etc., as required by manufacture installation instructions. • Installed within allowed weather conditions as defined by the product manufacturer. • Adequately sealed and attached to the substrate.	
5.4.3.1.3	Testing, acceptable materials and assemblies	Continuous air barrier materials and assemblies comply with specific manufacturer requirements or are tested for leakage resistance.	
5.4.3.2	Fenestration and doors	*Fenestration* and *doors* have manufacturer documentation that air leakage does not exceed allowable leakage rates.	
5.5.4.2	Fenestration and doors	*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 installation	Insulation material meets design specifications and is continuous.	
5.9	Inspection and verification	Envelope assemblies and *fenestration* comply with requirements. *Building envelope* performance is tested or verified.	
6.3.2	Simplified Approach HVAC criteria	HVAC *equipment* meets efficiency criteria and controls function properly.	
6.4.1	Equipment efficiencies, verification, and labeling	*Equipment* selected meets the minimum *efficiency* requirements and is correctly labeled.	
6.4.2	Load calculations	HVAC *equipment* matches load and pump head calculations.	
6.4.3.1/2	Zone thermostatic controls	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.	
6.4.3.7	Humidification and dehumidification	No simultaneous humidification and dehumidification operation.	
6.4.3.8	Freeze protection and ice/snow melt	*Automatic* shutoff based on outdoor temperature or precipitation.	
6.4.3.9	Ventilation controls for high-occupancy areas	*Demand controlled ventilation (DCV) system* where applicable.	
6.4.3.10	Single-zone VAV control	Single-zone systems have multi-peed or VAV control properly configured.	
6.4.4.1	Mechanical 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.	

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	Water 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	Simultaneous heat/cool: zone controls	Zone box minimum position and operating sequence, *deadband*, and *set points* configured properly.	
6.5.2.2	Simultaneous heat/cool: hydronic systems	Two-pipe changeover control *dead band* and hydronic heat-pump system controls configured properly.	
6.5.2.3/4	Simultaneous heat/cool: dehumidification and 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.	
6.9	System *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	Pool time switch controls	Proper configuration of pool heater and pump controls.	

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
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 application lighting control	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	Lighting functional 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.	
11.2(d), and G1.21l	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.	

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

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. 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 Cx 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 (*Cx* 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, 6.7.2, 8.7.1, 9.7.2)

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, 6.7.2, 8.7.2, 9.7.2)

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 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.

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

Addenda Description Information

ANSI/ASHRAE/IES Standard 90.1-2019 incorporates all addenda to ANSI/ASHRAE/IES Standard 90.1-2016. Table I-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 I-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2016

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
bg[b]	9.2, 9.3, Table 9.3	Adds a simplified building method for interior lighting in offices, schools, and retail buildings, and exterior lighting. This includes the addition of Table 9.3.	1/12/2019	10/3/2014	12/14/2018	2/13/2019
dn[c]	A9.4	Allows the use of the R-value of an airspace in enclosed cavities with or without insulation (Appendix A). Expands the R-value table in Appendix A (based on 2009 *ASHRAE Handbook—Fundamentals*, Chapter 26).	1/12/2019	1/16/2019	12/14/2018	1/17/2019
a	6.4.3.3.3, 6.3.3.4.2, 6.5.1.1.4	Changes term “ventilation air” to “outdoor air” in multiple locations. Revises tables and footnotes. Clarifies requirements for economizer return dampers.	1/20/2018	1/24/2018	1/8/2018	1/25/2018
b	5.5.3.1.1; 12	Updates reference to ANSI/CRRC S100 “Standard Test Methods for Determining Radiative Properties of Materials”.	6/24/2017	6/24/2017	6/13/2017	6/29/2017
c	3.2	Adds rooftop monitors to definition of fixed and operable vertical fenestration.	6/24/2017	6/24/2017	6/13/2017	6/29/2017
d	Table G3.1.1	Modifies text to make it consistent with other portions of Appendix G for projects undergoing phased permitting.	6/24/2017	6/24/2017	6/13/2017	6/29/2017
e	Table G3.1.11	Adds direction that SWH piping losses shall not be modeled.	6/24/2017	6/24/2017	6/13/2017	6/29/2017
f	G3.1.2.1	Modifies text to require that the capacity used for selecting the system efficiency represents that for the size of the actual zone instead of the size of the zones as combined into a single thermal block.	6/24/2017	6/24/2017	6/13/2017	6/29/2017
g	3.2; 6.3.2, 6.5.3.8	Provides definition of “occupied-standby mode” and adds new ventilation air requirements for zones served rooms in occupied-standby mode.	1/20/2018	1/24/2018	1/8/2018	1/25/2018

a. These descriptions may not be complete and are provided for information only.
b. Formerly addendum bg to Standard 90.1-2013.
c. Formerly addendum dn to Standard 90.1-2013.

Table I-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2016

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
h	6.5.6.1	Clarifies that exhaust air energy recovery systems should be sized to meet both heating and cooling design conditions unless one mode is not exempted by existing exceptions.	1/20/2018	1/24/2018	1/8/2018	1/25/2018
j	6.4.3.8	Changes an exception related to demand control ventilation.	6/24/2017	6/24/2017	6/13/2017	6/29/2017
k	3.2; 6.4.3.3.5	Revises definition of “networked guest room control system” and aligns HVAC and lighting time-out periods for guest rooms.	6/23/2018	6/27/2018	5/30/2018	7/25/2018
l	Table G3.1.2.9	Adds requirements for fan break horsepower for two systems.	1/20/2018	1/24/2018	1/8/2018	1/25/2018
m	Table G3.1.5	Lowers baseline building performance air leakage and sets an air leakage value to be used in conjunction with the air-barrier verification path.	1/12/2019	1/16/19	12/14/2018	2/13/2019
n	3.2	Removes ten unused definitions and changes definition of “unitary cooling equipment” to “unitary air conditioners.”	1/20/2018	1/24/2018	1/8/2018	1/25/2018
o	3.2; 4.2.2.3; 5.5, 5.7 through 11.7; G1.3	Revises the submittals section of the envelope and power chapters for consistency across the standard.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
p	Table 6.1.8 -14	Revises the rating conditions for indoor pool dehumidifiers.	1/20/2018	1/24/2018	1/8/2018	1/25/2018
q	5.4.3, 5.5, 5.8.3, 5.9.1	Clarifies and restructures air leakage requirements for the building envelope.	9/14/2018	10/10/2018	10/23/2018	12/7/2018
r	G3.1.2.6	Specifies air economizer control types for Appendix G.	1/20/2018	1/24/2018	1/8/2018	1/25/2018
s	4.2.1.1; 11.4.3.1; G2.4	Modifies the Performance Cost Index (PCI) equation to implement a 5% limitation on renewable energy usage and clarifies what types of renewable energy systems are eligible.	9/14/2018	10/10/2018	10/23/2018	12/7/2018
t	9.4.2, Table 9.4.2-2	Expands the exterior LPD application table to cover additional exterior spaces that are not currently in the exterior LPD table.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
v	6.5.6.3	Adds Section 6.5.6.3 containing heat recovery requirements for space conditioning in acute inpatient hospitals.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
x	4.1.1.2, 4.2.1.1, 4.2.1.2, 4.2.1.3	Clarifies compliance paths for new construction, additions, and alterations.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
y	G3.1.2.2	Fixes duct sizing run parameters within the Appendix G.	6/22/2019	6/26/2019	6/10/2019	7/1/2019

a. These descriptions may not be complete and are provided for information only.
b. Formerly addendum bg to Standard 90.1-2013.
c. Formerly addendum dn to Standard 90.1-2013.

Table I-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2016

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
z	G3.1.2.1, Table G3.5.1, Table G3.5.2	Modifies the formulas in Section 11 and G3.1.2.1 for removing fan energy from baseline packaged heating and cooling efficiency ratings to cap the system capacity equations in Section 11 to levels allowed in Section 6 and provide a fixed baseline efficiency rating for Appendix G.	9/14/2018	9/28/19	10/23/2018	10/1/2018
ab	3.2	Modifies definition of “door”, “entrance door”, “fenestration”, and “sectional garage door.”	6/23/2018	6/27/2018	5/30/2018	6/28/2018
ac	3.1, 3.2	Clarifies use of defined terms to include the term with different tense or plurality.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
ad	5.2 through 11.2	This addendum clarifies the requirements for showing compliance using the methods in Sections 5 through 10, or Section 11, or Appendix G.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
ae	3.2; 6.4.3.6; G3.1.3.18	Clarify humidification and dehumidification control requirements.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
ag	Table G3.1.12	Provides accounts for the inclusion of automatic receptacle controls in a proposed building design for spaces that are not required to have them.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
ah	9.1.4	Updates the language and terminology of the lighting wattage section. Also adds a section specifically to address using DC power over Cat6 structured cable for connection of LED lighting to a remote power supply.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
ai	3.2; 4.2.5; 5.2.9; 6.7.2.4; 9.4.3; 5.9 through 10.9; 11.2	Restructures commissioning and functional testing requirements in all sections of Standard 90.1 to require verification for smaller and simpler buildings and commissioning for larger and more complex buildings.	1/12/2019	1/16/2019	12/14/2018	2/13/2019
aj	3.2, 6.5.1, 6.5.2.3, 6.5.4.4	Adds a new definition “process application” and uses it throughout the standard in place of “process load.”	1/12/2019	1/16/2019	12/14/2018	2/13/2019
ak	Table G3.1.5, Tables G3.4-1 through G3.4-8	Defines SHGC baseline for buildings in zones where there is no prescriptive maximum SHGC.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
al	Table G3.1.3, Table G3.1.7	Clarifies the modeling rules within Section G3.1.	6/22/2019	6/26/2019	6/10/19	7/1/2019
am	6.5.6.4	Adds an indoor pool dehumidifier energy recovery requirement in new Section 6.5.6.4.	6/23/2018	6/27/2018	5/30/2018	6/28/2018
an	3.2; 10.4.7; Table 10.8-6; 12; Appendix E	Provides a new table (Table 10.8.6) of information about the new efficiency requirements for commercial and industrial clean water pumps to users of ASHRAE 90.1. It also provides new definitions that are needed to accompany the table. New Section 10.4.7 was also added.	6/22/2019	6/26/2019	6/10/2019	7/24/2019

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c. Formerly addendum dn to Standard 90.1-2013.

Table I-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2016

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
ao	3.2; 6.5.3.1.3; 12	Introduces the revised fan product efficiency requirement FEI and complements the fan power limitation in section 6.5.3.1.1.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
ap	6.5.3.5	Revises supply air temperature reset controls.	9/14/2018	9/28/19	10/23/2018	10/1/2018
aq	9.1.1, 9.2.2.3, 9.4.1.1, 9.4.1.3, 9.4.4, 9.6.2	Clarifies lighting control requirements for applications not covered in Section 9.6.2.	9/14/2018	9/28/19	10/23/2018	10/1/2018
ar	Table G3.1.12, G3.1.2.9, Table G3.5.5, Table G.3.5.6, Table G3.6, Table G3.9.1	Cleanup of motor requirements in Appendix G related to Addendum di in Standard 90.1-2016.	9/14/2018	9/28/19	10/23/2018	10/1/2018
as	Appendix I	Adds an informative appendix specific to commissioning.	NA	NA	NA	NA
at	11.5.1; G1.2.2	Revises language for energy accounting at buildings that provide fuel or electricity to vehicles.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
au	6.5.2.1	Eliminates the requirement that zones with DDC have air flow rates that are no more than 20% of the zone design peak flow rate.	1/12/2019	1/16/2019	12/14/2018	1/17/2019
aw	3.2; Tables 5.5-0 through 5.5-8, 5.8.2.5; 12	Revises the fenestration prescriptive criteria in Tables 5.5-0 through 5.5-8.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
ay	3.2; 6.5.6	Provides separate requirements for nontransient dwelling unit exhaust air energy recovery.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
az	Table G3.1.17	Revises the modeling methodology language to clarify the baseline and proposed designs for refrigeration equipment.	1/12/2019	1/16/2019	12/14/2018	1/17/2019
ba	Table G3.1.1, Table G3.1.11	Establishes a methodology for determining the baseline flow rates on projects where service water-heating is demonstrated to be reduced by water conservation measures that reduce the physical volume of service water required.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bb	Table 9.6.1	Revises the lighting power densities for the Space-by-Space Method.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
bd	Table 6.8.1-16	Adds the minimum efficiency requirements of heat pump and heat reclaim chiller packages.	6/22/2019	6/26/2019	6/10/2019	7/1/2019

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Table I-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2016

