STANDARD

ANSI/ASHRAE/IES Standard 90.1-2013
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2010)
Includes ANSI/ASHRAE/IES Addenda listed in Appendix F

Energy Standard for Buildings Except Low-Rise Residential Buildings

(SI Edition)

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.

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

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NOTE

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

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

FOREWORD

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

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

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

The most significant changes included are as follows:

a. ***Building Envelope.*** *Opaque elements and fenestration requirements have been revised to increase stringency while maintaining a reasonable level of cost-effectiveness. Opaque and fenestration assemblies in Tables 5.5-1 through 5.5-8 are revised in most climates. These changes include*
    1. *criteria requiring double-glazed fenestration in many climates;*
    2. *minimum VT/SHGC ratio to enable good daylighting with minimum solar gain, while not restricting triple and quadruple glazing; and*
    3. *simplification of the skylighting criteria.*

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

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

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

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

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

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

1. PURPOSE

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. These definitions are applicable to all sections of this standard. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based upon American standard English language usage as documented in an unabridged dictionary accepted by the adopting authority.

3.2 Definitions

above-grade wall: see *wall.*

access hatch: see *door.*

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

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.

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

attic and other roofs: see *roof.*

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

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

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

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

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

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

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

baseline building design: a computer representation of a hypothetical design based on the proposed building project. This representation is used as the basis for calculating the baseline building performance for rating above-standard design.

baseline building performance: the annual energy cost for a building design intended for use as a baseline for rating above-standard design.

below-grade wall: see *wall*.

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

> ***modulating boiler:*** a boiler that is capable of more than a single firing rate in response to a varying temperature or heating load.
>
> ***packaged boiler:*** a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls, and that is usually shipped in one or more sections. A packaged boiler includes factory-built boilers manufactured as a unit or system, disassembled for shipment, and reassembled at the site.

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

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

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

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

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

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

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

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

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

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

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

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

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

C-factor: see *thermal conductance.*

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

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

code official: see *building official*.

coefficient of performance (COP)—cooling: the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions.

coefficient of performance (COP), heat pump—heating: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, including the compressor and, if applicable, auxiliary heat, under designated operating conditions.

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 215 W/m^2 of conditioned floor area.

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

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

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

conditioned space: see *space*.

conductance: see *thermal conductance*.

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

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

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

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

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

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

control: to regulate the operation of equipment.

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

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

cooled space: see *space*, *conditioned space*.

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

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

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

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

daylight area:

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

a. the width of the vertical fenestration above the ceiling level plus, on each side, the smallest of
   1. 0.6 m,
   2. the distance to any 1.5 m 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).

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 below the ceiling (see Figure 3.2-3).

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 1.5 m 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 1.5 m 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 3.2-4):

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 1.5 m 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 1.5 m or higher opaque vertical obstruction.

If the adjacent primary sidelighted area ends at a 1.5 m or higher opaque vertical obstruction, there is no secondary sidelighted area beyond such obstruction.

daylighted area: the floor area substantially illuminated by daylight.

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

decorative lighting: see *lighting*, *decorative*.

dedicated replacement air: see *makeup air*.

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

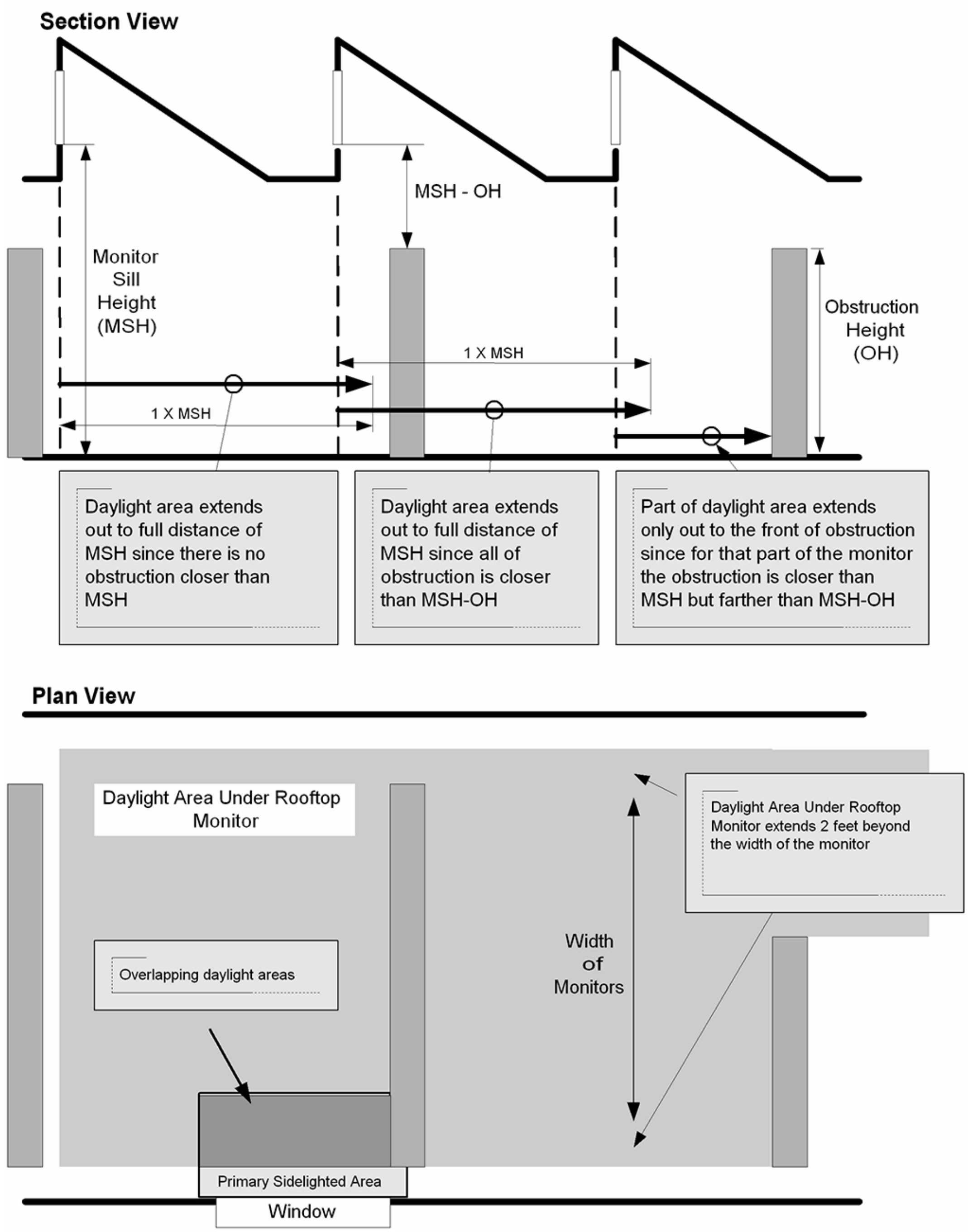


Figure 3.2-1. Computing the daylight area under roof monitors.

building envelope requirements, the classifications are defined as follows:

cooling degree-day base 10°C (CDD10): for any one day, when the mean temperature is more than 10°C, there are as many degree-days as degrees Celsius temperature difference between the mean temperature for the day and 10°C. Annual cooling degree-days (CDDs) are the sum of the degree-days over a calendar year.

heating degree-day base 18°C (HDD18): for any one day, when the mean temperature is less than 18°C, there are as many degree-days as degrees Celsius temperature difference between the mean temperature for the day and 18°C. Annual heating degree-days (HDDs) are the sum of the degree-days over a calendar year.

demand: the highest amount of power (average kW 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.

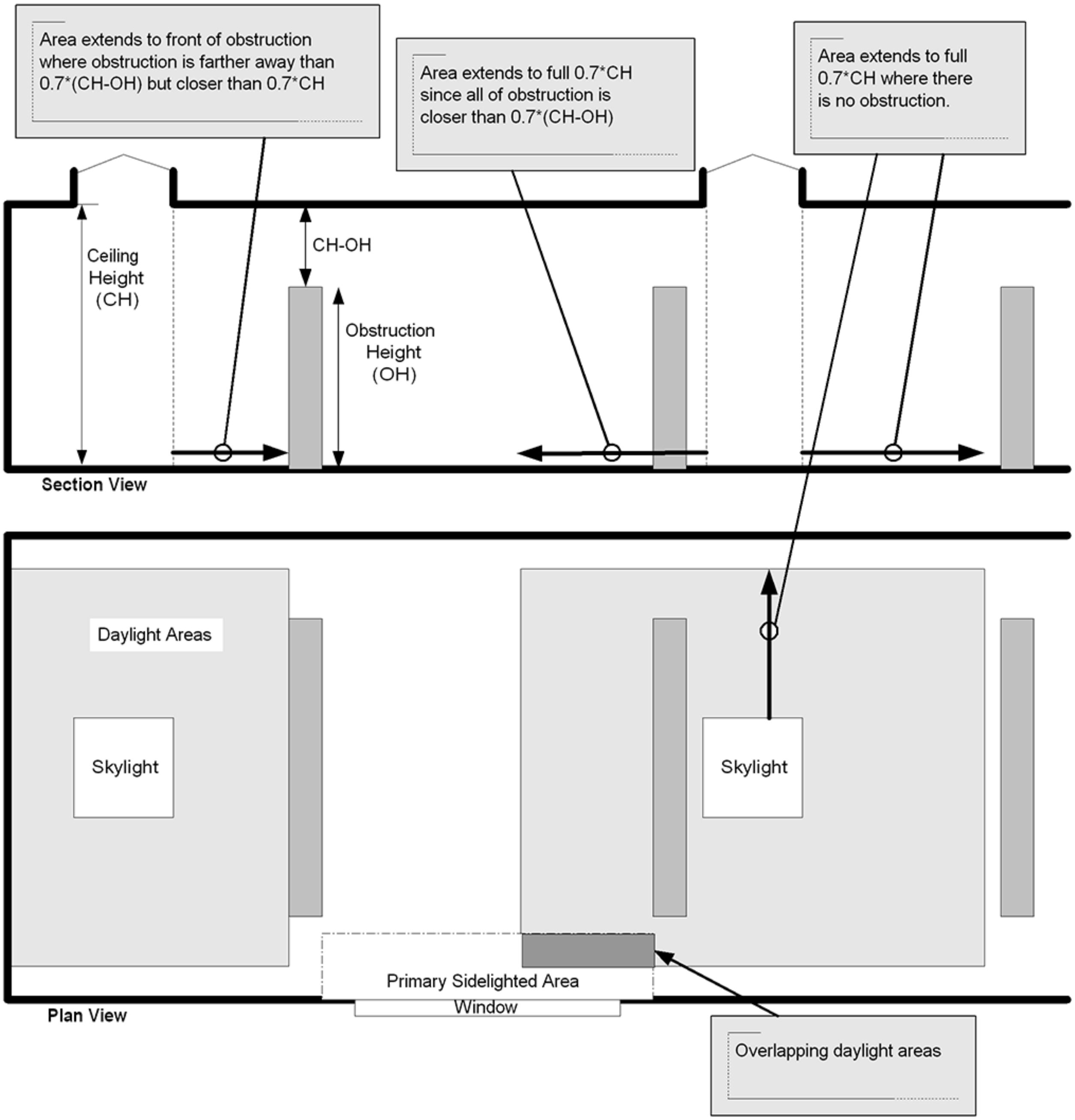


Figure 3.2-2. Computing the daylight area under skylights.

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

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

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

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

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

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

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

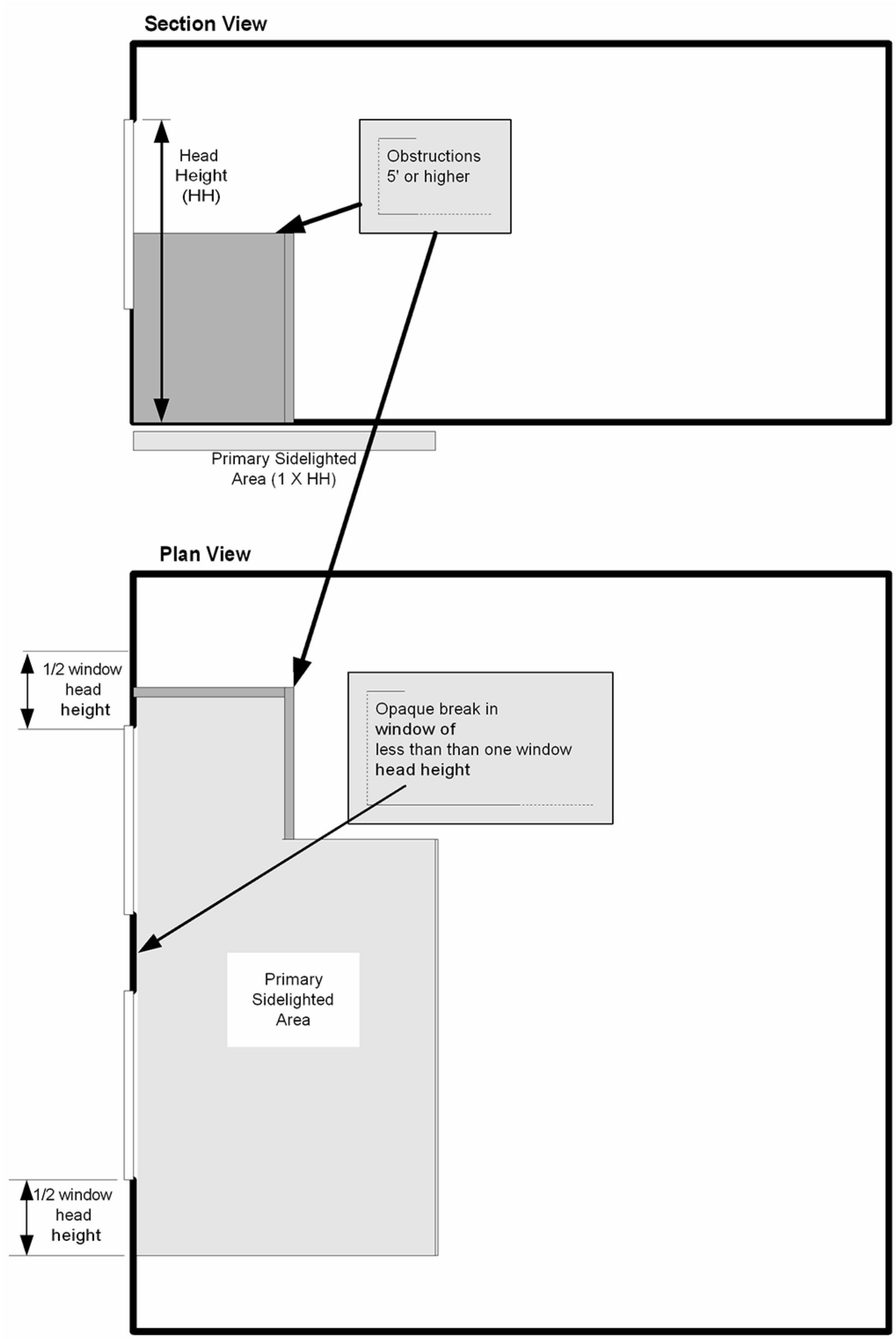


Figure 3.2-3. Computing the primary sidelighted area.