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
be	6.4.1.1; Table 6.8.1-10, and 6.8.1-17	Revises the efficiency requirements for Computer Room air conditioners.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bf	5.4.3.4; 10.4.5	Establishes an alternative to the requirement for vestibules by use of an air curtain that meets specific requirements prescribed in the proposed language. Adds new Section 10.4.5.	6/22/2019	6/26/2019	6/10/2019	7/24/2019
bh	Table 5.8.3.2	Corrects an omission related to nonswinging doors in Table 5.8.3.2.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bi	11.4.2; 12; Appendix C; Appendix G	Updates the reference year for Standard 140 in Sections 11 and 12 as well as Appendices C and G.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bj	6.5.5.1	Adds tables to the list of products that are exempt from meeting the requirements of Section 6.5.6.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bk	3.2; 11.4.3.2; G2.4.2	Clarifies that such projects must model the same electricity generation system in the baseline and proposed design and is aligned with the interpretation IC 90.1- 2013-16 of ANSI/ASHRAE/IES Standard 90.1-2013 from January 21, 2018.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bl	Table 6.8.1-1	Revises Table 6.8.1-1, "Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements."	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bm	Tables 6.8.1-2 and 6.8.1-15	Revises Table 6.8.1-2, "Electrically Operated Air Cooled Unitary Heat Pumps—Minimum Efficiency Requirements." Adds Table 6.8.1-15.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bn	3.2; Table 6.8.1-4; Table F-3	Revises 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." Adds Table F-3.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bo	3; Table 6.8.1-5; Table F-4	Revises 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" and adds Table F-4, "Residential Warm Air Furnaces—Minimum Efficiency Requirements for sale in the U.S. (see 10 CFR Part 430)."	6/26/2019	8/1/2019	7/19/2019	8/26/2019
bp	Table 6.8.1-6; Table F-5	Revises Table 6.8.1.6, "Gas and Oil-Fired Boilers—Minimum Efficiency Requirements" and adds Table F-5, "Residential Boiler Minimum Efficiency Requirements for applications in the U.S. (Refer to 10 CFR 430)."	7/22/2019	8/15/2019	7/19/2019	8/19/2019

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Table I-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2016

Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
bq	Table 6.8.1-7; 12	Revises Table 6.8.1-7, “Performance Requirements for Heat Rejection Equipment—Minimum Efficiency Requirements.”	6/22/2019	6/26/2019	6/10/2019	7/1/2019
br	Table 6.8.1-11	Revises the previous Tables 6.8.1-12 and 13 and combines them into one table: Table 6.8.1-13, “Commercial Refrigerators, Commercial Freezers and Refrigeration—Minimum Efficiency Requirements.”	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bs	Table 7.8; F2; Table F-2	Revises Table 7.8, Performance Requirements for Water-Heating Equipment—Minimum Efficiency Requirements” and Table F-2, “Minimum Energy Efficiency Requirements for Water Heaters.”	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bt	Table 4.2.1.1	Revises Table 4.2.1.1, “Building Performance Factor (BPF).”	6/22/2019	6/26/2019	6/10/2019	7/1/2019
bu	Table G3.1.1-1, G3.1.1, G3.1.3, Tables G3.4-1 through G3.4-8	Clarifies requirements in the Appendix G as they related to HVAC zones and baseline heating.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bv	6.2.1, 6.6.2, 8.2.1, 8.6.1	Clarifies that designers have the option to use ASHRAE Standard 90.4 requirements instead of ASHRAE 90.1 requirements in computer rooms that have an IT equipment load larger than 10 kW. Adds Section 8.6.1.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
bx	3.2; A6.1, A6.3	Adds heated slab F-factors for multiple combinations of under-slab and perimeter insulation in Appendix A. Adds Tables A6.3.1-1 and A6.3.1-2.	6/22/2019	6/26/2019	6/10/2019	6/27/2019
bz	3.2; C1.4, C2, C3.1.2, C3.3, C3.5.5.1, C3.5.8	Clarifies requirements of Appendix C as they pertain to informative outputs, the schedule of shades, energy costs, and updated references to Section 6.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
ca	Table A3.2.3	Adds U-factors to Table A3.2.3 for use of continuous insulation on metal building walls with double layer cavity insulation.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
cc	A9.4.6	Clarifies the limitations of the calculation procedures in A9.4.6.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
ce	6.5.3.1.2	Makes revisions to provide energy savings potential by removing one of three criteria for fan motor selections, increasing the design options for load-matching variable-speed fan applications, accommodating new motor and drive technologies, and simplifying the motor selection criteria for fans.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
cf	6.4.5	Adds vacuum insulating glazing to the list of options for reach-in doors in walk-in coolers and freezers.	7/22/2019	8/15/2019	7/19/2019	8/19/2019

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Addendum	Sections	Description of Changes[a]	ASHRAE Standard Committee Approval	ASHRAE BOD/ Tech. Council Approval	IES BOD Approval	ANSI Approval
cg	Table 9.5.1	Revises Table 9.5.1, "Lighting Power Density Allowances Using the Building Area Method."	6/22/2019	6/26/2019	6/10/2019	7/1/2019
ch	3.2; 9.4.1.1(e)	Clarifies daylighted area requirements as they relate to skylights and clarifies primary sidelighting requirements.	6/22/2019	6/26/2019	6/10/2019	6/27/2019
ci	Table 4.2.1.1	Further revises Table 4.2.1.1, "Building Performance Factor (BPF)."	6/22/2019	6/26/2019	6/10/2019	7/1/2019
cj	Table 11.5.1.6; Table G3.1.6; Table G3.7	Revises the energy cost budget method in reference to lighting.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
cl	3.2; 11; Appendix G	Clarifies requirements throughout Section 11 to better align with Appendix G providing greater consistency between the two sections.	6/26/2019	8/1/2019	7/19/2019	8/26/2019
cm	6.5.2.1	Revises exceptions related to DDC enabled zones.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
cn	6.4, 6.4.1.1, 6.4.5(m); Tables 6.8.1-18, -19, -20	Cleans up outdated language regarding walk-in cooler and walk-in freezer requirements, and make the requirements consistent with current federal regulations that either already came into effect June 5, 2017 or will come into effect July 10, 2020. Adds new Section 6.4.5(m) and Tables 6.8.1-18, 6.8.1-19, and 6.8.1-20.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
co	12	Revises the normative references in Standard 90.1.	6/22/2019	6/26/2019	6/10/2019	7/1/2019
cq	3.2; 6.4.1.2, 6.5.3.1.3	Makes clarifications ensure that the maximum fan power input is properly reported for installations both inside and outside the United States. Adds Sections 6.4.1.3 and 6.5.3.1.3.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
cs	Appendix E	Revises the informative references of the Informative Appendix E.	NA	NA	NA	NA
ct	12	Updates the CTI normative reference in Standard 90.1.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
cu	6.4.1.1, 6.4.1.5, Table 6.8.1-8	Revises requirements for liquid-to-liquid heat exchangers.	7/22/2019	8/15/2019	7/19/2019	8/19/2019
cv	9.4.1.2	Updates lighting control requirements for parking garages in Section 9.4.1.2.	6/26/2019	8/1/2019	7/19/2019	8/26/2019
cw	9.4.1.1(e), 9.4.1.1(f)	Revises the daylight responsiveness requirements to continuous dimming.	6/26/2019	8/1/2019	7/19/2019	8/26/2019
cy	9.4.1(e)	Revises the sidelighting requirement exceptions.	7/22/2019	8/15/2019	7/19/2019	8/19/2019

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This annex contains normative material from an existing ASHRAE standard that is cited in this standard. This annex is not part of this standard; its inclusion is merely informative. It is included here to facilitate use of this standard.

Annex 1

Reference Standard Reproduction Annex—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
Table 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.

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
Apache	5B	Tuolumne	4B
Coconino	5B	Del Norte	4C
Navajo	5B	Humboldt	4C

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
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
Pitkin	7	Evans	2A
Rio Grande	7	Glynn	2A
Routt	7	Grady	2A
San Juan	7	Irwin	2A
Summit	7	Jeff Davis	2A

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
Lanier	2A	Illinois (IL)	
Liberty	2A	Zone 5A except...	
Long	2A	Alexander	4A
Lowndes	2A	Bond	4A
McIntosh	2A	Calhoun	4A
Miller	2A	Christian	4A
Mitchell	2A	Clark	4A
Pierce	2A	Clay	4A
Seminole	2A	Clinton	4A
Tattnall	2A	Coles	4A
Thomas	2A	Crawford	4A
Tift	2A	Cumberland	4A
Toombs	2A	Edwards	4A
Ware	2A	Effingham	4A
Wayne	2A	Fayette	4A
Worth	2A	Franklin	4A
Hawaii (HI)		Gallatin	4A
Zone 1A		Greene	4A
Idaho (ID)		Hamilton	4A
Zone 6B except...		Hardin	4A
Ada	5B	Jackson	4A
Benewah	5B	Jasper	4A
Canyon	5B	Jefferson	4A
Cassia	5B	Jersey	4A
Clearwater	5B	Johnson	4A
Elmore	5B	Lawrence	4A
Gem	5B	Macoupin	4A
Gooding	5B	Madison	4A
Idaho	5B	Marion	4A
Jerome	5B	Massac	4A
Kootenai	5B	Monroe	4A
Latah	5B	Montgomery	4A
Lewis	5B	Perry	4A
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

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	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
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

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
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
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

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
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
Kittson	7	Marion	5A
Koochiching	7	Mercer	5A
Lake	7	Nodaway	5A
Lake of the Woods	7	Pike	5A
Mahnomen	7	Putnam	5A
Marshall	7	Ralls	5A
Norman	7	Schuyler	5A
Pennington	7	Scotland	5A
Pine	7	Shelby	5A
Polk	7	Sullivan	5A
Red Lake	7	Worth	5A
Roseau	7	Montana (MT)	
St. Louis	7	Zone 6B	
Wadena	7	Nebraska (NE)	
Mississippi (MS)		Zone 5A	
Zone 3A except...		Nevada (NV)	
George	2A	Zone 5B except...	
Hancock	2A	Clark	3B
Harrison	2A	Carson City	4B

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
Douglas	4B	Union	4B
Esmeralda	4B	Valencia	4B
Lincoln	4B	New York (NY)	
Lyon	4B	Zone 5A except...	
Mineral	4B	Bronx	4A
Nye	4B	Kings	4A
New Hampshire (NH)		Nassau	4A
Zone 6A except...		New York	4A
Hillsborough	5A	Queens	4A
Merrimack	5A	Richmond	4A
Rockingham	5A	Suffolk	4A
Strafford	5A	Chenango	6A
New Jersey (NJ)		Clinton	6A
Zone 4A except...		Delaware	6A
Bergen	5A	Essex	6A
Hunterdon	5A	Franklin	6A
Morris	5A	Fulton	6A
Passaic	5A	Hamilton	6A
Somerset	5A	Herkimer	6A
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

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
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
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

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
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
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

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
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
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

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
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
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

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
Schleicher	3B	Sherman	4B
Scurry	3B	Swisher	4B
Shackelford	3B	Yoakum	4B
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

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
Lewis	4A	Milwaukee	5A
Lincoln	4A	Monroe	5A
Logan	4A	Outagamie	5A

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
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	