fenestration). For the purposes of determining building envelope requirements, the classifications are defined as follows:

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

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

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

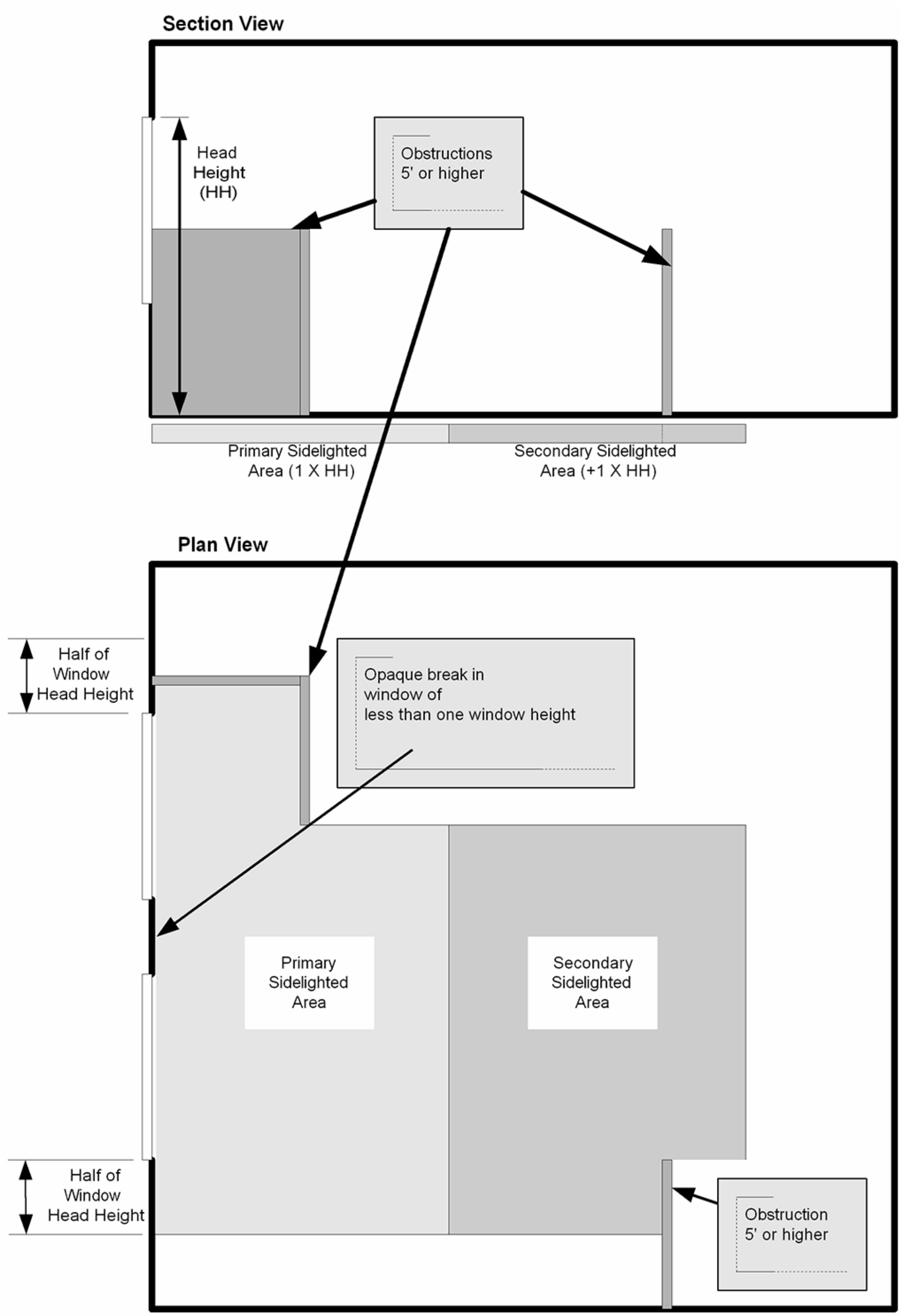


Figure 3.2-4. Computing the secondary sidelighted area.

dwelling unit: a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

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

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

economizer, water: a system by which the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling.

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

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

efficiency: performance at specified rating conditions.

electric resistance: see *resistance, electric*.

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 (J).

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 (kWh) to total rate of electric input in watts under designated operating conditions. (See *coefficient of performance [COP]—cooling*.)

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

entrance door: see *fenestration*.

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

> ***base envelope performance factor:*** the building envelope performance factor for the base design.
>
> ***proposed envelope performance factor:*** the building envelope performance factor for the proposed design.

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

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

a. Hospitals and other health care facilities having surgery or emergency treatment facilities
b. Fire, rescue, and police stations and emergency vehicle garages
c. Designated earthquake, hurricane, or other emergency shelters
d. Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response
e. Power-generating stations and other public utility facilities required as emergency backup facilities for other essential facilities
f. Structures containing highly toxic materials where the quantity of the material exceeds the maximum allowable quantities
g. Aviation control towers, air traffic control centers, and emergency aircraft hangars
h. Buildings and other structures having critical national defense functions

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

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

existing equipment: equipment previously installed in an existing building.

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

exterior building envelope: see *building envelope*.

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

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

F-factor: the perimeter heat loss factor for slab-on-grade floors (W/m·K).

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 input kilowatts (kW): the kilowatts delivered to the fan's shaft. Input kilowattsdoes not include the mechanical drive losses (belts, gears, etc.).

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

fan system input kilowatts (kW_i): the sum of the fan input kilowattsof all fans that are required to operate at fan system design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source or exhaust it to the outdoors.

fan system design conditions: operating conditions that can be expected to occur during normal system operation that result in the highest supply airflow rate to conditioned spaces served by the system.

fan system motor nameplate kilowatts (kW): the sum of the motor nameplate kilowatts of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source or exhaust it to the outdoors.

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

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

> ***field-fabricated fenestration:*** fenestration whose frame is made at the construction site of materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior glazed door. Field-fabricated fenestration does not include site-built fenestration designed to be glazed or assembled in the field using specific factory-cut or otherwise factory-formed framing and glazing units, such as storefront systems, curtain walls, and atrium roof systems.
>
> ***skylight:*** a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other 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 300 mm of a mass wall, are considered walls, not fenestration.

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

fixed: see *vertical fenestration*.

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

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

> ***mass floor:*** a floor with a heat capacity that exceeds (1)143 kJ/m^2·K or (2) 102 kJ/m^2·K, provided that the floor has a material unit mass not greater than 1920 kg/m^3.
>
> ***steel-joist floor:*** a floor that (1) is not a mass floor and (2) has steel joist members supported by structural members.
>
> ***wood-framed and other floors:*** all other floor types, including wood-joist floors.

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

floor area, gross: the sum of the floor areas of the spaces within the building, including basements, mezzanine and intermediate-floored tiers, and penthouses with a headroom height of 2.3 m or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

> ***gross building envelope floor area:*** the gross floor area of the building envelope, but excluding slab-on-grade floors.
>
> ***gross conditioned floor area:*** the gross floor area of conditioned spaces.
>
> ***gross lighted floor area:*** the gross floor area of lighted spaces.
>
> ***gross semiheated floor area:*** the gross floor area of semiheated spaces.

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

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

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

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

general lighting: see *lighting*, *general*.

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

a. is a single-speed induction motor;
b. is rated for continuous duty (MG1) operation or for duty type SI (IEC);
c. contains a squirrel-cage (MG1) or cage (IEC) rotor;
d. has foot-mounting that may include foot-mounting with flanges or detachable feet;
e. is built in accordance with NEMA T-frame dimensions or their IEC metric equivalents, including a frame size that is between two consecutive NEMA frame sizes or their IEC metric equivalents;
f. has performance in accordance with NEMA Design A (MG1) or B (MG1) characteristics, or equivalent designs, such as IEC Design N (IEC);
g. operates on polyphase alternating current 60 Hz sinusoidal power and
    1. is rated at 230 or 460 V (or both), including motors rated at multiple voltages that include 230 or 460 V (or both) or
    2. can be operated on 230 or 460 V (or both); and

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

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

a. Is built in accordance with NEMA U-frame dimensions, as described in NEMA MG-1-1967, or in accordance with the IEC metric equivalents, including a frame size that is between two consecutive NEMA frame sizes or their IEC metric equivalents
b. Has performance in accordance with NEMA Design C characteristics, as described in MG1, or an equivalent IEC design(s) such as IEC Design H
c. Is a close-coupled pump motor
d. Is a footless motor
e. Is a vertical, solid-shaft normal thrust motor (as tested in a horizontal configuration) built and designed in a manner consistent with MG1
f. Is an 8-pole motor (900 rpm)
g. Is a polyphase motor with voltage rating of not more than 600 V, is not rated at 230 or 460 V (or both), and cannot be operated on 230 or 460 V (or both)

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

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

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

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

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

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

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

heat capacity (HC): the amount of heat necessary to raise the temperature of a given mass 0.56°C. Numerically, the HC per unit area of surface ($kJ/m^2 \cdot K$) 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 (Wh) divided by the total electric energy input during the same period.

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

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

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

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

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

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

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

indirectly conditioned space: see *space.*

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

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

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

installed interior lighting power: the power in watts of all general, task, and furniture lighting systems for interior luminaires.***integrated coefficient of performance (ICOP):*** a single-number figure of merit expressing cooling part-load COP efficiency for commercial unitary air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment (analogous to IEER, but for SI or other consistent units).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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

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

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

mass floor: see *floor*.

mass wall: see *wall*.

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

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

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

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

metal building roof: see *roof.*

metal building wall: see *wall.*

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

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

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

a. Activating alternate sets of lights
b. Activating 100% of the lighting power
c. Deactivating all lights

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

nameplate kilowatt (kW): the nominal motor kilowatt 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.

nonautomatic: see *manual.*

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

nonrenewable energy: energy derived from a fossil fuel source.

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

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

nonswinging door: see *door.*

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

a. Is for indoor use only
b. Has rated cooling capacities no greater than 11 kW
c. Is a single-package unit requiring opening in an exterior wall with overall exterior dimensions that requires or uses an existing sleeve that meets one of the following criteria:
    1. Has a width of less than 813 mm and height of less than 1143 mm
    2. Fits inside an existing 845,160 mm^2 opening
d. Is commonly installed in site-built commercial buildings
e. Is of a similar cooling capacity and, if a heat pump, similar heating capacity
f. Draws outdoor air for heat exchange directly through an existing opening, used for both inlet and outlet, in the exterior wall
g. Is restricted to applications where an existing air conditioner, heat pump, or gas/electric unit, installed in an existing exterior wall opening, is to be replaced
h. Bears a permanent "Replacement" marking, conspicuously placed, and clearly indicating that its application is limited to installations where an existing air conditioner or heat pump is to be replaced

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

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

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

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

operable: see *vertical fenestration*.

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

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

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

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

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

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

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

performance rating method: a calculation procedure that generates an index of merit for the performance of building designs that substantially exceeds the energy efficiency levels required by this standard.

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

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

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

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

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

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

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

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

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

process energy: energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building.

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

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

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

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

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

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

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

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

R-value: see *thermal resistance*.

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

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

rated R-value of insulation: the thermal resistance of the insulation alone as specified by the manufacturer in units of $m^2 \cdot K/W$ at a mean temperature of 24°C. 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 this rating methodology.

readily accessible: capable of being reached quickly for operation, renewal, or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. In public facilities, accessibility may be limited to certified personnel through locking covers or by placing equipment in locked rooms.

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

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

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

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

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

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

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

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

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

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

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

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

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

roof: the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60 degrees from horizontal. For the 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 recovering: the process of installing an additional roof covering over an existing roof covering without removing the existing roof covering.

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

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

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

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

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

seasonal coefficient of performance—cooling ($SCOP_C$): 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 SI 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 SI 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 (Wh) divided by the total electric energy input during the same period (Wh).

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

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

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

semiheated space: see *space*.

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

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

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

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

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

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

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

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

setpoint: point at which the desired temperature (°C) 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 3 mm-thick clear, double-strength glass. SC does not include interior, exterior, or integral shading devices.

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

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

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

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

single-rafter roof: see *roof.*

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

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

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

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

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

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

where

skylight area	=	total fenestration area of skylights
skylight VT	=	area weighted average visible transmittance of skylights as determined in accordance with Section 5.8.2.6.
WF	=	area weighted average well factor, where well factor is 0.9 if light well depth is less than 0.6 m, or 0.7 if light well depth is 0.6 m or greater. Light well depth is measured vertically from the underside of the lowest point on the skylight glazing to the ceiling plane under the skylight.

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

slab-on-grade floor: that portion of a slab floor of the building envelope that is in contact with the ground and that is either above grade or is less than or equal to 600 mm below the final elevation of the nearest exterior grade.

heated slab-on-grade floor: a slab-on-grade floor with a heating source either within or below it.

unheated slab-on-grade floor: a slab-on-grade floor that is not a heated slab-on-grade floor.

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

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

solar heat gain coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space. (See *fenestration area*.)

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

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

a. ***cooled space:*** an enclosed space within a building that is cooled by a cooling system whose sensible output capacity exceeds 15 W/m^2 of floor area.
b. ***heated space:*** an enclosed space within a building that is heated by a heating system whose output capacity relative to the floor area is greater than or equal to the criteria in Table 3.2.
c. ***indirectly conditioned space:*** an enclosed space within a building that is not a heated space or a cooled space, which is heated or cooled indirectly by being connected to adjacent space(s) provided:
    1. the product of the U-factor(s) and surface area(s) of the space adjacent to connected space(s) exceeds the combined sum of the product of the U-factor(s) and surface area(s) of the space adjoining the outdoors, unconditioned spaces, and to or from semiheated spaces (e.g., corridors) or
    2. that air from heated or cooled spaces is intentionally transferred (naturally or mechanically) into the space at a rate exceeding 3 ach (e.g., atria).

semiheated space: an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 10 W/m^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*.)