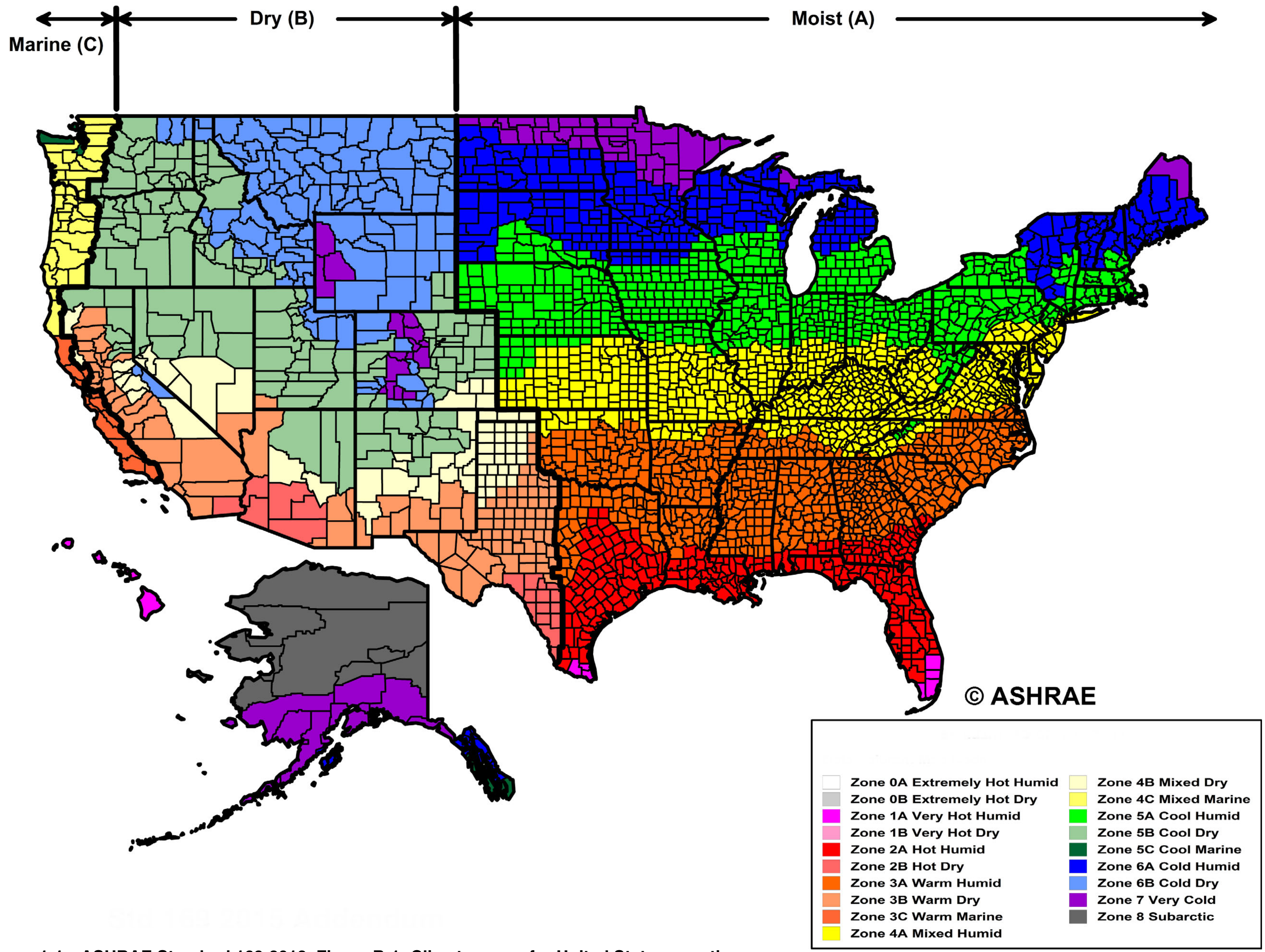

Figure Annex1-1 ASHRAE Standard 169-2013, Figure B-1: Climate zones for United States counties.

Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
Alberta (AB)						
BANFF CS	711220	51.19	–115.55	7	487	19
BOW ISLAND	712310	49.73	–111.45	6A	374	15
BOW VALLEY	712320	51.08	–115.07	7	584	23
BRETON PLOTS	712330	53.09	–114.44	7	460	18
BROOKS	714570	50.55	–111.85	6B	318	13
CALGARY INT'L A	718770	51.11	–114.02	7	425	17
CAMROSE	712540	53.03	–112.81	7	499	20
CARDSTON	711530	49.20	–113.29	6A	505	20
CLARESHOLM	712340	50.00	–113.64	6A	433	17
COLD LAKE A	711200	54.42	–110.28	7	464	18
COP UPPER	712350	51.08	–114.22	7	451	18
CORONATION (AUT)	718730	52.08	–111.45	7	405	16
CROWSNEST	712360	49.63	–114.48	7	664	26
DRUMHELLER EAST	712370	51.43	–112.67	7	390	15
EDMONTON CITY CENTRE A	718790	53.57	–113.52	7	481	19
EDMONTON INT'L A	711230	53.32	–113.58	7	493	19
EDMONTON NAMAO A	711210	53.67	–113.47	7	457	18
EDSON A	718810	53.60	–116.48	7	597	24
ELK ISLAND NAT PARK	712380	53.68	–112.87	7	442	17
ESTHER 1	712400	51.67	–110.21	7	323	13
FORT CHIPEWYAN A	719330	58.77	–111.12	8	417	16
FORT MCMURRAY A	719320	56.65	–111.22	7	476	19
GARDEN RIVER	712530	58.71	–113.87	7	385	15
GRANDE PRAIRIE A	719400	55.18	–118.88	7	477	19
HIGH LEVEL A	710660	58.62	–117.16	8	441	17
HIGHVALE	712410	53.45	–114.47	7	458	18
JASPER	718880	52.88	–118.07	7	415	16
JASPER WARDEN	714860	52.93	–118.03	7	415	16
LAC LA BICHE (AUT)	729310	54.77	–112.02	7	457	18
LACOMBE CDA 2	712420	52.45	–113.76	7	454	18
LETHBRIDGE A	718740	49.63	–112.80	6A	425	17
LETHBRIDGE CDA	712430	49.70	–112.78	6A	425	17
LLOYDMINSTER A	718710	53.31	–110.07	7	426	17
MEDICINE HAT A	718720	50.02	–110.72	6B	347	14
MILDRED LAKE	712550	57.04	–111.56	7	345	14
MILK RIVER	712440	49.13	–112.05	6B	364	14
NAKISKA RIDGETOP	712450	50.94	–115.19	8	605	24
ONEFOUR CDA	711160	49.12	–110.47	6A	347	14
PEACE RIVER A	710680	56.23	–117.45	7	412	16
PINCHER CREEK (AUT)	718750	49.52	–113.98	6A	484	19
RED DEER A	718780	52.18	–113.89	7	473	19
RED EARTH	712460	56.55	–115.28	7	430	17
ROCKY MTN HOUSE (AUT)	719280	52.42	–114.91	7	522	21
SLAVE LAKE A	710690	55.28	–114.78	7	525	21
SPRINGBANK A	718600	51.10	–114.37	7	491	19
STAVELY AAFC	715550	50.18	–113.88	6A	472	19
SUNDRE A	712480	51.78	–114.68	7	464	18
THREE HILLS	712490	51.83	–113.21	7	407	16
VAUXHALL CDA CS	712510	50.05	–112.13	6B	351	14
VEGREVILLE	714580	53.51	–112.10	7	375	15
WAINWRIGHT CFB AIRFIELD 21	711180	52.83	–111.10	7	431	17
WATERTON PARK GATE	711540	49.13	–113.81	6A	551	22
WHITECOURT A	719300	54.14	–115.79	7	594	23

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
British Columbia (BC)						
ABBOTSFORD A	711080	49.03	–122.36	4C	1168	46
AGASSIZ CS	711130	49.25	–121.77	4C	1769	70
ALERT BAY	711100	50.58	–126.93	5C	1668	66
AMPHITRITE POINT	711120	48.92	–125.54	5C	3212	126
BALLENAS ISLAND	717690	49.35	–124.16	4C	981	39
BLUE RIVER CS	718830	52.13	–119.29	6A	1032	41
BONILLA ISLAND (AUT)	714840	53.50	–130.63	5C	2169	85
BURNS LAKE DECKER LAKE	719520	54.38	–125.96	7	503	20
CAPE SCOTT	711110	50.78	–128.43	5C	2296	90
CAPE ST JAMES CS	711070	51.94	–131.02	5C	1599	63
CATHEDRAL POINT (AUT)	714820	52.19	–127.47	5C	3439	135
CLINTON (AUT)	714740	51.14	–121.50	7	392	15
COMOX A	718930	49.72	–124.90	5C	1340	53
CRANBROOK A	718800	49.61	–115.78	6A	408	16
CRESTON CAMPBELL SCIENTIFIC	717700	49.08	–116.50	5A	511	20
CUMSHEWA ISLAND	717710	53.03	–131.60	5C	2374	93
DEASE LAKE	719580	58.43	–130.01	7	452	18
DISCOVERY ISLAND	710310	48.42	–123.23	4C	646	25
ENTRANCE ISLAND CS	717720	49.22	–123.80	4C	1135	45
ESQUIMALT HARBOUR	717980	48.43	–123.44	4C	646	25
ESTEVAN POINT CS	718940	49.38	–126.54	5C	3276	129
FORT NELSON A	719450	58.84	–122.60	7	469	18
FORT ST JOHN A	719430	56.24	–120.74	7	477	19
GREY ISLET (AUT)	714760	54.58	–130.70	5A	2302	91
HERBERT ISLAND (AUT)	714850	50.94	–127.64	5C	2155	85
HOLLAND ROCK	712190	54.17	–130.36	5C	2353	93
HOPE	711140	49.37	–121.48	5C	1760	69
HOWE SOUND - PAM ROCKS	712110	49.49	–123.30	4C	1535	60
KAMLOOPS A	718870	50.70	–120.44	5B	286	11
KELOWNA A	712030	49.96	–119.38	5A	471	19
KINDAKUN ROCKS (AUT)	714720	53.32	–132.77	5C	1981	78
LANGARA	718990	54.26	–133.06	5C	1952	77
LILLOOET	719990	50.68	–121.93	5A	392	15
LUCY ISLAND LIGHTSTATION	712200	54.30	–130.61	5C	2317	91
LYTTON	718910	50.22	–121.58	5C	455	18
MACKENZIE A	719440	55.31	–123.14	7	687	27
MALAHAT	717740	48.57	–123.53	5C	1095	43
NAKUSP CS	712160	50.27	–117.81	5A	832	33
NELSON CS	717760	49.49	–117.31	5A	741	29
OSOYOOS CS	712150	49.03	–119.44	5B	319	13
PEMBERTON AIRPORT CS	717770	50.30	–122.74	5C	850	33
PENTICTON A	718890	49.46	–119.60	5B	303	12
PITT MEADOWS CS	717750	49.21	–122.69	4C	1483	58
POINT ATKINSON	710370	49.33	–123.26	4C	1535	60
PORT ALBERNI (AUT)	714750	49.32	–124.93	5C	1636	64
PORT HARDY A	711090	50.68	–127.37	5C	1917	75
PRINCE GEORGE A	718960	53.89	–122.68	7	658	26
PRINCE RUPERT A	718980	54.29	–130.44	5C	2690	106
PRINCETON CS	710320	49.47	–120.51	6A	369	15
PUNTZI MOUNTAIN (AUT)	710500	52.11	–124.14	7	394	16
QUESNEL A	711030	53.03	–122.51	6A	554	22
REVELSTOKE A	718820	50.96	–118.18	6A	1018	40
ROSE SPIT (AUT)	714770	54.16	–131.66	5A	1434	56

Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones *(Continued)*

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation	
					mm	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	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

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.
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

Table Annex1-2 ASHRAE Standard 169-2013, Table A-5: Canada Stations and Climate Zones *(Continued)*

Province/LOCATION	WMO#	Lat	Long	CZ	Precipitation	
					mm	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