TABLE 3.2 Heated Space Criteria

Heating Output, W/m^2	Climate Zone
15	1 and 2
30	3
45	4 and 5
60	6 and 7
75	8

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

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

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

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

thermal 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 ($W/m^2 \cdot K$). 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 ($m^2 \cdot K/W$).

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 ($W/m^2 \cdot K$).

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

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

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

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

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

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

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

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

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

U-factor: see *thermal transmittance.*

unconditioned space: see *space*.

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

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

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

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

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

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

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

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

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

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

vertical fenestration: all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 300 mm of a mass wall, are considered walls, not fenestration. For the purposes of determining building envelope requirements, the vertical fenestration classifications are defined as follows:

> ***metal framing:*** products with metal framing with or without thermal break.
>
> ***metal framing, entrance door:*** any doorway, set of doors, turnstile, vestibule, or other form of portal that is ordinarily used to gain access by its users and occupants to the building or to individual tenant spaces accessed from the exterior. (See *building entrance* and *door.*)
>
> ***metal framing, fixed:*** all types of vertical fenestration, other than entrance door and operable, including, but not limited to, curtain walls, window walls, fixed windows, picture windows, glass block walls, nonopenable clerestory windows, and nonopenable sidelights and transoms.
>
> ***metal framing, operable:*** all vertical fenestration that opens, except entrance doors, including, but not limited to, casement windows, projecting windows, pivoting windows, horizontal sliding windows, vertical sliding windows, openable clerestory windows, openable sidelights and transoms, sliding glass doors, and doors that are not entrance doors.
>
> ***nonmetal framing:*** all products with framing materials other than metal with or without metal reinforcing or cladding.

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

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

VT: see *visible transmittance*.

walk-in cooler: an enclosed storage space of <280 m^2 that can be walked into and that is designed to maintain a space temperature of >0°C and <13°C.

walk-in freezer: an enclosed storage space of <280 m^2 that can be walked into that is designed to maintain a space temperature of ≤0°C.

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) 143 kJ/m^2·K or (2) 102 kJ/m^2·K, provided that the wall has a material unit weight not greater than 1920 kg/m^3.
>
> ***metal building wall:*** a wall whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain wall systems).
>
> ***steel-framed wall:*** a wall with a cavity (insulated or otherwise) whose exterior surfaces are separated by steel framing members (i.e., typical steel stud walls and curtain wall systems).
>
> ***wood-framed and other walls:*** all other wall types, including wood stud walls.

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

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

water economizer: see *economizer, water*.

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

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

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

3.3 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
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	ASTM International
BSR	Board of Standards Review
C	Celsius
CDD	cooling degree-day
CDD10	cooling degree-days base 10°C
cfm	cubic feet per minute
c.i.	continuous insulation
COP	coefficient of performance
CTI	Cooling Technology Institute
DCV	demand control ventilation
DDC	direct digital control
DOE	U.S. Department of Energy
E_c	combustion efficiency
EER	energy efficiency ratio
EF	energy factor
ENVSTD	Envelope System Performance Compliance Program
E_t	thermal efficiency
FC	filled cavity
gr	grains of moisture per kilogram of dry air
h	hour
HC	heat capacity
HDD	heating degree-day
HDD18	heating degree-days base 18°C
HID	high-intensity discharge
HSPF	heating seasonal performance factor
HVAC	heating, ventilating, and air conditioning
HVACR	heating, ventilating, air conditioning, and refrigeration
IEC	International Electrotechnical Commission

IES	Illuminating Engineering Society of North America
IPLV	integrated part-load value
J	joule
K	kelvin
kg	kilogram
kJ	kilojoule
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
lb	pound
lin	linear
lin m	linear metre
LPD	lighting power density
Ls	liner system
LSG	light-to-solar-gain ratio
MICA	Midwest Insulation Contractors Association
MSH	monitor seal height
NAECA	U.S. National Appliance Energy Conservation Act
NFPA	National Fire Protection Association
NFRC	National Fenestration Rating Council
NPLV	nonstandard part-load value
PF	projection factor
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
R	R-value (thermal resistance)
R_c	thermal resistance of a material or construction from surface to surface
RCR	room cavity ratio
R_u	total thermal resistance of a material or construction including air film resistances
rpm	revolutions per minute
SC	shading coefficient
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SI	Systéme International d'Unites
SL	standby loss
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
T_{db}	dry-bulb temperature
T_{wb}	wet-bulb temperature
UL	Underwriters Laboratories Inc.
VAV	variable-air-volume
VT	visible transmittance (also known as visible light transmittance [VLT])
W	watt
WF	well factor
Wh	watt-hour
W/m^2	watts per square metre
$W/m^2·°C$	watts per square metre per degree Celsius
$W/m·K$	watts per metre per kelvin
$W/m^2·K$	watts per square metre per kelvin
$Wh/m^2·K$	watt-hours per square metre per kelvin

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. An extension or increase in the floor area or height of a building outside of the existing building envelope shall be considered additions to existing buildings and 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 or semiheated spaces in a building are converted to conditioned spaces, such conditioned spaces 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 were 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.

4.2 Compliance

4.2.1 Compliance Paths

4.2.1.1 New Buildings. New buildings shall comply with either the provisions of Section 5, "Building Envelope"; Section 6, "Heating, Ventilating, and Air Conditioning"; Section 7, "Service Water Heating"; Section 8, "Power"; 9, "Lighting"; and Section 10, "Other Equipment" or Section 11, "Energy Cost Budget Method."

4.2.1.2 Additions to Existing Buildings. Additions to existing buildings shall comply with either the provisions of Sections 5, 6, 7, 8, 9, and 10 or Section 11.

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; 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 5, 6, 7, 8, 9, and 10, provided, however, that nothing in this standard shall require compliance with any provision of this standard if such compliance will result in the increase of energy consumption of the building.

Exceptions:

1. 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.
2. Where one or more components of an existing building or portions thereof are being replaced, the annual energy consumption of the comprehensive design shall not be greater than the annual energy consumption of a substantially identical design, using the same energy types, in which compliance with the applicable requirements of Sections 5, 6, 7, 8, 9, and 10, as provided in Section 4.2.1.2,1, is verified by a design professional by the use of any calculation methods acceptable to the authority having jurisdiction.

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.

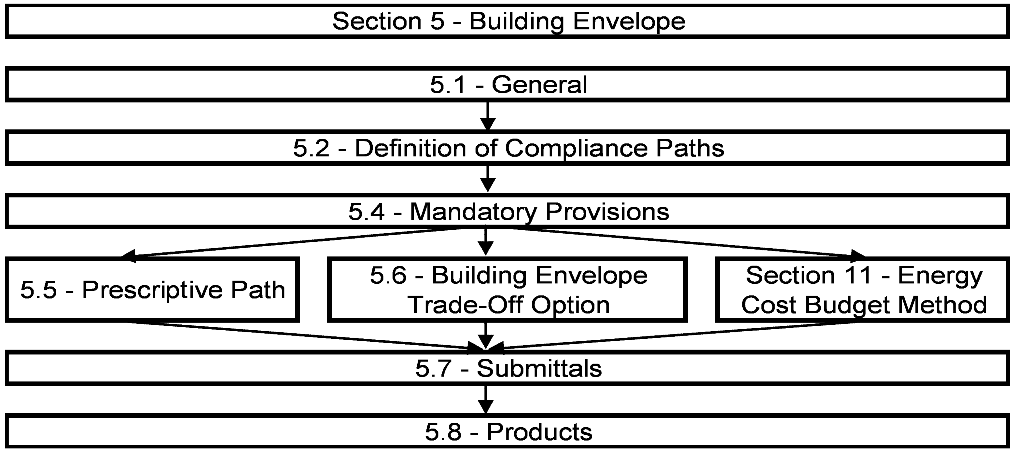
4.2.2.2 Supplemental Information. Supplemental information necessary to verify compliance with this standard, such as calculations, worksheets, compliance forms, vendor literature, or other data, shall be made available when required by the building official.

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 6.7.2.2, 8.7.2, and 9.7.2.2.

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 subject to the provisions of this standard shall be subject to inspection by the building official, and all such work shall remain accessible and exposed for inspection purposes until approved in accordance with the procedures specified by the building official. Items for inspection include at least the following:

a. Wall insulation after the insulation and vapor retarder are in place but before concealment
b. Roof/ceiling insulation after roof/insulation is in place but before concealment
c. Slab/foundation wall after slab/foundation insulation is in place but before concealment
d. Fenestration after all glazing materials are in place
e. Continuous air barrier after installation but before concealment
f. Mechanical systems and equipment and insulation after installation but before concealment
g. Electrical equipment and systems after installation but before concealment



5. BUILDING ENVELOPE

5.1 General

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

5.1.2 Space-Conditioning Categories

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

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

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

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

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

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

1. Installation of storm windows or glazing panels over existing glazing, provided the storm window or glazing panel contains a low-emissivity coating. However, a low-emissivity coating is not required where the existing glazing already has a low-emissivity coating. Installation is permitted to be either on the inside or outside of the existing glazing.
2. Replacement of glazing in existing sash and frame, provided the U-factor and SHGC will be equal to or lower than before the glass replacement.
3. Alterations to roof/ceiling, wall, or floor cavities that are insulated to full depth with insulation having a minimum nominal value of R-0.02/mm.
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. Use Figure B1-1 or Table B1-1 in Appendix B to determine the required climate zone.

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

5.1.4.2 International Locations. For locations in Canada that are listed in Table B1-2 in Appendix B, use this table to determine the required climate zone number and, when a climate zone letter is also required, use Table B1-4 and the Major Climate Type Definitions in Appendix B to determine the letter (A, B, or C). For locations in other international countries that are listed in Table B1-3, use this table to determine the required climate zone number and, when a climate zone letter is also required, use Table B1-4 and the Major Climate Type Definitions in Appendix B to determine the letter (A, B, or C). For all international locations that are not listed either in Table B1-2 or B1-3, use Table B1-4 and the Major Climate Type Definitions in Appendix B to determine both the climate zone letter and number.

5.2 Compliance Paths

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

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

5.2.2 Projects using the Energy Cost Budget Method (see Section 11 of this standard) must comply with Section 5.4, the mandatory provisions of this section, as a portion of that compliance path.

5.3 Simplified Building (Not Used)

5.4 Mandatory Provisions

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

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

5.4.3 Air Leakage

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

Exceptions:

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

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

a. All air barrier components of each building envelope assembly shall be clearly identified or otherwise noted on construction documents.
b. The joints, interconnections, and penetrations of the air barrier components, including lighting fixtures, shall be detailed or otherwise noted.
c. The continuous air barrier shall extend over all surfaces of the building envelope (at the lowest floor, exterior walls, and ceiling or roof).
d. The continuous air barrier shall be designed to resist positive and negative pressures from wind, stack effect, and mechanical ventilation.

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

a. Joints around fenestration and door frames (both manufactured and site-built)
b. Junctions between walls and floors, between walls at building corners, and between walls and roofs or ceilings
c. Penetrations through the air barrier in building envelope roofs, walls, and floors
d. Building assemblies used as ducts or plenums
e. Joints, seams, connections between planes, and other changes in air barrier materials

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

a. Materials that have an air permeance not exceeding 0.02 L/s·m^2 under a pressure differential of 0.02 L/s·m^2 at 75 Pa when tested in accordance with ASTM E 2178. The following materials meet these requirements:
   1. Plywood—minimum 10 mm
   2. Oriented strand board—minimum 10 mm
   3. Extruded polystyrene insulation board—minimum 12 mm
   4. Foil-faced urethane insulation board—minimum 12 mm
   5. Exterior gypsum sheathing or interior gypsum board—minimum 12 mm
   6. Cement board—minimum 12 mm
   7. Built-up roofing membrane
   8. Modified bituminous roof membrane
   9. Fully adhered single-ply roof membrane
   10. A Portland cement/sand parge, stucco, or gypsum plaster—minimum 12 mm thick
   11. Cast-in-place and precast concrete
   12. Sheet metal
   13. Closed-cell 32 kg/m^3 nominal density spray polyurethane foam—minimum 25 mm
b. Assemblies of materials and components (sealants, tapes, etc.) that have an average air leakage not to exceed 0.2 L/s·m^2 under a pressure differential of 0.2 L/s·m^2 at 75 Pa when tested in accordance with ASTM E 2357, ASTM E 1677, ASTM E 1680, or ASTM E283. The following assemblies meet these requirements:
   1. Concrete masonry walls that are
      (a) fully grouted, or
      (b) painted to fill the pores.

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

a. 18.3 m^3/h·m^2 for glazed swinging entrance doors and revolving doors, tested at a pressure of at least 75 Pa in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283;

b. 1.1 $m^3/h \cdot m^2$for curtainwall and storefront glazing, tested at a pressure of at least 75 Pa or higher in accordance with NFRC 400 or ASTM E283;

c. 5.5 $m^3/h \cdot m^2$ for unit skylights having condensation weep-age openings, tested at a pressure of at least 75 Pa in accordance with AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400, or 9.1 $m^3/h \cdot m^2$tested at a pressure of at least 300 Pa in accordance with AAMA/WDMA/CSA 101/I.S.2/A440;

d. 23.8 $m^3/h \cdot m^2$ for nonswinging doors intended for vehicular access and material transportation, with a minimum opening rate of 0.81 m/sec, tested at a pressure of at least 75 Pa or higher in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.

e. 7.3 $m^3/h \cdot m^2$ for other nonswinging opaque doors, glazed sectional garage doors, and upward acting nonswinging glazed doors tested at a pressure of at least 75 Pa or higher in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283; and

f. 3.7 $m^3/h \cdot m^2$ for all other products tested at a pressure of at least 75 Pa in accordance with AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400, or 5.5 $m^3/h \cdot m^2$ tested at a pressure of at least 300 Pa in accordance with AAMA/WDMA/CSA 101/I.S/A440.