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

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

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

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

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.
ONSLOW	943050	–21.63	115.12	1B	287	11
OUSE FIRE STATION	949570	–42.48	146.72	4A	544	21
PARABURDOO AERO	943160	–23.17	117.75	1B	267	10
PARKES (MACARTHUR ST)	947170	–33.13	148.17	3A	634	25
PAYNES FIND	944040	–29.27	117.68	2B	279	11
PEARCE RAAF	946120	–31.67	116.02	3A	660	26
PENRITH	947630	–33.72	150.68	3A	883	35
PERTH AIRPORT	946100	–31.93	115.97	3A	763	30
POINT WILSON	948470	–38.10	144.53	3A	561	22
PORT ARTHUR (PALM.)	949780	–43.17	147.83	4A	1165	46
PORT FAIRY AWS	948300	–38.40	142.23	3A	801	32
PORT HEDLAND AIRPOR	943120	–20.37	118.63	1B	277	11
PORT KEATS AWS AUT	941110	–14.23	129.45	0A	1491	59
PORT MACQUARIE AIRP	947860	–31.43	152.85	3A	1522	60
PORTLAND CASHMORE A	948280	–38.32	141.47	4C	812	32
PROSERPINE AIRPORT	943650	–20.50	148.53	2A	1455	57
QUILPIE AIRPORT	944940	–26.62	144.25	2B	365	14
RAVENSTHORPE HOPETO	956350	–33.93	120.13	3C	519	20
REDESDALE	948590	–37.02	144.53	4A	697	27
RENMARK	946870	–34.17	140.75	3B	259	10
RHYLL (AWS)	948920	–38.45	145.30	3A	829	33
RICHMOND POST OFFIC	943400	–20.73	143.13	1B	489	19
RICHMOND RAAF	957530	–33.60	150.78	3A	842	33
ROCKHAMPTON AERO	943740	–23.38	150.48	2A	791	31
ROEBOURNE POST OFFI	943090	–20.78	117.15	0B	296	12
ROMA AIRPORT	945150	–26.55	148.78	2A	616	24
ROTTNEST ISLAND	946020	–32.02	115.50	3A	629	25
RUNDLE ISLAND	943780	–23.53	151.28	2A	863	34
SCONE AIRPORT	957580	–32.03	150.83	3A	708	28
SCORESBY RESEARCH	958670	–37.87	145.25	3A	936	37
SHARK BAY (DENHAM)	944020	–25.92	113.52	2B	221	9
SHEOAKS AWS	948630	–37.90	144.12	4A	613	24
SHEPPARTON AIRPORT	948750	–36.43	145.40	3A	504	20
SMITHTON AERODROME	949530	–40.83	145.08	4C	1105	44
SOUTHERN CROSS	946340	–31.23	119.33	3B	323	13
SOUTHERN CROSS AIRF	956340	–31.23	119.35	3B	323	13
ST LAWRENCE POST OF	943690	–22.35	149.53	2A	990	39
STRAHAN AERODROME	949560	–42.15	145.28	4A	2101	83
SWAN HILL AERODROME	948430	–35.38	143.53	3B	337	13
SWANBOURNE	946140	–31.95	115.77	3A	820	32
SYDNEY AIRPORT AMO	947670	–33.93	151.18	3A	1104	43
SYDNEY REGIONAL OFF	947680	–33.85	151.20	3A	1253	49
TAMWORTH AIRPORT AW	957620	–31.07	150.83	3A	676	27
TELFER AERO	943190	–21.72	122.22	1B	302	12
TENNANT CREEK MET O	942380	–19.63	134.18	1B	446	18
TEWANTIN RSL PARK	945700	–26.38	153.03	2A	1678	66
THREDBO (CRACKENBACK)	959090	–36.50	148.28	7	975	38
TINDAL RAAF	941310	–14.52	132.37	0A	1013	40
TOOWOOMBA AIRPORT	955510	–27.55	151.92	3A	937	37
TOWN OF 1770	943840	–24.15	151.88	2A	1104	43
TOWNSVILLE AERO	942940	–19.25	146.77	1A	1042	41
TROUGHTON ISLAND	941020	–13.75	126.15	0A	955	38
TUGGERANONG ISABELL	949250	–35.42	149.10	4A	733	29

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
TUNNAK FIRE STATION	949600	–42.45	147.47	5A	611	24
ULLADULLA AWS	949380	–35.35	150.48	3A	1254	49
URANDANGIE	943290	–21.60	138.30	1B	314	12
VICTORIA RIVER DOWN	942320	–16.40	131.02	0B	743	29
WAGGA WAGGA AMO	949100	–35.17	147.45	3A	574	23
WALGETT AIRPORT	957150	–30.03	148.12	2B	507	20
WANGARATTA AERO	948890	–36.42	146.30	3A	679	27
WARBURTO POINT	946660	–34.00	137.53	3B	351	14
WARRNAMBOOL AIRPORT	948320	–38.28	142.43	4C	775	30
WARWICK	945550	–28.20	152.10	3A	728	29
WEIPA AERO	941700	–12.68	141.92	0A	1883	74
WILLIAMTOWN RAAF	947760	–32.80	151.83	3A	1144	45
WILLIS ISLAND	942990	–16.30	149.97	1A	1029	41
WILSONS PROMONTORY	948930	–39.12	146.42	3C	1088	43
WINDORAH	944880	–25.42	142.65	2B	269	11
WINTON (POST OFFICE)	943390	–22.38	143.03	1B	397	16
WONTHAGGI COMPOSITE	958810	–38.60	145.58	3A	954	38
WOOMERA AERODROME	946590	–31.15	136.82	3B	184	7
WYNDHAM	942140	–15.48	128.12	0B	759	30
WYNYARD AIRPORT	959570	–41.00	145.73	4C	960	38
YEPPOON AWS	943730	–23.13	150.75	2A	1220	48
YOUNG AIRPORT	947120	–34.25	148.25	3A	668	26
YULARA AERO	944620	–25.20	130.98	2B	333	13
Austria (AUT)						
AIGEN IM ENNSTAL	111570	47.53	14.13	6A	1300	51
ALLENTSTEIG	110190	48.68	15.37	5A	629	25
ALPINZENTRUM RUDOLF	111380	47.13	12.63	7	1130	44
AMSTETTEN	110180	48.10	14.90	5A	989	39
ARRIACH	112750	46.73	13.85	6A	1322	52
BAD RADKERSBURG	112480	46.68	15.98	5A	943	37
BISCHOFSHOFEN	111410	47.40	13.22	5A	1314	52
BREGENZ	111010	47.50	9.75	5A	1784	70
BRENNER	111280	47.00	11.52	6A	933	37
DELLACH IM DRAUTAL	112700	46.73	13.08	5A	1073	42
DORNBIRN	113020	47.43	9.73	5A	1393	55
EISENSTADT	111900	47.85	16.53	5A	610	24
FELDKIRCH	111050	47.27	9.62	5A	1393	55
FEUERKOGEL	111550	47.82	13.72	7	1361	54
FREISTADT	110150	48.50	14.50	5A	779	31
GMUNDEN	111540	47.90	13.80	5A	1416	56
GRAZ-THALERHOF-FLUG	112400	47.00	15.43	5A	847	33
GUMPOLDSKIRCHEN	110820	48.03	16.28	5A	604	24
HAHNENKAMM/EHRENBAC	111350	47.42	12.37	7	1242	49
HOHE WAND/HOCHKOGEL	113850	47.82	16.03	6A	745	29
INNSBRUCK-FLUGHAFEN	111200	47.27	11.35	5A	914	36
ISCHGL/IDALPE	113100	46.98	10.32	7	789	31
JAUERLING	110240	48.33	15.33	6A	646	25
KLAGENFURT-FLUGHAFE	112310	46.65	14.33	5A	905	36
KLEINZICKEN	111920	47.20	16.33	5A	741	29
KOETSCHACH-MAUTHEN	112550	46.68	13.00	5A	1427	56
KREMSMUENSTER	110120	48.05	14.13	5A	955	38
KUFSTEIN	111300	47.58	12.17	5A	1440	57
LANDECK	111120	47.13	10.57	5A	913	36

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.
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

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

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

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.
HAIYANG DAO	545870	39.05	123.22	4A	788	31
HALIUT	533360	41.57	108.52	6B	200	8
HAMI	522030	42.82	93.52	5B	36	1
HANGZHOU	584570	30.23	120.17	3A	1380	54
HANZHONG	571270	33.07	107.03	4A	900	35
HARBIN	509530	45.75	126.77	7	527	21
HECHI	590230	24.70	108.05	2A	1471	58
HEFEI	583210	31.87	117.23	3A	984	39
HENAN	560650	34.73	101.60	7	597	24
HEQU	535640	39.38	111.15	5B	418	16
HEYUAN	592930	23.80	114.73	2A	1922	76
HEZE/CAOZHOU	549060	35.25	115.43	4A	646	25
HEZUO	560800	35.00	102.90	7	549	22
HOBOKSAR	511560	46.78	85.72	7	136	5
HOHHOT	534630	40.82	111.68	6B	400	16
HONG KONG INTERNATI	450070	22.32	113.92	1A	1894	75
HONG KONG OBSERVATO	450050	22.30	114.17	2A	2225	88
HOTAN	518280	37.13	79.93	4B	35	1
HUA SHAN	570460	34.48	110.08	6A	875	34
HUADE	533910	41.90	114.00	7	319	13
HUADIAN	542730	42.98	126.75	7	743	29
HUAILAI	544050	40.40	115.50	5B	387	15
HUAJIALING	529960	35.38	105.00	7	513	20
HUANG SHAN	584370	30.13	118.15	5A	2317	91
HUILI	566710	26.65	102.25	3C	1134	45
HUIMIN	547250	37.50	117.53	4A	585	23
HUIZE	566840	26.42	103.28	3A	776	31
HULIN	509830	45.77	132.97	7	556	22
HUMA	503530	51.72	126.65	7	467	18
HUOSHAN	583140	31.40	116.33	3A	1339	53
JARTAI	535020	39.78	105.75	5B	103	4
JARUD QI	540260	44.57	120.90	6B	386	15
JIAN	543770	41.10	126.15	2A	942	37
JIAN	577990	27.12	114.97	6A	1477	58
JIANGCHENG	569770	22.62	101.82	2A	2229	88
JIANGLING	574760	30.33	112.18	3A	1083	43
JIEXIU	538630	37.03	111.92	5B	498	20
JINAN	548230	36.60	117.05	4A	733	29
JINGDEZHEN	585270	29.30	117.20	3A	1694	67
JINGHE	513340	44.62	82.90	6B	96	4
JINGHONG	569590	22.00	100.78	1A	1173	46
JINING	534800	41.03	113.07	7	361	14
JINZHOU	543370	41.13	121.12	5A	581	23
JIULONG	564620	29.00	101.50	5A	907	36
JIUQUAN	525330	39.77	98.48	5B	85	3
JIUXIAN SHAN	589310	25.72	118.10	4A	1720	68
JIXI	509780	45.28	130.95	7	546	21
JURH	532760	42.40	112.90	6B	213	8
KABA HE	510530	48.05	86.35	6B	176	7
KANGDING	563740	30.05	101.97	5A	801	32
KARAMAY	512430	45.60	84.85	6B	104	4
KASHI	517090	39.47	75.98	4B	62	2
KESHAN	506580	48.05	125.88	7	486	19
KORLA	516560	41.75	86.13	5B	53	2
KUANDIAN	544930	40.72	124.78	6A	1100	43
KUNMING	567780	25.02	102.68	3C	1004	40
KUOCANG SHAN	586530	28.82	120.92	5A	2097	83
KUQA	516440	41.72	82.95	5B	62	2
LANCANG	569540	22.57	99.93	2A	1639	65
LANGZHONG	573060	31.58	105.97	3A	1039	41
LANZHOU	528890	36.05	103.88	5B	317	12
LENGHU	526020	38.83	93.38	7	17	1
LETING	545390	39.43	118.90	5A	638	25
LHASA	555910	29.67	91.13	5B	440	17
LHUNZE	556960	28.42	92.47	6B	269	11
LIAN XIAN	590720	24.78	112.38	2A	1578	62
LIANGPING	574260	30.68	107.80	3A	1301	51
LIANPING	590960	24.37	114.48	2A	1781	70
LIJING	566510	26.83	100.47	3C	954	38
LINCANG	569510	23.95	100.22	3A	1187	47
LINDONG	540270	43.98	119.40	6B	370	15
LINGLING	578660	26.23	111.62	3A	1352	53
LINGXIAN	547150	37.33	116.57	4B	522	21
LINHAI	586600	28.85	121.13	3A	1778	70
LINHE	535130	40.77	107.40	5B	135	5
LINJIANG	543740	41.72	126.92	6A	837	33
LINXI	541150	43.60	118.07	6B	368	14
LINYI	549380	35.05	118.35	4A	870	34
LISHI	537640	37.50	111.10	5A	500	20
LISHUI	586460	28.45	119.92	3A	1371	54
LITANG	562570	30.00	100.27	7	712	28
LIUZHOU	590460	24.35	109.40	2A	1388	55
LIYANG	583450	31.43	119.48	3A	1144	45
LONGKOU	547530	37.62	120.32	4A	618	24
LONGYAN	589270	25.10	117.02	2A	1713	67
LONGZHOU	594170	22.37	106.75	2A	1380	54
LU SHAN	585060	29.58	115.98	4A	1965	77
LUODIAN	579160	25.43	106.77	2A	1150	45
LUSHI	570670	34.05	111.03	4A	636	25
LUSI	582650	32.07	121.60	3A	1037	41
LUXI	568860	24.53	103.77	3A	957	38
LUZHOU	576020	28.88	105.43	3A	1152	45
MACHENG	573990	31.18	114.97	3A	1216	48
MADOI	560330	34.92	98.22	8	309	12
MANDAL	531490	42.53	110.13	6B	168	7
MANGNAI	518860	38.25	90.85	7	49	2
MAZONG SHAN	523230	41.80	97.03	7	76	3
MEI XIAN	591170	24.30	116.12	2A	1509	59
MENGDING	569450	23.57	99.08	2A	1519	60
MENGJIN	570710	34.82	112.43	4A	603	24
MENGLA	569690	21.50	101.58	2A	1522	60
MENGSHAN	590580	24.20	110.52	2A	1691	67
MENGZI	569850	23.38	103.38	2A	855	34
MIANYANG	561960	31.45	104.73	3A	925	36
MINFENG	518390	37.07	82.72	5B	41	2
MINQIN	526810	38.63	103.08	5B	111	4

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

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'lvoire (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

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.
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