Exceptions:

1. Field-fabricated fenestration and doors
2. Metal coiling doors in semiheated spaces in Climate Zones 1 through 6
3. Products in buildings that comply with a whole building air leakage rate of 7.3 $m^3/h \cdot m^2$ under a pressure differential of 2 $L/s \cdot m^2$ at 75Pa when tested in accordance with ASTM E 779

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

5.4.3.4 Vestibules. Building entrances that separate conditioned space from the exterior shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. Interior and exterior doors shall have a minimum distance between them of not less than 2.1m when in the closed position. The floor area of each vestibule shall not exceed the greater of 5 m^2 or 2% of the gross conditioned floor area for that level of the building. The exterior envelope of conditioned vestibules shall comply with the requirements for a conditioned space. The interior and exterior envelope of unconditioned vestibules shall comply with the requirements for a semiheated space.

Exceptions:

1. Building entrances with revolving doors
2. Doors not intended to be used as a building entrance
3. Doors opening directly from a dwelling unit
4. Building entrances in buildings located in Climate Zone 1 or 2
5. Building entrances in buildings that are located in Climate Zone 3, less than four stories above grade, and less than 1000 m^2 in gross conditioned floor area
6. Building entrances in buildings that are located in Climate Zone 4, 5, 6, 7, or 8 and are less than 100 m^2 in gross conditioned floor area
7. Doors that open directly from a space that is less than 300 m^2 in area and is separate from the building entrance

5.4.3.4.1 Where vestibules are required under Section 5.4.3.4, for spaces having a gross conditioned floor area for that level of the building of 4000 m^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 4.8 m.

5.5 Prescriptive Building Envelope Option

5.5.1 For a conditioned space, the exterior building envelope shall comply with either the nonresidential or residential requirements in Tables 5.5-1 through 5.5-8 for the appropriate climate.

5.5.2 If a building contains any semiheated space or unconditioned space, then the semi-exterior building envelope shall comply with the requirements for semiheated space in Tables 5.5-1 through 5.5-8 for the appropriate climate. (See Figure 5.5.2.)

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

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

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

Exceptions:

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

5.5.3.1 Roof Insulation. All roofs shall comply with the insulation values specified in Tables 5.5-1 through 5.5-8. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-0.9, whichever is less.

Table 5.5-1 Building Envelope Requirements for Climate Zone 1 (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-0.273	R-3.5 c.i.	U-0.220	R-4.4 c.i.	U-1.240	R-0.7 c.i.
Metal Building[a]	U-0.233	R-1.8 + R-3.3 FC	U-0.233	R-1.8 + R-3.3 FC	U-0.653	R-1.8
Attic and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.459	R-2.3
Walls, above Grade						
Mass	U-3.293	NR	U-0.857[b]	R-1.0 c.i.[b]	U-3.293	NR
Metal Building	U-0.533	R-0 + R-1.7 c.i.	U-0.533	R-0 + R-1.7 c.i.	U-1.998	NR
Steel Framed	U-0.705	R-2.3	U-0.705	R-2.3	U-1.998	NR
Wood Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-1.660	NR
Wall, below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-1.825	NR	U-1.825	NR	U-1.825	NR
Steel Joist	U-1.986	NR	U-1.986	NR	U-1.986	NR
Wood Framed and Other	U-1.599	NR	U-1.599	NR	U-1.599	NR
Slab-on-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-2.839		U-3.975	
Nonswinging	U-8.233		U-2.839		U-8.233	

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%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-2.84[c]	SHGC-0.25	1.10	U-2.84[c]	SHGC-0.25	1.10	U-5.28	NR	NR
Metal framing, fixed	U-3.24[c]			U-3.24[c]			U-6.81		
Metal framing, operable	U-3.69[c]			U-3.69[c]			U-6.81		
Metal framing, entrance door	U-6.25[c]			U-6.25[c]			U-6.25[c]		
Skylight, 0%–3% of Roof									
All types	U-4.26	SHGC-0.35	NR	U-4.26	SHGC-0.35	NR	U-10.22	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.

c. For locations in Climate Zone 1 with a cooling design temperature of 35°C and greater, see Section 5.5.4.3 for the maximum U-factors for vertical fenestration.

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-0.220	R-4.4 c.i.	U-0.220	R-4.4 c.i.	U-0.982	R-0.9 c.i.
Metal Building[a]	U-0.233	R-1.8 + R-3.3 FC	U-0.233	R-1.8 + R-3.3 FC	U-0.545	R-2.8
Attic and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.300	R-3.3
Walls, above Grade						
Mass	U-0.857[b]	R-1.0 c.i.[b]	U-0.701	R-1.3 c.i.	U-3.293	NR
Metal Building	U-0.533	R-0 + R-1.7 c.i.	U-0.533	R-0 + R-1.7 c.i.	U-0.920	R-2.3
Steel Framed	U-0.479	R-2.3 + R-0.7 c.i.	U-0.365	R-2.3 + R-1.3 c.i.	U-0.705	R-2.3
Wood Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-0.504	R-2.3
Wall, below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.606	R-1.9	U-0.496	R-1.5	U-1.825	NR
Steel Joist	U-0.214	R-5.3	U-0.214	R-5.3	U-0.390	R-2.3
Wood Framed and Other	U-0.188	R-5.3	U-0.188	R-5.3	U-0.376	R-2.3
Slab-on-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.558	R-1.8 for 600 mm	F-1.489	R-2.6 for 600 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-2.839		U-3.975	
Nonswinging	U-2.839		U-2.839		U-8.233	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-2.27			U-2.27			U-5.28		
Metal framing, fixed	U-3.24			U-3.24			U-6.81		
Metal framing, operable	U-3.69	SHGC-0.25	1.10	U-3.69	SHGC-0.25	1.10	U-6.81	NR	NR
Metal framing, entrance door	U-4.71			U-4.37			U-4.71		
Skylight, 0%–3% of Roof									
All types	U-3.69	SHGC-0.35	NR	U-3.69	SHGC-0.35	NR	U-10.22	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 5.5-3 Building Envelope Requirements for Climate Zone 3 (A,B,C)*

Opaque Elements	Nonresidential			Residential			Semiheated		
	Assembly Maximum	Insulation Min. R-Value		Assembly Maximum	Insulation Min. R-Value		Assembly Maximum	Insulation Min. R-Value	
Roofs									
Insulation Entirely above Deck	U-0.220	R-4.4 c.i.		U-0.220	R-4.4 c.i.		U-0.677	R-1.3 c.i.	
Metal Building[a]	U-0.233	R-1.8 + R-3.3 FC		U-0.233	R-1.8 + R-3.3 FC		U-0.545	R-2.8	
Attic and Other	U-0.153	R-6.7		U-0.153	R-6.7		U-0.300	R-3.3	
Walls, above Grade									
Mass	U-0.701	R-1.3 c.i.		U-0.592	R-1.7 c.i.		U-3.293	NR	
Metal Building	U-0.533	R-0 + R-1.7 c.i.		U-0.410	R-0 + R-2.3 c.i.		U-0.920	R-2.3	
Steel Framed	U-0.435	R-2.3 + R-0.9 c.i.		U-0.365	R-2.3 + R-1.3 c.i.		U-0.705	R-2.3	
Wood Framed and Other	U-0.504	R-2.3		U-0.365	R-2.3 + R-0.7 c.i. or R-3.5		U-0.504	R-2.3	
Wall, below Grade									
Below Grade Wall	C-6.473	NR		C-6.473	NR		C-6.473	NR	
Floors									
Mass	U-0.420	R-1.8 c.i.		U-0.420	R-1.8 c.i.		U-0.780	R-0.7 c.i.	
Steel Joist	U-0.214	R-5.3		U-0.214	R-5.3		U-0.296	R-3.3	
Wood Framed and Other	U-0.188	R-5.3		U-0.188	R-5.3		U-0.288	R-3.3	
Slab-on-Grade Floors									
Unheated	F-1.264	NR		F-0.935	R-1.8 for 600 mm		F-1.264	NR	
Heated	F-1.489	R-2.6 for 600 mm		F-1.489	R-2.6 for 600 mm		F-1.766	R-1.3 for 300 mm	
Opaque Doors									
Swinging	U-3.975			U-2.839			U-3.975		
Nonswinging	U-2.839			U-2.839			U-8.233		
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-1.99			U-1.99			U-4.94		
Metal framing, fixed	U-2.84			U-2.84			U-6.81		
Metal framing, operable	U-3.41	SHGC-0.25	1.10	U-3.41	SHGC-0.25	1.10	U-6.81	NR	NR
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0%–3% of Roof									
All types	U-3.12	SHGC-0.35	NR	U-3.12	SHGC-0.35	NR	U-9.65	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 5.5-4 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-0.184	R-5.3 c.i.	U-0.184	R-5.3 c.i.	U-0.527	R-1.8 c.i.
Metal Building[a]	U-0.210	R-3.3 + R-1.9 Ls or R-4.4 + R-1.4 Ls	U-0.210	R-3.3 + R-1.9 Ls or R-4.4 + R-1.4	U-0.466	R-3.3
Attic and Other	U-0.119	R-8.6	U-0.119	R-8.6	U-0.192	R-5.3
Walls, above Grade						
Mass	U-0.592	R-1.7 c.i.	U-0.513	R-2.0 c.i.	U-3.293	NR
Metal Building	U-0.341	R-0 + R-2.8 c.i.	U-0.286	R-0 + R-3.3 c.i.	U-0.920	R-2.3
Steel Framed	U-0.365	R-2.3 + R-1.3 c.i.	U-0.365	R-2.3 + R-1.3 c.i.	U-0.705	R-2.3
Wood Framed and Other	U-0.365	R-2.3 + R-0.7 c.i. or R-3.5	U-0.365	R-2.3 + R-0.7 c.i. or R-3.5	U-0.504	R-2.3
Wall, below Grade						
Below Grade Wall	C-0.678	R-1.3 c.i.	C-0.522	R-1.8 c.i.	C-6.473	NR
Floors						
Mass	U-0.321	R-2.6 c.i.	U-0.287	R-2.9 c.i.	U-0.606	R-1.1 c.i.
Steel Joist	U-0.214	R-5.3	U-0.214	R-5.3	U-0.296	R-3.3
Wood Framed and Other	U-0.188	R-5.3	U-0.188	R-5.3	U-0.288	R-3.3
Slab-on-Grade Floors						
Unheated	F-0.900	R-2.6 for 600 mm	F-0.900	R-2.6 for 600 mm	F-1.264	NR
Heated	F-1.459	R-3.5 for 600 mm	F-1.191	R-3.5 for 1200 mm	F-1.558	R-1.8 for 600 mm
Opaque Doors						
Swinging	U-2.839		U-2.839		U-3.975	
Nonswinging	U-2.839		U-2.839		U-8.233	

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%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-1.99			U-1.99			U-2.90		
Metal framing, fixed	U-2.38			U-2.38			U-4.14		
Metal framing, operable	U-2.84	SHGC-0.40	1.10	U-2.84	SHGC-0.40	1.10	U-4.60	NR	NR
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0%–3% of Roof									
All types	U-2.84	SHGC-0.40	NR	U-2.84	SHGC-0.40	NR	U-6.53	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-0.184	R-5.3 c.i.	U-0.184	R-5.3 c.i.	U-0.360	R-2.6 c.i.
Metal Building[a]	U-0.210	R-3.3 + R-1.9 Ls or R-4.4 + R1.4 Ls	U-0.210	R-3.3 + R-1.9 Ls or R-4.4 + R1.4 Ls	U-0.466	R-3.3
Attic and Other	U-0.119	R-8.6	U-0.119	R-8.6	U-0.192	R-5.3
Walls, above Grade						
Mass	U-0.513	R-2.0 c.i.	U-0.453	R-2.3 c.i.	U-0.857[b]	R-1.0 c.i.[b]
Metal Building	U-0.286	R-0 + R-3.3 c.i.	U-0.286	R-0 + R-3.3 c.i.	U-0.533	R-0 + R-1.7 c.i.
Steel Framed	U-0.315	R-2.3 + R-1.8 c.i.	U-0.315	R-2.3 + R-1.8 c.i.	U-0.479	R-2.3+ R-0.7 c.i.
Wood Framed and Other	U-0.291	R-2.3 + R-0.9 c.i. or R-3.3 + R-0.9 c.i.	U-0.291	R-2.3 + R-0.9 c.i. or R-3.3 + R-0.9 c.i.	U-0.504	R-2.3
Wall, below Grade						
Below Grade Wall	C-0.678	R-1.3 c.i.	C-0.522	R-1.8 c.i.	C-6.473	NR
Floors						
Mass	U-0.321	R-2.6 c.i.	U-0.287	R-2.9 c.i.	U-0.606	R-1.1 c.i.
Steel Joist	U-0.214	R-5.3	U-0.214	R-5.3	U-0.296	R-3.3
Wood Framed and Other	U-0.188	R-6.7	U-0.188	R-6.7	U-0.288	R-3.3
Slab-on-Grade Floors						
Unheated	F-0.900	R-2.6 for 600 mm	F-0.882	R-3.5 for 600 mm	F-1.264	NR
Heated	F-1.191	R-3.5 for 1200 mm	F-1.191	R-3.5 for 1200 mm	F-1.558	R-1.8 for 600 mm
Opaque Doors						
Swinging	U-2.839		U-2.839		U-3.975	
Nonswinging	U-2.839		U-2.839		U-8.233	

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%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-1.82			U-1.82			U-2.56		
Metal framing, fixed	U-2.38			U-2.38			U-3.52		
Metal framing, operable	U-2.84	SHGC-0.40	1.10	U-2.84	SHGC-0.40	1.10	U-3.97	NR	NR
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0%–3% of Roof									
All types	U-2.84	SHGC-0.40	NR	U-2.84	SHGC-0.40	NR	U-5.56	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-0.184	R-5.3 c.i.	U-0.184	R-5.3 c.i.	U-0.360	R-2.6 c.i.
Metal Building[a]	U-0.175	R-4.4 + R-1.9 Ls	U-0.163	R-5.3 + R-1.9 Ls	U-0.341	R-3.3 + R-3.3
Attic and Other	U-0.119	R-8.6	U-0.119	R-8.6	U-0.192	R-5.3
Walls, above Grade						
Mass	U-0.453	R-2.3 c.i.	U-0.404	R-2.7 c.i.	U-0.857[b]	R-1.0 c.i.[b]
Metal Building	U-0.286	R-0 + R-3.3 c.i.	U-0.286	R-0 + R-3.3 c.i.	U-0.533	R-0 + R-1.7 c.i.
Steel Framed	U-0.277	R-2.3 + R-2.2 c.i.	U-0.277	R-2.3 + R-2.2 c.i.	U-0.479	R-2.3 + R-0.7 c.i.
Wood Framed and Other	U-0.291	R-2.3 + R-1.3 c.i. or R-3.3 + R-0.9 c.i.	U-0.291	R-2.3 + R-1.3 c.i. or R-3.3 + R-0.9 c.i.	U-0.504	R-2.3
Wall, below Grade						
Below Grade Wall	C-0.522	R-1.8 c.i.	C-0.358	R-2.6 c.i.	C-0.678	R-1.3 c.i
Floors						
Mass	U-0.287	R-2.9 c.i.	U-0.287	R-2.9 c.i.	U-0.496	R-1.5 c.i.
Steel Joist	U-0.183	R-6.7	U-0.183	R-6.7	U-0.296	R-3.3
Wood Framed and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.288	R-3.3
Slab-on-Grade Floors						
Unheated	F-0.882	R-3.5 for 600 mm	F-0.750	R-3.5 for 1200 mm	F-1.264	NR
Heated	F-1.191	R-3.5 for 1200 mm	F-1.162	R-4.4 for 1200 mm	F-1.489	R-2.6 for 600 mm
Opaque Doors						
Swinging	U-2.839		U-2.839		U-3.975	
Nonswinging	U-2.839		U-2.839		U-2.839	