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

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.
CALVI	077540	42.53	8.80	3A	672	26
CAP BEAR	077490	42.52	3.13	3A	595	23
CAP CEPET	076610	43.08	5.93	3A	727	29
CAP CORSE	077850	43.00	9.35	3A	705	28
CAP COURONNE	076530	43.33	5.05	3A	514	20
CAP DE LA HEVE	070280	49.50	0.07	4A	796	31
CAP FERRET	075000	44.63	–1.25	3A	904	36
CAP PERTUSATO	077700	41.37	9.17	3A	616	24
CAP POMEGUES	076520	43.27	5.30	3A	566	22
CAPE FERRAT	076950	43.68	7.33	3A	904	36
CAPE SAGRO	077910	42.80	9.48	3A	705	28
CARCASSONNE	076350	43.22	2.32	3A	728	29
CARPENTRAS	075860	44.08	5.05	3A	749	30
CAZAUX	075020	44.53	–1.13	4A	904	36
CHAMBERY/AIX-LES-BA	074910	45.63	5.87	4A	1218	48
CHARLEVILLE	070750	49.78	4.63	5A	1013	40
CHARTRES	071430	48.47	1.50	4A	611	24
CHASSIRON	073140	46.05	–1.42	3A	730	29
CHATEAUROUX/DEOLS	073540	46.85	1.72	4A	774	30
CLERMONT-FERRAND	074600	45.78	3.17	4A	595	23
COGNAC	074120	45.67	–0.32	4A	852	34
DIEPPE	070400	49.93	1.10	4A	854	34
DIJON	072800	47.27	5.08	4A	747	29
DINARD	071250	48.58	–2.07	4A	685	27
DUNKERQUE	070100	51.05	2.33	4A	685	27
EMBRUN	075910	44.57	6.50	5A	844	33
EVREUX/FAUVILLE FAF	070380	49.02	1.22	4A	685	27
FIGARI	077800	41.50	9.10	3A	616	24
GOURDON	075350	44.75	1.40	4A	871	34
GRENOBLE-ST-GEOIRS	074860	45.37	5.33	4A	991	39
GROUIN DE CANCALE	071270	48.72	–1.85	4A	688	27
HYERES	076670	43.10	6.15	3A	745	29
ILE ROUSSE	077530	42.63	8.92	3A	672	26
ISTRES	076470	43.52	4.92	3A	623	25
L IIE D YEU	073000	46.70	–2.33	4A	796	31
LA CHIAPPA	077680	41.60	9.37	3A	746	29
LA ROCHELLE	073150	46.15	–1.15	4A	758	30
LA ROCHE-SUR-YON	073060	46.70	–1.38	4A	856	34
LANGRES	072830	47.85	5.33	5A	849	33
LE BOURGET	071500	48.97	2.43	4A	647	25
LE LUC	076750	43.38	6.38	3A	907	36
LE MANS	072350	47.93	0.20	4A	682	27
LE PUY	074710	45.08	3.77	5A	769	30
LE RAIZET/GUADELOUP	788970	16.27	–61.60	0A	1475	58
LILLE LESQUI	070150	50.57	3.10	4A	698	27
LIMOGES	074340	45.87	1.18	4A	1013	40
LONS-LE-SAUNIER	073900	46.68	5.52	4A	1368	54
LORIENT LAN BIHOUE	072050	47.77	–3.45	4A	867	34
LUXEUIL	072920	47.80	6.38	5A	1155	45
LYON-BRON	074800	45.72	4.93	4A	808	32
LYON-SATOLAS	074810	45.73	5.08	4A	927	37
MACON	073850	46.30	4.80	4A	847	33
MARIGNANE	076500	43.45	5.23	3A	514	20
MARTIN DE VIVIES (ILE AMST.)	619960	–37.80	77.50	3A	1101	43
MAUPERTUS	070240	49.65	–1.48	4A	845	33
MELUN	071530	48.62	2.68	4A	651	26
METZ/FRESCATY	070900	49.08	6.13	4A	768	30
MEYENHEIM-COLMAR	071970	47.92	7.40	4A	746	29
MILLAU	075580	44.12	3.02	4A	921	36
MONT AIGOUAL	075600	44.12	3.58	6A	1444	57
MONT-DE-MARSAN	076070	43.92	–0.50	4A	945	37
MONTELIMAR	075770	44.58	4.73	4A	930	37
MONTPELLIER	076430	43.58	3.97	3A	869	34
NANCY-ESSEY	071800	48.68	6.22	5A	768	30
NANCY-OCHEY	071810	48.58	5.97	5A	837	33
NANTES	072220	47.15	–1.60	4A	778	31
NEVERS	072600	47.00	3.10	4A	786	31
NICE	076900	43.65	7.20	3A	790	31
NIMES/GARONS (NAVY)	076460	43.75	4.42	3A	714	28
NIMES-COURBESSAC	076450	43.87	4.40	3A	775	31
NIORT	073300	46.32	–0.40	4A	903	36
ORANGE	075790	44.13	4.83	3A	719	28
ORLEANS	072490	47.98	1.78	4A	641	25
OUESSANT	071000	48.48	–5.05	4A	869	34
PARIS-AEROPORT CHAR	071570	49.02	2.53	4A	701	28
PARIS-MONTSOURIS	071560	48.82	2.33	4A	647	25
PARIS-ORLY	071490	48.72	2.38	4A	634	25
PAU	076100	43.38	–0.42	4A	1173	46
PERPIGNAN	077470	42.73	2.87	3A	572	23
POINTE DU RAZ	071030	48.03	–4.73	4A	797	31
POITIERS	073350	46.58	0.30	4A	712	28
PORQUEROLLES	076700	43.00	6.23	3A	681	27
PORT EN BESSIN	070290	49.35	–0.77	4A	796	31
PTE DE LA HAGUE	070200	49.72	–1.93	4A	809	32
PTE DE PENMARCH	072000	47.80	–4.37	4A	875	34
QUIMPER	072010	47.97	–4.17	4A	919	36
REIMS	070700	49.30	4.03	4A	656	26
RENNES	071300	48.07	–1.73	4A	710	28
ROUEN	070370	49.38	1.18	4A	790	31
SAINT GIRONS	076270	43.00	1.10	4A	1163	46
SAINT-DIZIER	071690	48.63	4.90	4A	891	35
SAINT-NAZAIRE-MONTO	072170	47.32	–2.17	4A	735	29
SAINT-QUENTIN	070610	49.82	3.20	5A	696	27
SAINT-YAN	073790	46.42	4.02	4A	884	35
SERGE-FROLOW (ILE TROMELIN)	619760	–15.80	54.50	1A	850	33
SETE	076410	43.40	3.68	3A	650	26
SOCOA	076000	43.40	–1.68	3A	1824	72
SOLENZARA	077650	41.92	9.40	3A	843	33
ST-AUBAN-SUR-DURANC	075880	44.07	6.00	4A	746	29
ST-ETIENNE BOUTHEON	074750	45.53	4.30	4A	765	30
STRASBOURG-ENTZHEIM	071900	48.55	7.63	4A	623	25
TARBES-OSSUN	076210	43.18	0.00	4A	1140	45
TOULON	076600	43.10	5.93	3A	674	27
TOULOUSE BLAGNAC	076300	43.63	1.37	4A	669	26
TOURS	072400	47.45	0.73	4A	674	27
TRAPPES	071450	48.77	2.00	4A	672	26

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.
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

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
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

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

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

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.
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
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

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

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

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
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

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

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

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

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

Country/LOCATION	WMO#	Lat	Long	CZ	Precipitation mm	Precipitation in.
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

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
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

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

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.
SIGHETUL MARMATIEI	150040	47.93	23.92	5A	820	32	BALASOV	341520	51.55	43.15	6A	500	20
SUCEAVA	150230	47.63	26.25	5A	595	23	BARABINSK	296120	55.33	78.37	7	377	15
SULINA	153600	45.17	29.73	4B	270	11	BARENCBURG	201070	78.07	14.25	8	468	18
TARGOVISTE	153750	44.93	25.43	5A	663	26	BARNAUL	298380	53.43	83.52	7	441	17
TG. JIU	153400	45.03	23.27	5A	806	32	BATAMAJ	246560	63.52	129.48	8	293	12
TG. MURES	151450	46.53	24.53	5A	601	24	BEJA	299620	53.05	90.92	7	399	16
TIMISOARA	152470	45.77	21.25	4A	611	24	BELOGORSK	315130	50.92	128.47	7	554	22
TR. MAGURELE	154900	43.75	24.88	4A	547	22	BELYJ	265850	55.85	32.95	6A	709	28
TULCEA	153350	45.18	28.82	4A	434	17	BEREZOVO	236310	63.93	65.05	8	526	21
VARFU OMU	152800	45.45	25.45	8	935	37	BERINGOVSKAJA	256770	63.05	179.32	8	574	23
ZALAU	150630	47.18	23.08	5A	643	25	BEZECK	272170	57.80	36.70	7	541	21
Russian Federation (RUS)							BIJSK ZONALNAJA	299390	52.68	84.95	7	534	21
ABAKAN	298650	53.75	91.40	7	324	13	BIKIN	318320	46.80	134.27	7	645	25
ACINSK	294670	56.28	90.50	7	422	17	BIRILIUSSY	293670	57.13	90.70	7	501	20
ADLER	371710	43.43	39.90	4A	1559	61	BIROBIDZHAN	317130	48.73	132.95	7	666	26
AGATA	233830	66.88	93.47	8	464	18	BIRSK	286210	55.42	55.53	7	580	23
AGINSKOE	296760	55.25	94.88	7	461	18	BLAGOVESCENSK	315100	50.25	127.57	7	559	22
AGINSKOE	308590	51.10	114.52	8	371	15	BODAJBO	302530	57.85	114.23	8	447	18
AGZU	318250	47.60	138.40	7	663	26	BOGORODSKOE	314390	52.38	140.47	8	504	20
AJAN	311680	56.45	138.15	8	887	35	BOGOTOL	295530	56.23	89.58	7	499	20
AKJAR	350370	51.87	58.18	7	361	14	BOGUCANY	292820	58.38	97.45	8	339	13
AKSA	309570	50.27	113.27	7	386	15	BOGUCAR	343360	49.93	40.57	6A	514	20
ALATYR`	276790	54.82	46.58	7	518	20	BOL`SIE-UKI	284910	56.93	72.67	7	447	18
ALDAN	310040	58.62	125.37	8	676	27	BOLOGOE	262980	57.90	34.05	7	629	25
ALEJSKAJA	299370	52.52	82.77	7	431	17	BOLSHAJA MURTA	294710	56.90	93.13	7	413	16
ALEKSANDROV-GAJ	343910	50.15	48.55	6A	316	12	BOLSHERECHE	285930	56.10	74.63	7	364	14
ALEKSANDROVSKIJ ZAV	309710	50.92	117.93	8	399	16	BOLSOJ SANTAR	311740	54.83	137.53	8	524	21
ALEKSANDROVSKOE	239550	60.43	77.87	8	501	20	BOMNAK	312530	54.72	128.93	8	574	23
ALEKSANDROVSK-SAHAL	320610	50.90	142.17	7	622	24	BOR	238840	61.60	90.02	8	588	23
AMDERMA	230220	69.75	61.70	8	380	15	BORZJA	309650	50.40	116.52	8	296	12
AMGA	249620	60.90	131.98	8	256	10	BRATOLJUBOVKA	315210	50.78	129.33	8	564	22
ANADYR	255630	64.78	177.57	8	333	13	BRATSK	303090	56.28	101.75	8	374	15
ANAPA	370010	44.88	37.28	4A	520	20	BRJANSK	268980	53.25	34.32	6A	649	26
ANDREYA ISLAND	213010	76.80	110.83	8	210	8	BUDENNOVSK	370610	44.78	44.13	5A	406	16
ANTIPAJETA	230580	69.08	76.85	8	268	11	BUGULMA	287110	54.58	52.80	7	523	21
ANUCINO	319810	43.97	133.07	7	719	28	BUHTA PROVIDENJA	255940	64.42	–173.23	8	666	26
APUKA	259560	60.43	169.67	8	515	20	BUJ	272420	58.48	41.53	7	633	25
ARHANGELSK	225500	64.55	40.58	7	579	23	BURUKAN	313480	53.05	136.03	8	642	25
ARHARA	315940	49.42	130.08	7	640	25	BUZULUK	289090	52.82	52.22	7	470	19
ARKA	249880	60.08	142.33	8	446	18	CAJVO	320360	52.37	143.18	8	683	27
ARMAVIR	370310	44.98	41.12	5A	572	23	CAPE BOLVANSKIJ	209460	70.45	59.07	8	256	10
ASTRAHAN	348800	46.28	48.05	5B	214	8	CAPE KAMENNYJ	231460	68.47	73.60	8	389	15
ASTRAHANKA	319210	44.72	132.07	7	582	23	CAPE MENSHIKOVA	209430	70.72	57.62	8	588	23
ATKA	259020	60.85	151.77	8	328	13	CAPE STERLEGOVA	204760	75.42	88.90	8	296	12
B. PRONCHISHCHEVOY	214050	75.53	113.52	8	212	8	CAPE VASILEVA	322170	50.02	155.40	7	1240	49
BABAEVO	270080	59.40	35.93	7	621	24	CEKUNDA	315320	50.87	132.25	8	672	26
BABUSKIN	308220	51.72	105.85	7	523	21	CELINA	347470	46.55	41.05	5A	546	21
BAEVO	298270	53.27	80.77	7	328	13	CEMAL	360580	51.43	86.00	7	513	20
BAGDARIN	305540	54.47	113.58	8	378	15	CENTRALNYJ RUDNIK	296540	55.22	87.65	7	951	37
BAJANDAJ	306270	53.10	105.53	8	375	15	CEREPOVEC	271130	59.25	37.97	7	667	26
BAKALY	286150	55.18	53.80	7	462	18	CERLAK	287990	54.17	74.80	7	348	14
BAKCHAR	293280	57.08	81.92	7	464	18	CERNUSKA	284280	56.50	56.13	7	559	22
BALAGANSK	306120	54.00	103.07	8	326	13	CHANY	296020	55.28	76.60	7	338	13