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%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-1.82			U-1.82			U-2.56		
Metal framing, fixed	U-2.38			U-2.38			U-2.90		
Metal framing, operable	U-2.84	SHGC-0.40	1.10	U-2.84	SHGC-0.40	1.10	U-3.35	NR	NR
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0%–3% of Roof									
All types	U-2.84	SHGC-0.40	NR	U-2.84	SHGC-0.40	NR	U-4.83	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-0.158	R-6.2 c.i.	U-0.158	R-6.2 c.i.	U-0.220	R-4.4 c.i.
Metal Building[a]	U-0.163	R-5.3 + R-1.9 Ls	U-0.163	R-5.3 + R-1.9 Ls	U-0.210	R-3.3 + R-1.9 Ls or R-4.4. + R-1.4 Ls
Attic and Other	U-0.098	R-10.6	U-0.098	R-10.6	U-0.153	R-6.7 c.i.
Walls, above Grade						
Mass	U-0.404	R-2.7 c.i.	U-0.404	R-2.7 c.i.	U-0.701	R-1.3 c.i.
Metal Building	U-0.248	R-0 + R-3.9 c.i.	U-0.248	R-0 + R-3.9 c.i.	U-0.410	R-0 + R-2.3 c.i.
Steel Framed	U-0.277	R-2.3 + R-2.2 c.i.	U-0.240	R-2.3 + R-2.7 c.i.	U-0.365	R-2.3 + R-1.3 c.i.
Wood Framed and Other	U-0.291	R-2.3 + R-1.3 c.i. or R-3.3 + R-0.9 c.i.	U-0.291	R-2.3 + R-1.3 c.i. or R-3.3 + R-0.9 c.i.	U-0.365	R-2.3 + R-0.7 c.i.
Wall, below Grade						
Below Grade Wall	C-0.358	R-2.6 c.i.	C-0.358	R-2.6 c.i.	C-0.678	R-1.3 c.i.
Floors						
Mass	U-0.236	R-3.7 c.i.	U-0.236	R-3.7 c.i.	U-0.420	R-1.8 c.i.
Steel Joist	U-0.183	R-6.7	U-0.183	R-6.7	U-0.296	R-3.3
Wood Framed and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.288	R-3.3
Slab-on-Grade Floors						
Unheated	F-0.882	R-3.5 for 600 mm	F-0.750	R-3.5 for 1200 mm	F-1.264	NR
Heated	F-1.162	R-4.4 for 1200 mm	F-1.162	R-4.4 for 1200 mm	F-1.489	R-2.6 for 600 mm
Opaque Doors						
Swinging	U-2.839		U-2.839		U-3.975	
Nonswinging	U-2.839		U-2.839		U-2.839	

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%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-1.82			U-1.82			U-1.82		
Metal framing, fixed	U-2.16			U-2.16			U-2.16		
Metal framing, operable	U-2.27	SHGC-0.45	1.10	U-2.27	SHGC-0.45	1.10	U-2.50	NR	NR
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0%–3% of Roof									
All types	U-2.84	NR	NR	U-2.84	NR	NR	U-4.83	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		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-0.158	R-6.2 c.i.	U-0.158	R-6.2 c.i.	U-0.220	R-4.4 c.i.
Metal Building[a]	U-0.147	R-4.4 + R-1.9 + R-1.9 Ls	U-0.147	R-4.4 + R-1.9 + R-1.9 Ls	U-0.210	R-3.3 + R-1.9 Ls or R-4.4 + R-1.4 Ls
Attic and Other	U-0.098	R-10.6	U-0.098	R-10.6	U-0.153	R-6.7 c.i.
Walls, above Grade						
Mass	U-0.273	R-3.3 c.i.	U-0.273	R-3.3 c.i.	U-0.592	R-1.7 c.i.
Metal Building	U-0.220	R-0 + R-4.4 c.i.	U-0.220	R-0 + R-4.4 c.i.	U-0.341	R-0 + R-2.8 c.i.
Steel Framed	U-0.212	R-2.3 + R-3.3 c.i.	U-0.212	R-2.3 + R-3.3 c.i.	U-0.365	R-2.3 + R-1.3 c.i.
Wood Framed and Other	U-0.182	R-2.3 + R-3.3 c.i.	U-0.182	R-2.3 + R-3.3 c.i.	U-0.291	R-2.3 + R-1.3 c.i.
Wall, below Grade						
Below Grade Wall	C-0.358	R-2.6 c.i.	C-0.358	R-2.6 c.i.	C-0.678	R-1.3 c.i.
Floors						
Mass	U-0.217	R-4.1 c.i.	U-0.217	R-4.1 c.i.	U-0.363	R-2.2 c.i.
Steel Joist	U-0.183	R-6.7	U-0.183	R-6.7	U-0.296	R-3.3
Wood Framed and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.188	R-5.3
Slab-on-Grade Floors						
Unheated	F-0.750	R-3.5 for 1200 mm	F-0.734	R-4.4 for 1200 mm	F-0.935	R-1.8 for 600 mm
Heated	F-1.162	R-4.4 for 1200 mm	F-0.646	R-3.5 full slab	F-1.489	R-2.6 for 600 mm
Opaque Doors						
Swinging	U-2.839		U-2.839		U-2.839	
Nonswinging	U-2.839		U-2.839		U-2.839	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-1.82			U-1.82			U-1.82		
Metal framing, fixed	U-2.16			U-2.16			U-2.16		
Metal framing, operable	U-2.27	SHGC-0.45	1.10	U-2.27	SHGC-0.45	1.10	U-2.50	NR	NR
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0%–3% of Roof									
All types	U-2.84	NR	NR	U-2.84	NR	NR	U-4.83	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).

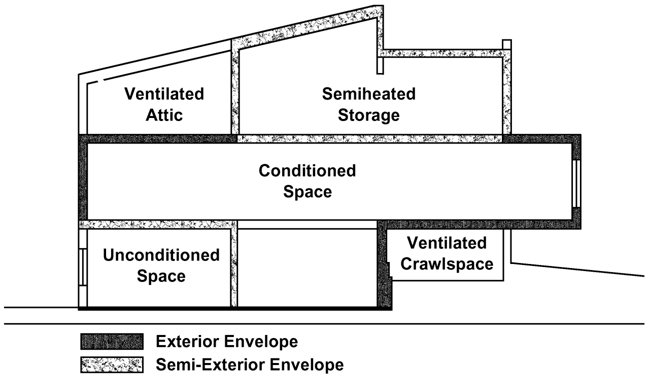


Figure 5.5.2. Exterior and semiexterior building envelope.

5.5.3.1.1 Roof Solar Reflectance and Thermal Emittance. Roofs in Climate Zones 1 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-1 Standard
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 12 $W/m^2 \cdot K$, based on three-year-aged solar reflectance and three-year-aged thermal emittance tested in accordance with CRRC-1 Standard
c. Increased roof insulation levels found in Table 5.5.3.1.1

Exceptions:

1. Ballasted roofs with a minimum stone ballast of 74 kg/m^2 or 117 kg/m^2 pavers
2. Vegetated roof systems that contain a minimum thickness of 63.5 mm 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

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

5.5.3.2 Above-Grade Wall Insulation. All above-grade walls shall comply with the insulation values specified in Tables 5.5-1 through 5.5-8.

Exception: Alternatively, for mass walls, where the requirement in Tables 5.5-1 through 5.5-8 is for a maximum assembly U-0.86 followed by footnote "b," ASTM C90 concrete block walls, ungrouted or partially grouted at 800 mm or less on center vertically and 1200 mm or less on center horizontally, shall have ungrouted cores filled with material having a maximum thermal conductivity of 0.063 W/m·K. Other mass walls with integral insulation shall meet the criteria when their U-factors are equal to or less than those for the appropriate thickness and density in the "Partly Grouted, Cells Insulated" column of Table A3.1-3.

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

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

5.5.3.3 Below-Grade Wall Insulation. Below-grade walls shall have a rated R-value of insulation no less than the insulation values specified in Tables 5.5-1 through 5.5-8.

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

5.5.3.4 Floor Insulation. All floors shall comply with the insulation values specified in Tables 5.5-1 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 5.5-1 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 5.5-1 through 5.5-8.

5.5.4 Fenestration

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

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

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
Insulation entirely above deck	U-0.030	R-33	U-0.029	R-34
Metal buildings	U-0.028	R-35		

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 5.5-1 through 5.5-8.

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

5.5.4.2.2 Maximum Skylight Fenestration Area. The total skylight area shall not be greater than that specified in Tables 5.5-1 through 5.5-8.

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

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

a. 232 m^2 and greater;
b. directly under a roof with ceiling heights greater than 4.6 m; and
c. one of the following space types: office, lobby, atrium, concourse, corridor, storage (including nonrefrigerated warehouse), gymnasium, fitness/exercise area, playing area, gymnasium seating area, convention exhibit/event space, courtroom, automotive service, fire station engine room, manufacturing corridor/transition and bay areas, retail, library reading and stack areas, distribution/sorting area, transportation baggage and seating areas, or workshop,

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

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

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

Exceptions:

1. Enclosed spaces in Climate Zones 6 through 8
2. Enclosed spaces where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.

Table 5.5.4.4.1 SHGC Multipliers for Permanent Projections

Projection Factor	SHGC Multiplier (all Other Orientations)	SHGC Multiplier (North-Oriented)
0–0.10	1.00	1.00
>0.10–0.20	0.91	0.95
>0.20–0.30	0.82	0.91
>0.30–0.40	0.74	0.87
>0.40–0.50	0.67	0.84
>0.50–0.60	0.61	0.81
>0.60–0.70	0.56	0.78
>0.70–0.80	0.51	0.76
>0.80–0.90	0.47	0.75
>0.90–1.00	0.44	0.73

3. Enclosed spaces where the daylight area under roof monitors is greater than 50% of the enclosed space floor area
4. Enclosed spaces where it is documented that 90% of the skylight area is shaded on June 21 in the Northern Hemisphere (December 21 in the Southern Hemisphere) at noon by permanent architectural features of the building
5. Enclosed spaces where the total area minus the primary and secondary sidelighted area(s) is less than 232 m^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 5.5-1 through 5.5-8.

However, for locations in Climate Zone 1 with a cooling design temperature of 35°C and greater, the maximum allowed U-factors for vertical fenestration for all conditioned spaces, nonresidential and residential, are U-1.82 for nonmetal framing, U-2.84 for fixed metal framing, U-3.69 for operable metal framing, and U-4.71 for entrance door metal framing.

Exception: The U-factor for skylights is permitted to be increased to no greater than 5.11 $W/m^2 \cdot K$ in Climate Zones 1 through 3 and 4.26 $W/m^2 \cdot K$ in Climate Zones 4 through 8, provided the skylights meet all of the criteria in Exception (1) to Section 5.5.4.4.2.

5.5.4.4 Fenestration Solar Heat Gain Coefficient (SHGC)

5.5.4.4.1 SHGC of Vertical Fenestration. Vertical fenestration shall have an SHGC not greater than that specified in Tables 5.5-1 through 5.5-8.

Exceptions:

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

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

where

O_s = percent opacity of the shading device

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

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

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

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

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

3. Vertical fenestration that is located on the street side of the street-level story only, provided that
   a. the street side of the street-level story does not exceed 6 m in height,
   b. the fenestration has a continuous overhang with a weighted average PF greater than 0.5, and
   c. the fenestration area for the street side of the street-level story is less than 75% of the gross wall area for the street side of the street-level story.

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

5.5.4.4.2 SHGC of Skylights. Skylights shall have an SHGC not greater than that specified in Tables 5.5-1 through 5.5-8.

Exceptions:

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

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

a. $A_W \le (A_T)/4$ and $A_E \le (A_T)/4$

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

where

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

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

A_T = total vertical fenestration area

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

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

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

Exceptions:

1. Vertical fenestration that complies with Exception (3) Section 5.5.4.4.1.
2. Buildings that have an existing building or existing permanent infrastructure within 6 m to the south (north in the southern hemisphere) that is at least half as tall as the proposed building
3. Buildings with shade on 75% of the west- and east-oriented vertical fenestration areas from permanent projections, existing buildings, existing permanent infrastructure, or topography at 9 a.m. and 3 p.m. on the summer solstice (June 21 in the northern hemisphere)
4. Alterations and additions with no increase in vertical fenestration area
5. Buildings where the west-oriented and east-oriented vertical fenestration area (as defined in Section 5.5.4.5) does not exceed 20% of the gross wall area for each of those façades, and SHGC on those facades is no greater than 90% of the criteria in Tables 5.5-1 through 5.5-8
6. Buildings in Climate Zone 8

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

Exceptions:

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

5.6 Building Envelope Trade-Off Option

5.6.1 The building envelope complies with the standard if

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

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

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

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

5.7 Submittals

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

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

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

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

5.8 Product Information and Installation Requirements

5.8.1 Insulation

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

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

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

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

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

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

5.8.1.5 Substantial Contact. Insulation shall be installed in a permanent manner in substantial contact with the inside surface in accordance with manufacturers' recommendations for the framing system used. Flexible batt insulation installed in floor cavities shall be supported in a permanent manner by supports no greater than 600 mm on center.

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

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

a. the total combined area affected (including necessary clearances) is less than 1% of the opaque area of the assembly,
b. the entire roof, wall, or floor is covered with insulation to the full depth required, or
c. the effects of reduced insulation are included in calculations using an area-weighted-average method and compressed insulation values obtained from Table A9.4-2.