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.
CHARA	303720	56.90	118.27	8	346	14	HOLM	263780	57.15	31.18	6A	645	25
CHELJABINSK-BALANDI	286420	55.30	61.53	7	441	17	HOLMSK	321280	47.05	142.05	6A	795	31
CHERDYN	239140	60.40	56.52	7	712	28	HORINSK	307390	52.17	109.78	8	283	11
CHERNISHEVSKIJ	247240	63.03	112.50	8	337	13	HOSEDA-HARD	232190	67.08	59.38	8	455	18
CHERNJAEVO	313710	52.78	126.00	8	485	19	HULARIN	314840	51.42	135.08	7	605	24
CHERSKIJ	251230	68.75	161.28	8	210	8	ICA	324110	55.58	155.58	7	741	29
CHITA	307580	52.08	113.48	8	346	14	IDRINSKOE	297660	54.37	92.13	7	382	15
CHOKURDAH	219460	70.62	147.88	8	217	9	IGARKA	232740	67.47	86.57	8	494	19
CJULBJU	311230	57.77	130.90	8	384	15	IGNASINO	306860	53.47	122.40	8	421	17
CUGUEVKA	319390	44.15	133.87	7	719	28	IKEJ	305070	54.18	100.08	8	470	18
CULMAN	303930	56.83	124.87	8	530	21	ILYINSKIY	321210	47.98	142.20	7	856	34
CULYM	296250	55.10	80.97	7	379	15	IM POLINY OSIPENKO	314160	52.42	136.50	8	471	19
CURAPCA	247680	62.03	132.60	8	245	10	IM. M.V. POPOVA	206670	73.33	70.05	8	206	8
DALNERECHENSK	318730	45.87	133.73	7	637	25	IRBEJSKOE	295870	55.63	95.47	7	434	17
DEMJANSKOE	280760	59.60	69.28	7	534	21	IRKUTSK	307100	52.27	104.32	7	475	19
DIVNOE	348580	45.92	43.35	5A	434	17	ISIM	285730	56.10	69.43	7	377	15
DUDINKA	230740	69.40	86.17	8	456	18	ISIT	249510	60.82	125.32	8	290	11
DUKI	314820	51.72	135.93	8	646	25	IVDEL	239210	60.68	60.45	7	510	20
DUVAN	285370	55.70	57.90	7	515	20	IZHEVSK	284110	56.83	53.45	7	527	21
DZALINDA	306950	53.47	123.90	8	471	19	JAKUTSK	249590	62.02	129.72	8	234	9
DZARDZAN	241430	68.73	124.00	8	304	12	JALTUROVOSK	284650	56.68	66.35	7	423	17
DZERZHINSKOE	294810	56.85	95.22	7	350	14	JANAUL	284190	56.27	54.90	7	479	19
EGVEKINOT	253780	66.35	–179.12	8	389	15	JARCEVO	239870	60.25	90.23	8	590	23
EKATERINBURG	284400	56.83	60.63	7	511	20	JARENSK	227980	62.17	49.12	7	599	24
EKATERINO-NIKOLSKOE	317070	47.73	130.97	7	625	25	JASKUL	348660	46.18	45.35	5B	249	10
EKIMCHAN	313290	53.07	132.98	8	693	27	JUBILEJNAJA	219310	70.77	136.22	8	245	10
ELABUGA	285060	55.77	52.07	7	544	21	JUR`EVEC	273550	57.33	43.12	7	600	24
ELAT`MA	276480	54.95	41.77	7	605	24	JUZHNO-KURILSK	321650	44.02	145.87	6A	1238	49
ELEC	279280	52.63	38.52	6A	579	23	JUZHNO-SAHALINSK	321500	46.95	142.72	7	863	34
ENISEJSK	292630	58.45	92.15	8	470	19	KACUG	306220	53.97	105.90	8	310	12
ERBOGACEN	248170	61.27	108.02	8	340	13	KAJLASTUJ	309780	49.83	118.38	7	341	13
ERMAKOVSKOE	298690	53.30	92.42	7	528	21	KALAC	342470	50.42	41.05	6A	486	19
EROFEJ PAVLOVIC	306830	53.97	121.93	8	419	16	KALACINSK	286960	55.03	74.58	7	340	13
ERSOV	341860	51.37	48.30	6A	393	15	KALAKAN	304690	55.12	116.77	8	395	16
GAJNY	239090	60.28	54.35	7	626	25	KALEVALA	224080	65.22	31.17	7	533	21
GAR	313840	52.57	129.07	8	574	23	KALININGRAD	267020	54.72	20.55	5A	796	31
GARI	280490	59.43	62.33	7	468	18	KALUGA	277030	54.57	36.40	6A	642	25
GLAZOV	282140	58.13	52.58	7	587	23	KAMEN-NA-OBI	298220	53.82	81.27	7	330	13
GMO IM.E.K. FEDOROV	202920	77.72	104.30	8	213	8	KAMENSKOE	257440	62.43	166.08	8	413	16
GORIN	314890	51.20	136.80	8	606	24	KAMYSIN	343630	50.07	45.37	6A	378	15
GORJACINSK	307310	52.98	108.28	7	400	16	KAMYSLOV	284510	56.85	62.72	7	459	18
GOR'KIJ	275530	56.22	43.82	7	606	24	KANDALAKSA	222170	67.15	32.35	7	509	20
GRIDINO	224220	65.90	34.77	7	429	17	KANIN NOS	221650	68.65	43.30	7	431	17
GROSSEVICHI	318230	47.97	139.53	7	694	27	KANSK	295810	56.20	95.63	7	312	12
GROZNYJ	372350	43.35	45.68	5A	462	18	KARASUK	298140	53.70	78.07	7	299	12
GUGA	314210	52.70	137.53	8	474	19	KARGASOK	291220	59.05	80.95	8	449	18
GVASJUGI	318010	47.67	136.18	7	915	36	KARGOPOL	228450	61.50	38.93	7	617	24
HABAROVSK	317350	48.52	135.17	7	673	27	KAZACHINSK	303370	56.32	107.62	8	400	16
HADAMA	298920	53.95	98.82	8	529	21	KAZAN	275950	55.60	49.28	7	532	21
HAKASSKAJA	298620	53.77	91.32	7	310	12	KEDON	256210	64.00	158.92	8	274	11
HANTY-MANSIJSK	239330	61.02	69.03	8	535	21	KEM	225220	64.95	34.65	7	434	17
HATANGA	208910	71.98	102.47	8	283	11	KEMCHUG	295620	56.10	91.67	7	507	20
HILOK	308440	51.35	110.47	8	380	15	KEMEROVO	296420	55.23	86.12	7	465	18

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.
KESTENGA	224030	65.88	31.83	7	540	21	MAKUSINO	286660	55.25	67.30	7	366	14
KINGISEPP	260590	59.37	28.60	6A	686	27	MALYE KARMAKULY	207440	72.37	52.70	8	343	13
KIRENSK	302300	57.77	108.07	8	383	15	MAMA	301570	58.32	112.87	8	554	22
KIROV	271960	58.65	49.62	7	613	24	MARESALE	230320	69.72	66.80	8	258	10
KIROV	271990	58.60	49.63	7	613	24	MARIINSK	295510	56.22	87.75	7	441	17
KIROVSKIJ	318780	45.08	133.53	7	670	26	MARKOVO	255510	64.68	170.42	8	397	16
KIRS	280090	59.37	52.22	7	607	24	MASLJANINO	297360	54.33	84.22	7	454	18
KJAHTA	309250	50.37	106.45	7	350	14	MATUA	322070	48.07	153.22	7	1321	52
KJUSJUR	219210	70.68	127.40	8	343	14	MEDVEZEGORSK	227210	62.92	34.43	7	672	26
KLJUCHI	323890	56.32	160.83	7	618	24	MELEUZ	289250	52.95	55.97	7	443	17
KLJUCI	360210	52.25	79.13	7	318	13	MEZEN	224710	65.87	44.22	7	509	20
KOCHKI	297240	54.30	80.50	7	358	14	MINERALNYE VODY	370540	44.23	43.07	5A	524	21
KOCUBEJ	370850	44.40	46.55	4B	243	10	MOGOCA	306730	53.75	119.73	8	426	17
KOJNAS	225830	64.75	47.65	7	609	24	MONDY	308020	51.68	100.98	8	332	13
KOLBA	296750	55.08	93.37	7	591	23	MOROZOVSK	345450	48.35	41.87	5A	414	16
KOLPASEVO	292310	58.32	82.95	7	504	20	MOSKVA	276120	55.83	37.62	6A	684	27
KOLYVAN	296310	55.30	82.75	7	411	16	MOZDOK	371450	43.73	44.67	5A	531	21
KOMMUNAR	297590	54.33	89.28	7	860	34	MURMANSK	221130	68.97	33.05	7	473	19
KORF	259540	60.35	166.00	8	423	17	MUZI	234260	65.38	64.72	8	514	20
KOTEL`NIKOVO	346550	47.63	43.15	5A	402	16	MYS SHALAUROVA	216470	73.18	143.23	8	116	5
KOTLAS	228870	61.23	46.72	7	538	21	MYS SHMIDTA	251730	68.90	–179.37	8	248	10
KOZ`MODEM`JANSK	274790	56.33	46.58	7	586	23	MYS UELEN	253990	66.17	–169.83	8	377	15
KRASNODAR	349290	45.03	39.15	4A	702	28	MYS ZELANIJA	203530	76.85	68.55	8	314	12
KRASNOJARSK	295740	56.00	92.88	7	495	19	NAGORNYJ	304930	55.97	124.88	8	568	22
KRASNOJARSK OPYTNOE	295700	56.03	92.75	7	495	19	NAJAHAN	258210	61.95	158.97	8	448	18
KRASNOOZERSK	298130	53.97	79.23	7	355	14	NAPAS	290230	59.85	81.95	8	569	22
KRASNOSCELE	222350	67.35	37.05	8	519	20	NARJAN-MAR	232050	67.63	53.03	8	463	18
KRASNOUFIMSK	284340	56.65	57.78	7	531	21	NAZYVOEVSK	285880	55.57	71.37	7	378	15
KRASNYE BAKI	273690	57.13	45.17	7	631	25	NELKAN	311520	57.67	136.15	8	407	16
KRASNYJ CHIKOJ	309350	50.37	108.75	8	347	14	NERCHINSKIJ ZAVOD	308790	51.32	119.62	8	438	17
KRASNYJ JAR	318450	46.53	135.32	7	872	34	NIKOL`SK	270660	59.53	45.47	7	606	24
KRESCHENKA	295240	55.85	80.03	7	422	17	NIKOLAEVSK-NA-AMURE	313690	53.15	140.70	8	640	25
KUDYMKAR	281160	58.98	54.65	7	548	22	NIKOLAEVSKOE	261670	58.57	29.80	6A	652	26
KUPINO	297060	54.37	77.28	7	308	12	NIKOLO-POLOMA	272520	58.35	43.38	7	620	24
KUR	316320	49.93	134.63	7	752	30	NIKOLSKOE	326180	55.20	165.98	7	673	26
KURGAN	286610	55.47	65.40	7	380	15	NIZHNEANGARSK	304330	55.78	109.55	8	360	14
KURSK	340090	51.77	36.17	6A	627	25	NIZHNEUDINSK	296980	54.88	99.03	7	404	16
KYRA	309490	49.57	111.97	7	377	15	NIZHNYJ TAGIL	282400	57.88	60.07	7	532	21
KYSTOVKA	294050	56.60	76.57	7	416	16	NIZNIJ NOVGOROD	274590	56.27	44.00	7	608	24
KYZYL	360960	51.72	94.50	8	233	9	NJAKSIMVOL	237240	62.43	60.87	8	528	21
LAKE TAJMYR	205940	74.50	102.50	8	227	9	NJANDOMA	228540	61.67	40.18	7	729	29
LENSK	249230	60.72	114.88	8	375	15	NJURBA	246390	63.28	118.33	8	283	11
LEUSI	280640	59.62	65.72	7	488	19	NOGLIKI	320530	51.92	143.13	7	693	27
LJUBAN	260780	59.35	31.23	7	635	25	NOLINSK	273930	57.55	49.95	7	641	25
LOKSAK	312630	54.73	130.45	8	577	23	NORSK	313880	52.35	129.92	8	559	22
LOSINOBORSKOE	292530	58.43	89.37	8	553	22	NOVOKUZNETSK	298460	53.82	86.88	7	462	18
LOVOZERO	221270	68.00	35.03	8	486	19	NOVOSELENGINSK	308290	51.10	106.65	7	268	11
LUKOJANOV	276650	55.03	44.50	7	572	23	NOVOSIBIRSK	296340	55.08	82.90	7	436	17
MAGADAN	259130	59.55	150.78	8	528	21	NOZOVKA	283190	57.08	54.75	7	531	21
MAGDAGACI	312950	53.47	125.82	8	470	18	OBJACEVO	229960	60.37	49.65	7	606	24
MAGNITOGORSK	288380	53.35	59.08	7	365	14	OBLUCE	317020	49.00	131.08	7	720	28
MAHACKALA	374720	43.02	47.48	4B	336	13	ODESSKOE	287970	54.20	72.97	7	330	13
MAJSK	292090	57.78	77.28	7	494	19	OHANSK	283210	57.72	55.38	7	549	22