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

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

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

5.8.1.7.2 Foundation vents shall not interfere with the insulation.

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

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

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

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

5.8.2 Fenestration and Doors

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

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

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

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

Exceptions:

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

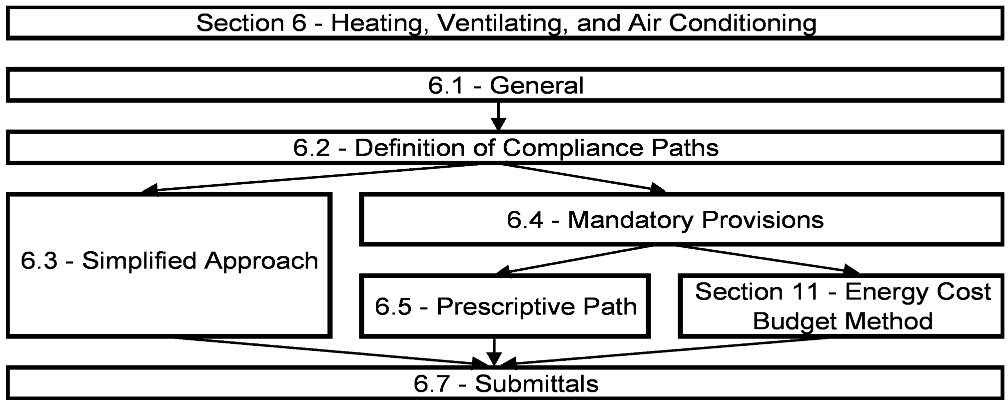
5.8.2.4 Solar Heat Gain Coefficient. SHGC for the overall fenestration area shall be determined in accordance with NFRC 200.

Exceptions:

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

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

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



6. HEATING, VENTILATING, AND AIR CONDITIONING

6.1 General

6.1.1 Scope

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

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

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

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

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

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

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

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

6.1.1.3.5 New and replacement piping shall comply with Section 6.4.4.1.

Exceptions: Compliance shall not be required

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

6.2 Compliance Paths

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

a. Section 6.3, “Simplified Approach Option for HVAC Systems”
b. Sections 6.4, “Mandatory Provisions” and 6.5, “Prescriptive Path”
c. Sections 6.4, “Mandatory Provisions” and 6.6, “Alternative Compliance Path”

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

6.3 Simplified Approach Option for HVAC Systems

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

a. The building is two stories or fewer in height.
b. Gross floor area is less than 2300 m^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 Section 6.5.1.
e. Heating (if any) shall be provided by a unitary packaged or split-system heat pump that meets the applicable efficiency requirements shown in Table 6.8.1-2 (heat pumps) or Table 6.8.1-4 (packaged terminal and room air conditioners and heat pumps), a fuel-fired furnace that meets the applicable efficiency requirements shown in Table 6.8.1-5 (furnaces, duct furnaces, and unit heaters), an electric resistance heater, or a baseboard system connected to a boiler that meets the applicable efficiency requirements shown in Table 6.8.1-6 (boilers).
f. The system shall meet the exhaust air energy recovery requirements of Section 6.5.6.1.
g. The system shall be controlled by a manual changeover or dual setpoint thermostat.
h. If a heat pump equipped with auxiliary internal electric resistance heaters is installed, controls shall be provided that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles. The heat pump must be controlled by either (1) a digital or electronic thermostat designed for heat-pump use that energizes auxiliary heat only when the heat pump has insufficient capacity to maintain setpoint or to warm up the space at a sufficient rate or (2) a multistage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last stage of the space thermostat and when outdoor air temperature is less than 4.4°C.

Exception: Heat pumps that comply with the following:

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

i. The system controls shall not permit reheat or any other form of simultaneous heating and cooling for humidity control.
j. Systems serving spaces other than hotel/motel guest rooms, and other than those requiring continuous operation, which have both a cooling or heating capacity greater than 4.4 kW and a supply fan motor power greater than 0.56 kW, shall be provided with a time clock that (1) can start and stop the system under different schedules for seven different day types per week, (2) is capable of retaining programming and time setting during a loss of power for a period of at least ten hours, (3) includes an accessible manual override that allows temporary operation of the system for up to two hours, (4) is capable of temperature setback down to 13°C during off hours, and (5) is capable of temperature setup to 32°C during off hours.
k. Except for piping within manufacturers' units, HVAC piping shall be insulated in accordance with Tables 6.8.3-1 and 6.8.3-2. Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation.
l. Ductwork and plenums shall be insulated in accordance with Tables 6.8.2-1 and 6.8.2-2 and shall be sealed in accordance with Section 6.4.4.2.1.
m. Construction documents shall require a ducted system to be air balanced in accordance with industry accepted procedures.
n. Outdoor air intake and exhaust systems shall meet the requirements of Section 6.4.3.4.
o. Where separate heating and cooling equipment serves the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling.
p. Systems with a design supply air capacity greater than 5000 L/s shall have optimum start controls.
q. The system shall comply with the demand control ventilation requirements in Section 6.4.3.8.
r. The system complies with the door switch requirements in Section 6.5.10.

6.4 Mandatory Provisions

6.4.1 Equipment Efficiencies, Verification, and Labeling Requirements

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

Tables are as follows:

a. Table 6.8.1-1—Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements
b. Table 6.8.1-2—Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements
c. Table 6.8.1-3—Water-Chilling Packages—Efficiency Requirements (see Section 6.4.1.2 for water-cooled centrifugal water-chilling packages that are designed to operate at nonstandard conditions.)

d. Table 6.8.1-4—Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single-Package Vertical Heat Pumps, Room Air Conditioners, and Room Air Conditioner Heat Pumps—Minimum Efficiency Requirements
e. Table 6.8.1-5—Warm-Air Furnaces, Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters
f. Table 6.8.1-6—Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements
g. Table 6.8.1-7—Performance Requirements for Heat Rejection Equipment
h. Table 6.8.1-8—Heat Transfer Equipment
i. Table 6.8.1-9—Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements
j. Table 6.8.1-10—Electrically Operated Variable-Refrigerant-Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements
k. Table 6.8.1-11—Air Conditioners and Condensing Units Serving Computer Rooms
l. Table 6.8.1-12—Commercial Refrigerators and Freezers
m. Table 6.8.1-13—Commercial Refrigeration

All furnaces with input ratings of ≥65 kW, including electric furnaces, that are not located within the conditioned space shall have jacket losses not exceeding 0.75% of the input rating. Air conditioners primarily serving computer rooms and covered by ASHRAE Standard 127 shall meet the requirements in Table 6.8.1-11. All other air conditioners shall meet the requirements in Table 6.8.1-1.

6.4.1.2 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 551/591 test conditions of 7.0°C leaving and 12.0°C entering chilled-fluid temperatures, and with 30.0°C entering and 35.0°C leaving condenser-fluid temperatures shall have maximum full-load (FL) COP and part-load rating requirements adjusted using the following equations:

$$FL_{adj} = FL \times K_{adj}$$

$$PLV_{adj} = IPLV \times K_{adj}$$

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

where

FL = full-load COP value from Table 6.8.1-3

FL_{adj} = minimum full-load COP rating, adjusted for nonstandard conditions

IPLV = IPLV value from Table 6.8.1-3

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

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

B = $0.0027 \times LvgEvap + 0.982$

LIFT = LvgCond – LvgEvap

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

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

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

- Minimum Evaporator Leaving Temperature: 2.0°C
- Maximum Condenser Leaving Temperature: 46°C
- 11.0°C ≤ LIFT ≤ 44.0°C

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

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

Example: Path A 2110 kW centrifugal chiller Table 6.8.1-3 efficiencies effective 1/1/2015:

FL = 6.286 COP

IPLV = 7.041 COP

LvgCond = 37.00°C

LvgEvap = 6.00°C

37.00 – 6.00 = 31.00°CK_{adj}=$A \times B$

A = $0.0000015318 \times (30.0)^4 - 0.000202076 \times (30.0)^3 + 0.0101800 \times (30.0)^2 - 0.264958 \times 30.0 + 3.930196 = 0.9282$

B = $0.0027 \times 6.00 + 0.9811 = 0.9973$

FL_{adj} = $6.286 \times 0.9302 \times 0.9973 = 5.831$ COP

PLV_{adj} = $7.041 \times 0.9302 \times 0.9973 = 6.531$ COP

6.4.1.2.2 Positive Displacement (Air- and Water-Cooled) Chilling Packages. Equipment with an evaporator leaving fluid temperature higher than 0°C and water-cooled positive displacement chilling packages with a condenser leaving fluid temperature below 46°C shall show compliance with Table 6.8.1-3 when tested or certified with water at standard rating conditions, per the referenced test procedure.

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

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

a. Equipment covered under EPACT shall comply with U.S. Department of Energy certification requirements.
b. If a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, then the product shall be listed in the certification program.

c. If a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report.
d. If no certification program exists for a covered product, the equipment efficiency ratings shall be supported by data furnished by the manufacturer.
e. Where components such as indoor or outdoor coils from different manufacturers are used, the system designer shall specify component efficiencies whose combined efficiency meets the minimum equipment efficiency requirements in Section 6.4.1.
f. Requirements for plate-type liquid-to-liquid heat exchangers are listed in Table 6.8.1-8.

6.4.1.5 Labeling

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

6.4.1.5.2 Packaged Terminal Air Conditioners. Nonstandard-size packaged terminal air conditioners and heat pumps with existing sleeves having an external wall opening of less than 406 mm high or less than 1070 mm wide and having a cross-sectional area less than 0.4343 m^2 shall be factory labeled as follows: *Manufactured for nonstandard-size applications only: Not to be installed in new construction projects.*

6.4.2 Calculations

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

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

6.4.3 Controls

6.4.3.1 Zone Thermostatic Controls

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

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

1. the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for 15 contiguous metres or more and
2. the perimeter system heating and cooling supply is controlled by a thermostatic control(s) located within the zones(s) served by the system.

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

6.4.3.1.2 Dead Band. Where used to control both heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or dead band of at least 3°C within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

Exceptions:

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

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

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

Exceptions:

1. HVAC systems intended to operate continuously
2. HVAC systems having a design heating capacity and cooling capacity less than 4.4 kW that are equipped with readily accessible manual on/off controls

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

a. Controls that can start and stop the system under different time schedules for seven different day types per week, are capable of retaining programming and time setting during loss of power for a period of at least ten hours, and include an accessible manual override, or equivalent function, that allows temporary operation of the system for up to two hours
b. An occupant sensor that is capable of shutting the system off when no occupant is sensed for a period of up to 30 minutes
c. A manually operated timer capable of being adjusted to operate the system for up to two hours
d. An interlock to a security system that shuts the system off when the security system is activated

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

TABLE 6.4.3.4.3 Maximum Damper Leakage, L/s per m² at 250 Pa wc

Climate Zone	Ventilation Air Intake		Exhaust/Relief	
	Nonmotorized[a]	Motorized	Nonmotorized[a]	Motorized
1, 2	—	—	—	—
Any height	100	20	100	20
3	—	—	—	—
Any height	100	50	100	50
4, 5b, 5c	—	—	—	—
Fewer than three stories	NA	50	100	50
Three or more stories	NA	50	NA	50
5a, 6, 7, 8	—	—	—	—
Fewer than three stories	NA	20	100	20
Three or more stories	NA	20	NA	20

a. Dampers smaller than 600 mm in either dimension may have leakage of 200 L/s per m².
NA = Not allowed

6.4.3.3.2 Setback Controls. Heating systems shall be equipped with controls configured to automatically restart and temporarily operate the system as required to maintain zone temperatures above an adjustable heating setpoint at least 5.6°C below the occupied heating setpoint. Cooling systems shall be equipped with controls configured to automatically restart and temporarily operate the mechanical cooling system as required to maintain zone temperatures below an adjustable cooling setpoint at least 2.8°C above the occupied cooling setpoint or to prevent high space humidity levels.

Exception: Radiant heating systems configured with a setback heating setpoint at least 2°C below the occupied heating setpoint

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

6.4.3.3.4 Zone Isolation. HVAC systems serving zones that are intended to operate or be occupied nonsimultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 2300 m² of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outdoor air to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting the requirements of Section 6.4.3.3.1. For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

Exceptions: Isolation devices and controls are not required for

1. exhaust air and outdoor air connections to isolation zones when the fan system to which they connect is 2400 L/s and smaller;
2. exhaust airflow from a single isolation zone of less than 10% of the design airflow of the exhaust system to which it connects; or
3. zones intended to operate continuously or intended to be inoperative only when all other zones are inoperative.

6.4.3.4 Ventilation System Controls

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

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

Exceptions:

1. Back draft gravity (nonmotorized) dampers are acceptable for exhaust and relief in buildings less than three stories in height and for ventilation air intakes and exhaust and relief dampers in buildings of any height located in Climate Zones 1, 2, and 3. Back draft dampers for ventilation air intakes must be protected from direct exposure to wind.
2. Back draft gravity (nonmotorized) dampers are acceptable in systems with a design outdoor air intake or exhaust capacity of 140 L/s or less.
3. Dampers are not required in ventilation or exhaust systems serving unconditioned spaces.

4. Dampers are not required in exhaust systems serving Type 1 kitchen exhaust hoods.

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

6.4.3.4.4 Ventilation Fan Controls. Fans with motors greater than 0.56 kW shall have automatic controls complying with Section 6.4.3.3.1 that are capable of shutting off fans when not required.

Exception: HVAC systems intended to operate continuously.

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

Exceptions:

1. Garages less than 2800 m^2 with ventilation systems that do not utilize mechanical cooling or mechanical heating
2. Garages that have a garage area to ventilation system motor nameplate kW ratio that exceeds 187 m^2/kW and do not utilize mechanical cooling or mechanical heating.
3. Where not permitted by the authority having jurisdiction.

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

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

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

Exceptions:

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

6.4.3.7 Freeze Protection and Snow/Ice Melting Systems. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls capable of shutting off the systems when outdoor air temperatures are above 4.4°C or when the conditions of the protected fluid will prevent freezing. Snow- and ice-melting systems shall include automatic controls capable of shutting off the systems when the pavement temperature is above 10°C and no precipitation is falling, and an automatic or manual control that will allow shutoff when the outdoor temperature is above 4.4°C 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 50 m^2 and with a design occupancy for ventilation of greater than ≥25 people per 100 m^2 of floor area and served by systems with one or more of the following:

a. Air-side economizer
b. Automatic modulating control of outdoor air damper
c. Design outdoor airflow greater than 1400 L/s.