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.
OHOTSK	310880	59.37	143.20	8	489	19	RA-IZ	233310	66.90	65.67	8	774	30
OKTJABRSKOE	237340	62.45	66.05	8	591	23	REBOLY	226020	63.83	30.82	7	596	23
OLEKMINSK	249440	60.40	120.42	8	307	12	REBRIHA	299230	53.07	82.30	7	409	16
OLENEK	241250	68.50	112.43	8	290	11	REMONTNOE	347590	46.57	43.67	5A	379	15
OLOVJANNAJA	309610	50.95	115.58	7	327	13	RJAZAN'	277310	54.62	39.72	6A	584	23
OMSK	286980	55.02	73.38	7	381	15	RJAZAN`	277300	54.63	39.70	6A	584	23
ONEGA	226410	63.90	38.12	7	591	23	ROMANOVKA	306500	53.20	112.78	8	359	14
ONGUDAJ	362310	50.73	86.15	7	363	14	ROSLAVL	268820	53.93	32.83	6A	604	24
OPARINO	270830	59.85	48.28	7	658	26	ROSTOV	273290	57.20	39.42	7	590	23
ORDYNSKOE	297260	54.37	81.95	7	398	16	ROSTOV-NA-DONU	347310	47.25	39.82	5A	593	23
OREL	279060	52.93	36.00	6A	639	25	RUBCOVSK	360340	51.50	81.22	7	341	13
ORENBURG	351210	51.68	55.10	7	365	14	RUDNAJA PRISTAN	319590	44.37	135.85	7	776	31
OSTASKOV	263890	57.13	33.12	7	615	24	RUSSKAYA GAVAN`	203570	76.18	62.57	8	377	15
OSTROV CHETYREHSTOL	219650	70.63	162.48	8	88	3	RYBINSK	272250	58.10	38.68	7	671	26
OSTROV DIKSON	206740	73.50	80.40	8	348	14	RZEV	264980	56.27	34.32	6A	626	25
OSTROV GOLOMJANNYJ	200870	79.55	90.62	8	226	9	SADRINSK	285520	56.07	63.65	7	433	17
OSTROV KOTELNYJ	214320	76.00	137.87	8	135	5	SAIM	239290	60.32	64.22	7	457	18
OSTROV PREOBRAZENIJ	215040	74.67	112.93	8	158	6	SAKUN`JA	273730	57.67	46.63	7	600	24
OSTROV UEDINENIJA	202740	77.50	82.20	8	158	6	SALEHARD	233300	66.53	66.67	8	442	17
OSTROV VIZE	200690	79.50	76.98	8	209	8	SAMARA	289000	53.25	50.45	7	530	21
OSTROV VRANGELJA	219820	70.98	–178.48	8	171	7	SAMARY	283340	57.35	58.22	7	660	26
OZERNAJA	325940	51.48	156.48	7	809	32	SANGARY	246520	63.97	127.47	8	311	12
PADUN	221060	68.60	31.85	7	525	21	SAR`JA	272710	58.37	45.53	7	643	25
PARTIZANSK	319870	43.15	133.02	6A	782	31	SARAN-PAUL	235270	64.28	60.88	8	499	20
PAVELEC	278230	53.78	39.25	7	542	21	SARATOV	341720	51.57	46.03	6A	431	17
PECHORA	234180	65.12	57.10	8	569	22	SARGATSKOE	285980	55.60	73.48	7	399	16
PENZA	279620	53.12	45.02	7	540	21	SEGEZA	226210	63.77	34.28	7	586	23
PERM	282250	57.95	56.20	7	614	24	SEJAHA	209670	70.17	72.52	8	364	14
PERVOMAJSKOE	293480	57.07	86.22	7	439	17	SEJMCHAN	257030	62.92	152.42	8	311	12
PETROPAVLOVSK-KAMCH	325400	53.08	158.58	7	1127	44	SEKTAGLI	315340	50.43	131.02	8	724	29
PETROPAVLOVSK-KAMCH	325830	52.98	158.65	7	1152	45	SELAGONCY	243290	66.25	114.28	8	292	11
PETROVSKIJ ZAVOD	308380	51.32	108.87	8	328	13	SELEMDZA	313380	53.13	133.97	8	666	26
PETROZAVODSK	228200	61.82	34.27	7	574	23	SEMJACHIK	325090	54.12	159.98	7	1297	51
PIHTOVKA	295340	55.98	82.70	7	410	16	SENKURSK	227680	62.10	42.90	7	568	22
PILVO	320690	50.05	142.17	7	639	25	SERAFIMOVIC	343570	49.57	42.75	6A	435	17
PINEGA	225630	64.70	43.38	7	557	22	SERBAKUL	287910	54.63	72.43	7	338	13
PIROVSKOE	293630	57.63	92.27	8	481	19	SEROV	280440	59.60	60.53	7	487	19
PJALICA	223490	66.18	39.53	7	447	18	SEVERNOE	294180	56.35	78.35	7	443	17
POGIBI	320270	52.22	141.63	8	570	22	SEVERO-KURILSK	322150	50.68	156.13	7	1731	68
POGRANICHNOE	320760	50.40	143.77	8	751	30	SHEREMETYEVO	275155	55.97	37.42	7	674	27
POGRANICHNYJ	319150	44.40	131.38	7	618	24	SHILKA	308620	51.87	116.03	8	339	13
POJARKOVO	315870	49.62	128.65	7	533	21	SIMANOVSK	314420	51.98	127.65	8	534	21
POKROVSKAJA	248560	61.48	129.15	8	269	11	SIMUSIR	321950	46.85	151.87	7	1310	52
POLARGMO IM. E.T. K	200460	80.62	58.05	8	256	10	SIRA	297560	54.50	89.93	7	454	18
POLTAVKA	319170	44.03	131.32	7	588	23	SKOVORODINO	306920	54.00	123.97	8	434	17
PORONAJSK	320980	49.22	143.10	7	750	30	SLAVGOROD	299150	52.97	78.65	7	304	12
POSET	319690	42.65	130.80	6A	742	29	SMIDOVICH	317250	48.62	133.83	7	699	28
PREOBRAZHENIE	319890	42.90	133.90	6A	784	31	SMOLENSK	267810	54.75	32.07	6A	674	27
PRIARGUNSK	309750	50.40	119.07	8	357	14	SOFIJSKIJ PRIISK	314780	52.27	133.98	8	739	29
PRIMORSKO-AHTARSK	348240	46.03	38.15	5A	565	22	SOJNA	222710	67.88	44.13	8	401	16
PSKOV	262580	57.82	28.42	6A	629	25	SOLNETHNAYA	305370	54.03	108.27	7	267	10
PUDINO	293130	57.53	79.37	7	452	18	SOLOVEVSK	309670	49.90	115.75	7	303	12
PUDOZ	228310	61.80	36.52	7	690	27	SORTAVALA	228020	61.72	30.72	7	606	24

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

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

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

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

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

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

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.
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

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.
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

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.
MIDDLE WALLOP	037490	51.15	–1.57	4A	749	29	THORNEY ISLAND	038720	50.82	–0.92	4A	793	31
MILDENHALL RAF	035773	52.37	0.48	4A	586	23	TIREE	031000	56.50	–6.88	5A	1182	47
MILFORD HAVEN	036040	51.70	–5.05	4A	861	34	TRAWSGOED	035030	52.35	–3.95	5A	1174	46
MUCKLE FLUGGA	030010	60.85	–0.88	5A	1210	48	TULLOCH BRIDGE	030470	56.87	–4.70	5A	1553	61
MUCKLE HOLM	030070	60.58	–1.27	5A	1076	42	TYNEMOUTH	032620	55.02	–1.42	5A	646	25
MUMBLES	036090	51.57	–3.98	4A	1198	47	UPPER HEYFORD RAF	036553	51.93	–1.25	5A	645	25
NEWCASTLE	032433	55.03	–1.68	5A	668	26	VALLEY	033020	53.25	–4.53	4A	839	33
NEWCASTLE WEATHER C	032460	54.98	–1.60	5A	666	26	WADDINGTON	033770	53.17	–0.52	5A	603	24
NEWHAVEN (LGT-H)	038800	50.78	0.05	4A	841	33	WAINFLEET	033920	53.08	0.27	5A	584	23
NORTH RONA	030110	59.12	–5.82	5A	1398	55	WALNEY ISLAND	032140	54.12	–3.25	5A	1238	49
NORTHOLT	036720	51.55	–0.42	4A	602	24	WALTON-ON-NAZE	036960	51.85	1.28	4A	546	21
NORWICH WEA CNTRE	034920	52.63	1.32	4A	648	26	WARCOP RANGE	032260	54.57	–2.42	5A	1249	49
NOTTINGHAM/WATNALL	033540	53.00	–1.25	5A	715	28	WATTISHAM	035900	52.12	0.97	5A	582	23
OBAN	031140	56.42	–5.47	5A	2131	84	WEST FREUGH	031320	54.85	–4.95	5A	977	38
ODIHAM	037610	51.23	–0.95	4A	799	31	WEYBOURNE	034880	52.95	1.13	4A	667	26
ORSAY (LGT-H)	031020	55.67	–6.50	5A	1266	50	WICK	030750	58.45	–3.08	5A	787	31
PEMBREY SANDS	036050	51.72	–4.37	4A	1215	48	WITTERING	034620	52.62	–0.47	5A	580	23
PENDENNIS POINT	038100	50.15	–5.07	4A	1117	44	WYTON(RAF)	035660	52.35	–0.12	5A	537	21
PENDINE (AUT)	036080	51.75	–4.52	4A	1212	48	YEOVILTON	038530	51.00	–2.63	4A	727	29
PERSHORE	035290	52.15	–2.03	5A	633	25	Uruguay (URY)						
PETERHEAD HARBOUR	030920	57.50	–1.77	5A	724	29	ARTIGAS	863300	–30.38	–56.50	3A	1486	59
PLYMOUTH MOUNT BATT	038270	50.35	–4.12	4A	1004	40	CARRASCO	865800	–34.83	–56.00	3A	950	37
PORTGLENONE	039150	54.87	–6.45	5A	1098	43	COLONIA	865600	–34.45	–57.83	3A	1108	44
PORTLAND HELIPORT	038580	50.57	–2.45	4A	912	36	PASO DE LOS TOROS	864600	–32.80	–56.52	3A	1315	52
PRESTWICK RNAS	031360	55.52	–4.58	5A	949	37	PRADO	865850	–34.85	–56.20	3A	1069	42
PRESTWICK(CIV/NAVY)	031350	55.50	–4.58	5A	949	37	RIVERA	863500	–30.88	–55.53	3A	1500	59
REDESDALE CAMP	032300	55.28	–2.28	5A	957	38	ROCHA	865650	–34.48	–54.30	3A	1051	41
RHYL	033130	53.25	–3.50	4A	1007	40	SALTO	863600	–31.38	–57.95	3A	1264	50
SCILLY: ST MARYS AI	038030	49.92	–6.30	4A	909	36	TREINTA Y TRES	865000	–33.22	–54.38	3A	1335	53
SELLA NESS	030060	60.45	–1.27	5A	1106	44	Uzbekistan (UZB)						
SENNYBRIDGE	035070	52.07	–3.62	5A	1495	59	AK-BAJTAL	381780	43.15	64.33	5B	117	5
SHAP	032250	54.50	–2.68	5A	1373	54	BUHARA	386830	39.72	64.62	4B	146	6
SHAWBURY	034140	52.80	–2.67	5A	658	26	BUZAUBAJ	384030	41.75	62.47	4B	88	3
SHEERNESS	037910	51.45	0.75	4A	599	24	CHIMBAJ	382620	42.95	59.82	5B	120	5
SHOBDON	035200	52.25	–2.88	5A	827	33	DARGANATA	385450	40.47	62.28	4B	140	6
SHOEBURYNESS	036930	51.55	0.83	4A	504	20	DZIZAK	385790	40.12	67.83	4B	385	15
SHOREHAM AIRPORT	038760	50.83	–0.28	4A	715	28	FERGANA	386180	40.37	71.75	4B	175	7
SKYE/LUSA	030370	57.25	–5.80	5A	2115	83	KARSHI	388120	38.80	65.72	3B	253	10
SOLENT M.R.S.C.	038740	50.80	–1.22	4A	786	31	KUNGRAD	381490	43.08	58.93	5B	118	5
SOUTHAMPTON WX CNTR	038650	50.90	–1.40	4A	789	31	NAMANGAN	386110	40.98	71.58	4B	189	7
SOUTHEND	036913	51.57	0.68	4A	558	22	NUKUS	382640	42.45	59.62	5B	106	4
SPADEADAM	032240	55.05	–2.55	5A	1226	48	NURATA	385650	40.55	65.68	4B	238	9
ST ANGELO	039030	54.40	–7.65	5A	1300	51	PSKEM	384620	41.90	70.37	5C	854	34
ST BEES HEAD NO.2	032100	54.52	–3.60	5A	1136	45	SAMARKAND	386960	39.57	66.95	4B	340	13
ST. CATHERINES POIN	038660	50.58	–1.30	4A	764	30	SYR-DARJA	385830	40.82	68.68	4A	312	12
ST. MAWGAN	038170	50.43	–5.00	4A	1148	45	TAMDY	384130	41.73	64.62	4B	127	5
STANSTED AIRPORT	036830	51.88	0.23	5A	623	25	TASHKENT	384570	41.27	69.27	4A	435	17
STORNOWAY	030260	58.22	–6.32	5A	1188	47	TERMEZ	389270	37.23	67.27	3B	148	6
STRATHALLEN AIRFIEL	031440	56.32	–3.73	5A	954	38	URGENCH	383960	41.57	60.57	4B	92	4
SULE SKERRY	030100	59.08	–4.40	5A	1278	50	Vanuatu (VUT)						
SUMBURGH (CAPE)	030030	59.88	–1.30	5A	1124	44	ANEITYUM	915680	–20.23	169.77	1A	1416	56
TAIN RANGE	030620	57.82	–3.97	5A	770	30	BAUERFIELD (EFATE)	915570	–17.70	168.30	1A	2249	89
THAMES TOWER (AUT)	036950	51.67	1.10	4A	557	22	PEKOA AIRPORT (SANTO)	915540	–15.52	167.22	1A	2823	111