Exceptions:

1. Systems with the exhaust air energy recovery complying with 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 375 L/s
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 space(s)
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 Heating in Vestibules. Heating for vestibules, in accordance with Section 5.4.3.4, and air curtains shall include automatic controls configured to shut off the heating system when outdoor air temperatures are above 7°C. Vestibule heating systems shall also be controlled by a thermostat in the vestibule with a setpoint limited to a maximum of 16°C.

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

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 7.45 kW and larger
New building	Chilled-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 87.9 kW and larger
New building	Hot-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 87.9 kW and larger
Alteration or addition	Zone terminal unit such as VAV box	Where existing zones served by the same air-handling, chilled-water, or hot-water system have DDC
Alteration or addition	Air-handling system or fan coil	Where existing air-handling system(s) and fan-coil(s) served by the same chilled- or hot-water plant have DDC
Alteration or addition	New air-handling system and all new zones served by the system	Individual systems with fan system bhp of 7.45 kW and larger and supplying more than three zones and more than 75% of zones are new
Alteration or addition	New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 87.9 kW and larger
Alteration or addition	New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 87.9 kW and larger

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

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

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

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

a. Monitoring zone and system demand for fan pressure, pump pressure, heating, and cooling
b. Transferring zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers
c. Automatically detecting those zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator
d. Readily allowing operator removal of zone(s) from the reset algorithm

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

6.4.4 HVAC System Construction and Insulation

6.4.4.1 Insulation

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

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

6.4.4.1.2 Duct and Plenum Insulation. All supply and return ducts and plenums installed as part of an HVAC air distribution system shall be thermally insulated in accordance with Tables 6.8.2-1 and 6.8.2-2.

Exceptions:

1. Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with Section 6.4.1.
2. Ducts or plenums located in heated spaces, semiheated spaces, or cooled spaces.

3. For runouts less than 3 m in length to air terminals or air outlets, the rated R-value of insulation need not exceed R-0.6.
4. Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas exceeding 0.5 m^2 need not exceed R-0.4; those 0.5 m^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:

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 16°C and 41°C, inclusive.
3. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electricity (such as roof and condensate drains, domestic cold-water supply, natural-gas piping).
4. Where heat gain or heat loss will not increase energy usage (such as liquid refrigerant piping)
5. In piping 25 mm 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-0.62. Adjacent envelope insulation counts toward this requirement.

6.4.4.1.5 Radiant Floor Heating. The bottom surfaces of floor structures incorporating radiant heating shall be insulated with a minimum of R-0.62. Adjacent envelope insulation counts toward this requirement.

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

6.4.4.2 Ductwork and Plenum Leakage

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

6.4.4.2.2 Duct Leakage Tests. Ductwork that is designed to operate at static pressures in excess of 750 Pa 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

$$L_{max} = C_L(P^{0.65}/1000)$$

where

L_{max}	=	maximum permitted leakage, L/s·m^2 duct surface area
C_L	=	6, duct leakage class, L/s·m^2 duct surface area at 250 Pa
P	=	test pressure, which shall be equal to the design duct pressure class rating, Pa

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

a. Shall be equipped with automatic door closers that firmly close walk-in doors that have been closed to within 25mm of full closure.

Exception: Doors wider than 1.1 m or taller than 2.1 m

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-4.4 and walk-in freezers at least R-5.6.

Exception: Glazed portions of doors or structural members

d. Walk-in freezers shall contain floor insulation of at least R-4.9.
e. Evaporator fan motors that are less than 0.75 kW and less than 460 V shall use electronically commutated motors (brushless direct-current motors) or three-phase motors.
f. Lights shall use light sources with an efficacy of 40 lm/W or more, including ballast losses (if any). Light sources with an efficacy of less than 40 lm/W, including ballast losses (if any), may be used in conjunction with a timer or device that turns off the lights within 15 minutes of when the walk-in cooler or walk-in freezer is not occupied by people.
g. Transparent reach-in doors for walk-in freezers, and windows in walk-in freezer doors, shall be of triple-pane glass, either filled with inert gas or with heat-reflective treated glass.
h. Transparent reach-in doors for walk-in coolers, and windows in walk-in cooler doors, shall be double-pane glass with heat-reflective treated glass and gas filled, or they shall be triple-pane glass, either filled with inert gas or with heat-reflective treated glass.
i. Antisweat heaters without antisweat heater controls shall have a total door rail, glass, and frame heater power draw

of ≤76 W/m^2 of door opening for walk-in freezers and 32 W/m^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 0.75 kW shall use electronically commutated motors, permanent split capacitor-type motors, or three-phase motors.

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

Exception: Walk-in coolers and walk-in freezers combined in a single enclosure greater than 280 m^2

6.4.6 Refrigerated Display Case

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

b. Lighting in refrigerated display cases and glass doors installed on walk-in coolers and freezers shall be controlled by one of the following:
   1. Automatic time-switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases or walk-in coolers and freezers may be used to turn the lights on for up to one hour and shall automatically time out to turn the lights off.
   2. Motion sensor controls on each display case or walk-in door section that reduce lighting power by at least 50% within three minutes after the area within the sensor range is vacated.

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

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

6.5 Prescriptive Path

6.5.1 Economizers. Each cooling system that has a fan shall include either an air or water economizer meeting the requirements of Sections 6.5.1.1 through 6.5.1.6.

Exceptions: Economizers are not required for the following systems:

1. Individual fan-cooling units with a supply capacity less than the minimum listed in Table 6.5.1-1 for comfort cooling applications and Table 6.5.1-2 for computer room applications.
2. Systems that include nonparticulate air treatment as required by Section 6.2.1 in Standard 62.1.
3. In hospitals and ambulatory surgery centers, where more than 75% of the air designed to be supplied by the system is to spaces that are required to be humidified above 2°C dew-point temperature to comply with applicable codes or accreditation standards; in all other buildings, where more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 2°C dew-point temperature to satisfy process needs. This exception does not apply to computer rooms.
4. Systems that include a condenser heat recovery system with a minimum capacity as defined in Section 6.5.6.2.2.
5. Systems that serve residential spaces where the system capacity is less than five times the requirement listed in Table 6.5.1-1.
6. Systems that serve spaces whose sensible cooling load at design conditions, excluding transmission and infiltration loads, is less than or equal to transmission and infiltration losses at an outdoor temperature of 16°C.
7. Systems expected to operate less than 20 hours per week.
8. Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems.
9. For comfort cooling where the cooling efficiency meets or exceeds the efficiency improvement requirements in Table 6.5.1-3.
10. Systems primarily serving computer rooms where
    a. the total design cooling load of all computer rooms in the building is less than 880 kW 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 175 kW 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 175 kW of computer-room cooling equipment capacity is being added to an existing building.

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

Climate Zones	Cooling Capacity for Which an Economizer is Required
1a, 1b	No economizer requirement
2a, 2b, 3a, 4a, 5a, 6a 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	≥16 kW

TABLE 6.5.1-2 Minimum Fan-Cooling Unit Size for which an Economizer is Required for Computer Rooms

Climate Zones	Cooling Capacity for Which an Economizer is Required
1a, 1b, 2a, 3a, 4a	No economizer requirement
2b, 5a, 6a, 7, 8	≥40 kW
3b, 3c, 4b, 4c, 5b, 5c, 6b	≥19kW

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

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

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

11. 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 modulating 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 dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed-air temperature.

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

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

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

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

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

a. Dry-bulb and wet-bulb temperatures shall be accurate to ±1.1°C over the range of 4.4°C to 27°C.
b. Enthalpy and the value of a differential enthalpy sensor shall be accurate to ±5 kJ/kg over the range of 35 to 63 kJ/kg.
c. Relative humidity shall be accurate to ±5% over the range of 20% to 80% RH.

6.5.1.2 Water Economizers

6.5.1.2.1 Design Capacity. Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100% of the expected system cooling load at outdoor air temperatures of 10°C dry bulb/7°C wet bulb and below.

Exceptions:

1. Systems primarily serving computer rooms in which 100% of the expected system cooling load at the dry-bulb and wet-bulb temperatures listed in Table 6.5.1.2.1 is met with evaporative water economizers
2. Systems primarily serving computer rooms in which 100% of the expected system cooling load at the dry-bulb temperatures listed in Table 6.5.1.2.1 is met with dry cooler water economizers
3. Systems where dehumidification requirements cannot be met using outdoor air temperatures of 10°C dry-bulb/7°C wet-bulb and where 100% of the expected system cooling load at 7°C dry-bulb/4°C wet-bulb is met with evaporative water economizers

6.5.1.2.2 Maximum Pressure Drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a water-side pressure drop of less than 45 kPa of water, or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

6.5.1.3 Integrated Economizer Control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even when

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

Control Type	Allowed Only in Climate Zone at Listed Setpoint	Required High-Limit Setpoints (Economizer Off When):	
		Equation	Description
Fixed dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	$T_{OA} > 24°C$	Outdoor air temperature exceeds 24°C
	5a, 6a	$T_{OA} > 21°C$	Outdoor air temperature exceeds 21°C
	1a, 2a, 3a, 4a,	$T_{OA} > 18°C$	Outdoor air temperature exceeds 18°C
Differential dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperature	All	$h_{OA} > 47$ kJ/kg[a] or $T_{OA} > 24°C$	Outdoor air enthalpy exceeds 47 kJ/kg[a] of dry air[a] or outdoor air temperature exceeds 24°C
Differential enthalpy with fixed dry-bulb temperature	All	$h_{OA} > h_{RA}$ or $T_{OA} > 24°C$	Outdoor air enthalpy exceeds return air enthalpy or outdoor air temperature exceeds 24°C

a. At altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 24°C and 50% RH. As an example, at approximately 1830 m elevation, the fixed enthalpy limit is approximately 53.5 kJ/kg.
b. Devices with selectable rather than adjustable setpoints shall be capable of being set to within 1.1°C and 3.4kJ/kg of the setpoint listed.

TABLE 6.5.1.2.1 Water Economizer Sizing Dry-Bulb and Wet-Bulb Requirements for Computer Rooms

Zone		Evaporative Water Economizer		Dry Cooler Water Economizer
		Dry Bulb, °C	Wet Bulb, °C	Dry Bulb, °C
1	A	NR		NR
1	B	NR		NR
2	A	4.4	1.7	–1.1
2	B	1.7	–1.1	–1.1
3	A	4.4	1.7	–3.9
3	B	–1.1	–3.9	–3.9
3	C	–1.1	–3.9	–1.1
4	A	4.4	1.7	–3.9
4	B	–1.1	–3.9	–3.9
4	C	–1.1	–3.9	–3.9
5	A	4.4	1.7	–6.7
5	B	–1.1	–3.9	–6.7
5	C	–1.1	–3.9	–3.9
6	A	1.7	–1.1	–6.7
6	B	–1.1	–3.9	–6.7
7		–1.1	–3.9	–6.7
8		–1.1	–3.9	–6.7

NR—Not required

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 7°C.
b. DX units that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of two stages of mechanical cooling capacity per the following effective dates:

    ≥22kW Rated Capacity—Effective 1/1/2014

    ≥18kW Rated Capacity—Effective 1/1/2016

6.5.1.4 Effective 1/1/2014, all other DX units, including those that control space temperature by modulating the airflow to the space, shall comply with the requirements of Table 6.5.1.4.

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

Exceptions: Economizers on VAV systems that cause zone-level heating to increase due to a reduction in supply air temperature

6.5.1.6 Economizer Humidification System Impact. Systems with hydronic cooling and humidification systems

TABLE 6.5.1.4 DX Cooling Stage Requirements for Modulating Airflow Units

Rating Capacity, kW	Minimum Number of Mechanical Cooling Stages	Minimum Compressor Displacement[a]
≥18 and <70	3	≤35% of full load
≥70	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.

designed to maintain inside humidity at a dew-point temperature greater than 2°C shall use a water 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 controls shall prevent

a. reheating;
b. recooling;
c. mixing or simultaneously supplying air that has been previously mechanically heated and air that has been previously cooled, either by mechanical cooling or by economizer systems; and
d. other simultaneous operation of heating and cooling systems to the same zone.

Exceptions:

1. Zones without DDC for which the volume of air that is reheated, recooled, or mixed is less than the larger of the following:
   a. 30% of the zone design peak supply rate
   b. The outdoor airflow rate required to meet the ventilation requirements of ASHRAE Standard 62.1 for the zone
   c. Any higher rate that can be demonstrated, to the satisfaction of the authority having jurisdiction, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake 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) 20% of the zone design peak supply rate
      (2) The outdoor airflow rate required to meet the ventilation requirements of ASHRAE Standard 62.1 for the zone
      (3) Any higher rate that can be demonstrated, to the satisfaction of the authority having jurisdiction, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake
      (4) The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates
   b. The airflow rate that is reheated, recooled, or mixed shall be less than 50% of the zone design peak supply rate.
   c. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint while the airflow is maintained at the dead band flow rate.
   d. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate.
3. Laboratory exhaust systems that comply with Section 6.5.7.2
4. Zones where at least 75% of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered (including condenser heat) or site-solar energy source

6.5.2.1.1 Supply Air Temperature Reheat Limit. Where reheating is permitted by other parts of this standard, zones that have both supply and return/exhaust air openings greater than 2 mabove floor shall not supply heating air more than 11°C above the space temperature setpoint.

Exceptions:

1. Laboratory exhaust systems that comply with Section 6.5.7.2.
2. During preoccupancy building warm-up and setback

6.5.2.2 Hydronic System Controls. The heating of fluids in hydronic systems that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections 6.5.2.2.1 through 6.5.2.2.3.

6.5.2.2.1 Three-Pipe System. Hydronic systems that use a common return system for both hot water and chilled water shall not be used.

6.5.2.2.2 Two-Pipe Changeover System. Systems that use a common distribution system to supply both heated and chilled water are acceptable provided all of the following are met:

a. The system is designed to allow a dead band between changeover from one mode to the other of at least 8°C 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 17°C apart.