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

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

$$P < 0.44 \times (T - 7) \qquad \text{(I-P)}$$

$$P < 20.0 \times (T + 14) \qquad \text{(SI)}$$

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)

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

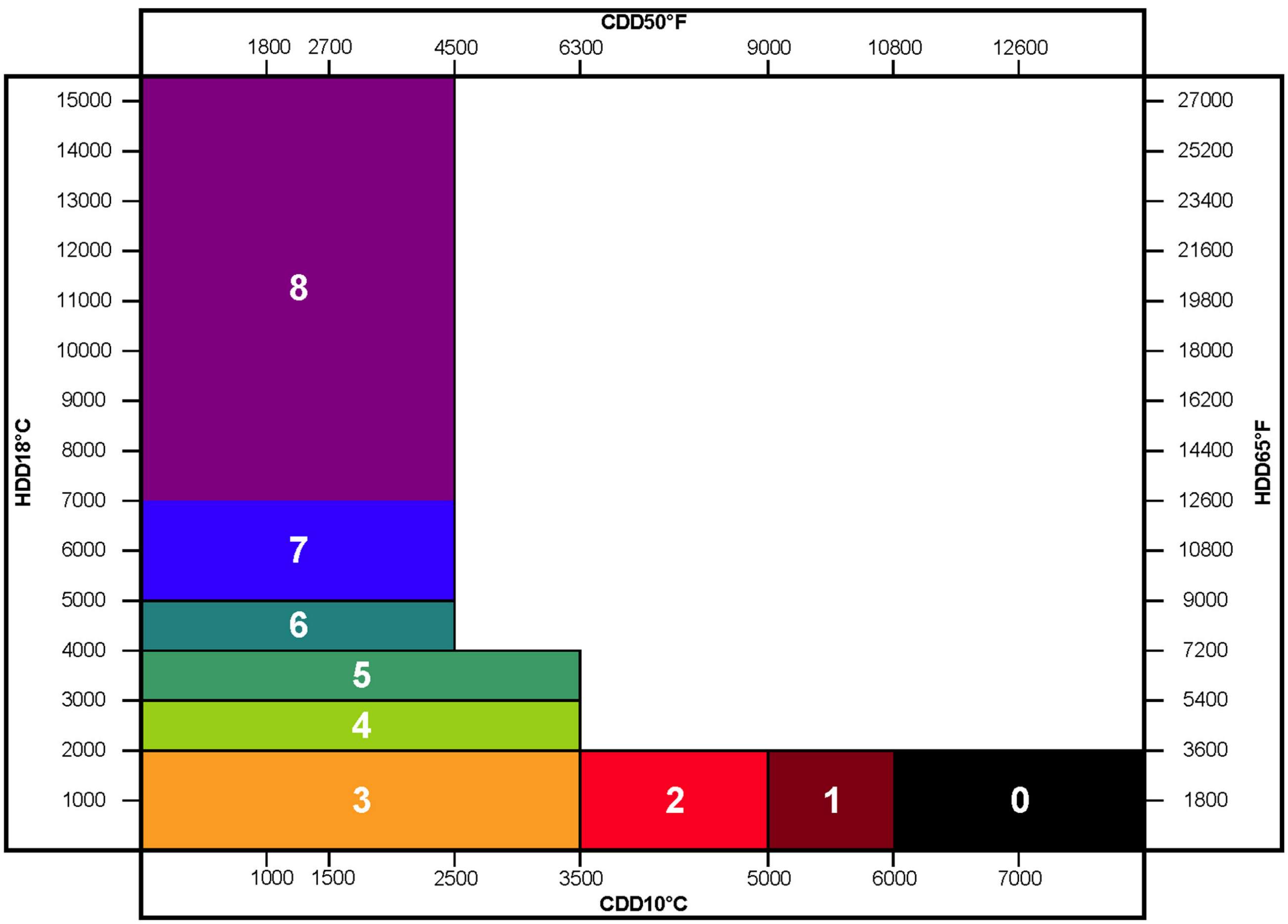

Figure Annex1-2 ASHRAE Standard 169-2013, Figure A-1: Thermal climate zones as a function of heating and cooling degree-days.

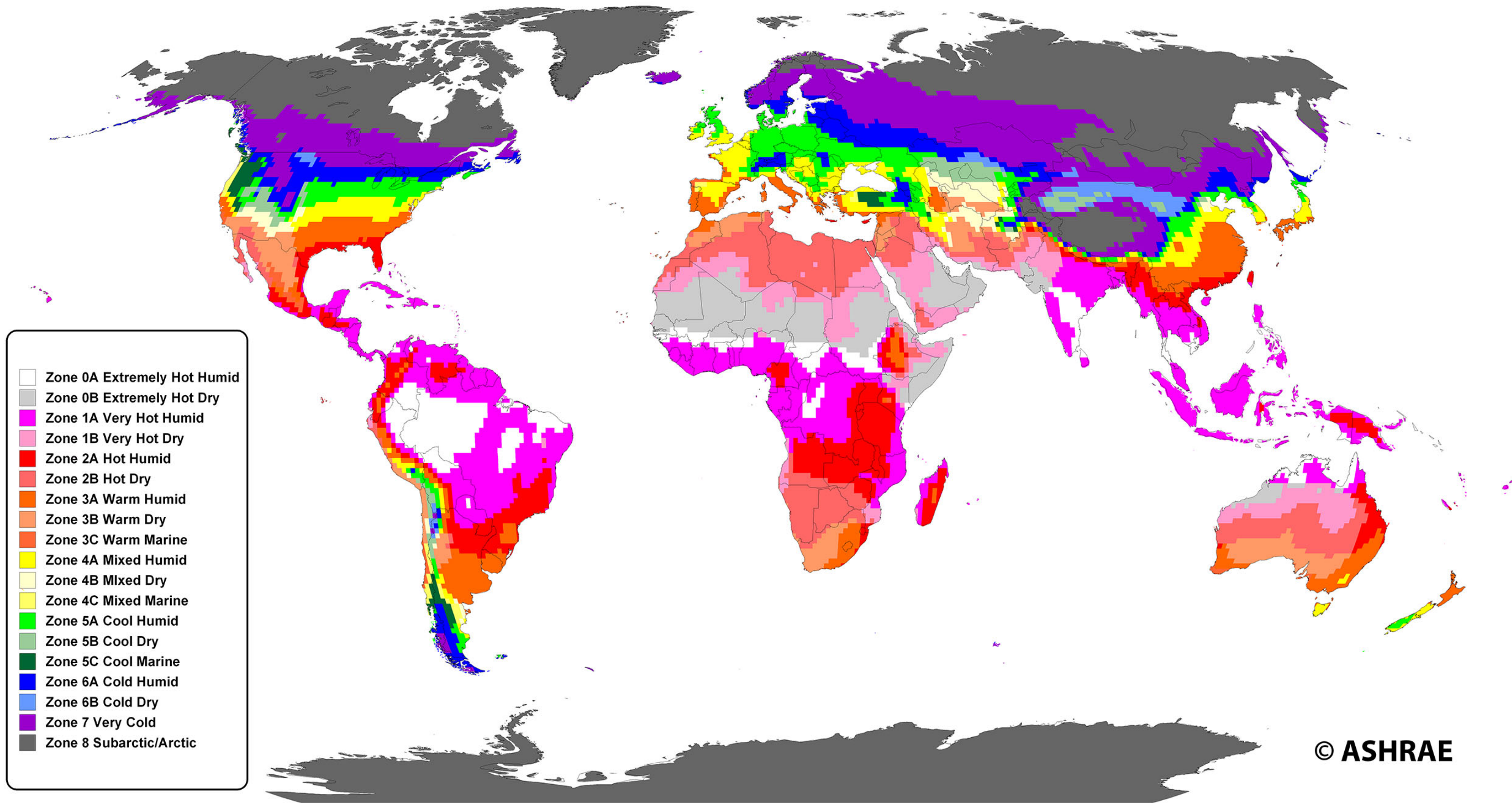

Figure Annex1-3 ASHRAE Standard 169-2013, Figure C-2: World climate zones map.

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.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

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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About ASHRAE

Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

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.

To stay current with this and other ASHRAE Standards and Guidelines, visit www.ashrae.org/standards, and connect on LinkedIn, Facebook, Twitter, and YouTube.

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ASHRAE offers its Standards and Guidelines in print, as immediately downloadable PDFs, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected Standards and Guidelines are also offered in redline versions that indicate the changes made between the active Standard or Guideline and its previous edition. For more information, visit the Standards and Guidelines section of the ASHRAE Bookstore at www.ashrae.org/bookstore.

IMPORTANT NOTICES ABOUT THIS STANDARD

To ensure that you have all of the approved addenda, errata, and interpretations for this Standard, visit www.ashrae.org/standards to download them free of charge.

Addenda, errata, and interpretations for ASHRAE Standards and Guidelines are no longer distributed with copies of the Standards and Guidelines. ASHRAE provides these addenda, errata, and interpretations only in electronic form to promote more sustainable use of resources.

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