6.5.2.2.3 Hydronic (Water Loop) Heat Pump Systems. Hydronic heat pumps connected to a common heat-pump water loop with central devices for heat rejection (e.g., cooling tower) and heat addition (e.g., boiler) shall have the following:

a. Controls that are capable of providing a heat-pump water supply temperature dead band of at least 11°C between initiation of heat rejection and heat addition by the central devices (e.g., tower and boiler).
b. For Climate Zones 3 through 8, if a closed-circuit tower (fluid cooler) is used, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers shall be provided. If an open-circuit tower is used directly in the heat-pump loop, an automatic valve shall be installed to bypass all heat-pump water flow around the tower. If an open-circuit tower is used in conjunction with a separate heat exchanger to isolate the tower from the heat-pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

Exception: Where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 12°C shall be allowed.

6.5.2.3 Dehumidification. Where humidity controls are provided, such controls shall prevent reheating, mixing of hot and cold airstreams, or other means of simultaneous heating and cooling of the same airstream.

Exceptions:

1. The system is configured to reduce supply air volume to 50% or less of the design airflow rate or the minimum outdoor air ventilation rate specified in ASHRAE Standard 62.1 or other applicable federal, state, or local code or recognized standard, whichever is larger, before simultaneous heating and cooling takes place.
2. The individual fan cooling unit has a design cooling capacity of 19 kW or less and is capable of unloading to 50% capacity before simultaneous heating and cooling takes place.
3. The individual mechanical cooling unit has a design cooling capacity of 12 kW or less. An individual mechanical cooling unit is a single system composed of a fan or fans and a cooling coil capable of providing mechanical cooling.
4. Systems serving spaces where specific humidity levels are required to satisfy process needs, such as vivariums, museums, surgical suites, pharmacies, and buildings with refrigerating systems, such as supermarkets, refrigerated warehouses, and ice arenas, and the building includes site-recovered or site solar energy source that provide energy equal to at least 75% of the annual energy for reheating or for providing warm air in mixing systems. This exception does not apply to computer rooms.
5. At least 90% of the annual energy for reheating or for providing warm air in mixing systems is provided from a site-recovered (including condenser heat) or site-solar energy source.
6. Systems where the heat added to the airstream is the result of the use of a desiccant system and 75% of the heat added by the desiccant system is removed by a heat exchanger, either before or after the desiccant system with energy recovery.

6.5.2.4 Humidification

6.5.2.4.1 Humidifiers with preheating jackets mounted in the airstream shall be provided with an automatic valve to shut off preheat when humidification is not required.

6.5.2.4.2 Humidification system dispersion tube hot surfaces in the airstreams of ducts or air-handling units shall be insulated with a product with an insulating value of at least R-0.09.

Exception: Systems where mechanical cooling, including economizer operation, does not occur simultaneously with humidification

6.5.2.5 Preheat Coils. Preheat coils shall have controls that stop their heat output whenever mechanical cooling, including economizer operation, is occurring.

6.5.3 Air System Design and Control. Each HVAC system having a total fan system motor nameplate kW exceeding 4 kW shall meet the provisions of Sections 6.5.3.1 through 6.5.3.5.

6.5.3.1 Fan System Power and Efficiency

6.5.3.1.1 Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate kW (Option 1) or fan system input kW (Option 2) as shown in Table 6.5.3.1-1. This includes supply fans, return/relief fans, exhaust fans, and fan-powered terminal units associated with systems providing heating or cooling capability. Single-zone variable-air-volume systems shall comply with the constant-volume fan power limitation.

Exceptions:

1. Hospital, vivarium, and laboratory systems that utilize flow control devices on exhaust and/or 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 kW of 0.75 kW or less.

6.5.3.1.2 Motor Nameplate Kilowatts. For each fan, the selected fan motor shall be no larger than the first available motor size greater than the input kW. The fan input kW

TABLE 6.5.3.1-1 Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan system motor nameplate kW	Allowable nameplate motor kW	$kW \le L/S_S \cdot 0.0017$	$kW \le L/S_S \cdot 0.0024$
Option 2: Fan system input kW	Allowable fan system input kW	$kW_i \le L/S_S \cdot 0.0015 + A$	$kW_i \le L/S_S \cdot 0.0021 + A$

a. where
L/S_S = maximum design supply airflow rate to conditioned spaces served by the system in litres per second
kW= maximum combined motor nameplate kW
kW_i = maximum combined fan input kW
A = sum of (PD × L/S_D/65,0000)
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1-2 in Pa.
L/S_D = the design airflow through each applicable device from Table 6.5.3.1-2 in litres per second

TABLE 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	125 Pa (535 Pa for laboratory and vivarium systems)
Return and/or exhaust airflow control devices	125 Pa
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	125 Pa
Particulate Filtration Credit: MERV 13 through 15	225 Pa
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	(550 × Energy Recovery Effectiveness) – 125 Pa for each airstream
Coil runaround loop	150 Pa 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)	38 Pa
Exhaust system serving fume hoods	85 Pa
Laboratory and vivarium exhaust systems in high-rise buildings	60 Pa/30 m of vertical duct exceeding25 m
Deductions	
Systems without central cooling device	150 Pa
Systems without central heating device	75 Pa
Systems with central electric resistance heat	50 Pa

must be indicated on the design documents to allow for compliance verification by the code official.

Exceptions:

1. For fans less than 4.5 kW, where the first available motor larger than the input kW has a nameplate rating within 50% of the input kW, the next larger nameplate motor size may be selected.
2. For fans 4.5 kW and larger, where the first available motor larger than the input kW has a nameplate rating within 30% of the input kW, the next larger nameplate motor size may be selected.
3. Systems complying with Section 6.5.3.1.1, Option 1.

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

Exceptions:

1. Single fans with a motor nameplate horsepower of 3.75 kW or less

TABLE 6.5.3.2.1 Effective Dates for Fan Control

Cooling System Type	Fan Motor Size, kW	Mechanical Cooling Capacity, kW	Effective Date
DX cooling	Any	≥32	
		≥22	1/1/2014
		≥19	1/1/2016
Chilled-water and evaporative cooling	≥0.75	Any	
	≥0.2	Any	1/1/2014

2. Multiple fans in series or parallel (e.g., fan arrays) that have a combined motor nameplate horsepower of 4 kW or less and are operated as the functional equivalent of a single fan
3. Fans that are part of equipment listed under Section 6.4.1.1
4. Fans included in equipment bearing a third-party-certified seal for air or energy performance of the equipment package
5. Powered wall/roof ventilators (PRV)
6. Fans outside the scope of AMCA 205
7. Fans that are intended to only operate during emergency conditions

6.5.3.2 Fan Control

6.5.3.2.1 Fan Airflow Control Each cooling system listed in Table 6.5.3.2.1 shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

a. DX and chilled-water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have a minimum of two stages of fan control. Low or minimum speed shall not exceed 66% of full speed. At low or minimum speed, the fan system shall draw no more than 40% of the fan power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.
b. All other units, including DX cooling units and chilled-water units that control the space temperature by modulating the airflow to the space, shall have modulating fan control. Minimum speed shall not exceed 50% of full speed. At minimum speed, the fan system shall draw no more than 30% of the power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.
c. Units that include an air-side economizer to meet the requirements of Section 6.5.1 shall have a minimum of two speeds of fan control during economizer operation.

Exceptions:

1. Modulating fan control is not required for chilled-water and evaporative cooling units with <0.75 kW fan motors if the units are not used to provide ventilation air and the indoor fan cycles with the load.
2. If the volume of outdoor air required to meet the ventilation requirements of Standard 62.1 at low speed exceeds the air that would be delivered at the speed defined in Section 6.5.3.2.1(a) or 6.5.3.2.1(b) then the minimum speed shall be selected to provide the required ventilation air.

6.5.3.2.2 VAV Static Pressure Sensor Location. Static pressure sensors used to control VAV fans shall be located such that the controller setpoint is no greater than 300 Pa. If this results in the sensor being located downstream of major duct splits, sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.

Exception: Systems complying with Section 6.5.3.2.3

6.5.3.2.3 VAV Setpoint Reset. For systems with DDC of individual zones reporting to the central control panel, static pressure setpoint shall be reset based on the zone requiring the most pressure; i.e., the setpoint is reset lower until one zone damper is nearly wide open. Controls shall provide the following:

a. Monitor zone damper positions or other indicator of need for static pressure
b. Automatically detect those zones that may be excessively driving the reset logic and generate an alarm to the system operator
c. Readily allow operator removal of zone(s) from the reset algorithm

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

Exceptions:

1. VAV systems with zonal transfer fans that recirculate air from other zones without directly mixing it with outdoor air, dual-duct dual-fan VAV systems, and VAV systems with fan-powered terminal units
2. Systems required to have the exhaust air energy recovery complying with Section 6.5.6.1

3. Systems where total design exhaust airflow is more than 70% of total design outdoor air intake flow requirements

6.5.3.4 Supply Air Temperature Reset Controls. Multiple zone HVAC systems must include controls that automatically reset the supply air temperature in response to representative building loads, or to outdoor air temperature. The controls shall reset the supply air temperature at least 25% of the difference between the design supply air temperature and the design room air temperature. Controls that adjust the reset based on zone humidity are allowed. Zones that are expected to experience relatively constant loads, such as electronic equipment rooms, shall be designed for the fully reset supply temperature.

Exceptions:

1. Climate Zones 1a, 2a, and 3a
2. Systems that prevent reheating, recooling, or mixing of heated and cooled supply ai.
3. Systems in which at least 75% of the energy for reheating (on an annual basis) is from site recovered or site solar energy sources

6.5.3.5 Fractional Kilowatt Fan Motors. Motors for fans that are 62.1 W or greater and less than 0.746 kW shall be electronically-commutated motors or shall have a minimum motor efficiency of 70% when rated in accordance with DOE 10 CFR 431. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

Exceptions:

1. Motors in the airstream within fan-coils and terminal units that operate only when providing heating to the space served
2. Motors installed in space conditioning equipment certified under Section 6.4.1
3. Motors covered by Table 10.8-4 or 10.8-5

6.5.4 Hydronic System Design and Control

6.5.4.1 Boiler Turndown. Boiler systems with design input of at least 293 kW 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. HVAC pumping systems having a total pump system power exceeding 7.5 kW that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual chilled-water pumps serving variable-flow systems having motors exceeding 3.7 kW shall have controls and/or devices (such as variable-speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum

TABLE 6.5.4.1 Boiler Turndown

Boiler System Design Input, kW	Minimum Turndown Ratio
≥293 and ≤1465	3 to 1
>1465 and ≤2931	4 to 1
>2931	5 to 1

measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure. The differential pressure setpoint shall be no more than 110% of that required to achieve design flow through the heat exchanger. Where differential pressure control is used to comply with this section and DDC systems are used, the setpoint shall be reset downward based on valve positions until one valve is nearly wide open.

Exceptions:

1. Systems where the minimum flow is less than the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system, such as chillers, and where total pump system power is 56 kW or less
2. Systems that include no more than three control valves

6.5.4.3 Chiller and Boiler Isolation

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

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

6.5.4.4 Chilled- and Hot-Water Temperature Reset Controls. Chilled- and hot-water systems with a design capacity exceeding 88 kW supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature.

Exceptions:

1. Where the supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidifying, or dehumidifying systems
2. Hydronic systems, such as those required by Section 6.5.4.1, that use variable flow to reduce pumping energy

TABLE 6.5.4.6 Piping System Design Maximum Flow Rate in L/s

Operating Hours/Year	≤2000 Hours/Year		>2000 and ≤4400 Hours/Year		>4400 Hours/Year	
Nominal Pipe Size, mm	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
75	8	11	5	8	4	7
90	1	17	9	13	7	11
110	22	33	16	25	13	20
140	26	39	20	30	16	23
160	47	69	36	54	28	43
225	76	114	57	88	44	69
280	114	170	82	126	63	101
315	158	240	120	183	95	145
Maximum velocity for pipes over 355–600 mm in size	2.6 m/s	4.0 m/s	2.0 m/s	2.9 m/s	1.5 m/s	2.3 m/s

6.5.4.5 Hydronic (Water Loop) Heat Pumps and Water-Cooled Unitary Air-Conditioners

6.5.4.5.1 Each hydronic heat pump and water-cooled unitary air-conditioner shall have a two-position automatic valve interlocked to shut off water flow when the compressor is off.

Exception: Units employing water economizer

6.5.4.5.2 Hydronic heat pumps and water-cooled unitary air-conditioners having a total pump system power exceeding 3.7 kW shall have controls and/or devices (such as variable-speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

6.5.4.6 Pipe Sizing. All chilled-water and condenser-water piping shall be designed such that the design flow rate in each piping segment shall not exceed the values listed in Table 6.5.4.6 for the appropriate total annual hours of operation. Piping size selections for systems that operate under variable flow conditions (e.g., modulating two-way control valves at coils) and that contain variable-speed pump motors are allowed to be made from the "Variable Flow/Variable Speed" columns. All others shall be made from the "Other" columns.

Exceptions:

1. Design flow rates exceeding the values in Table 6.5.4.6 are allowed in specific sections of piping if the piping in question is not in the critical circuit at design conditions and is not predicted to be in the critical circuit during more than 30% of operating hours.
2. Piping systems that have equivalent or lower total pressure drop than the same system constructed with standard weight steel pipe with piping and fittings sized per Table 6.5.4.6

6.5.5 Heat Rejection Equipment

6.5.5.1 General. Section 6.5.5 applies to heat rejection equipment used in comfort cooling systems, such as air-cooled condensers, dry coolers, open-circuit cooling towers, closed-circuit cooling towers, and evaporative condensers.

Exception: Heat rejection devices whose energy usage is included in the equipment efficiency ratings listed in Tables 6.8.1-1 through 6.8.1-4

6.5.5.2 Fan Speed Control

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

Exceptions:

1. Condenser fans serving multiple refrigerant circuits
2. Condenser fans serving flooded condensers
3. Installations located in Climate Zones 1 and 2

6.5.5.2.2 Multicell heat rejection equipment with variable-speed fan drives shall

a. operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components and
b. control all fans to the same fan speed required for the instantaneous cooling duty, as opposed to staged (on/off) operation. Minimum fan speed shall comply with the minimum allowable speed of the fan drive system per the manufacturer's recommendations.

6.5.5.3 Limitation on Centrifugal Fan Open-Circuit Cooling Towers. Centrifugal fan open-circuit cooling towers with a combined rated capacity of 69 L/s or greater at 35°C condenser water return, 29°C condenser water supply, and 24°C outdoor air wet-bulb temperature shall meet the energy

TABLE 6.5.6.1-1 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Less than 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, L/s							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B,5C	NR	NR	NR	NR	≥12271	≥5663	≥2360	≥1888
6B	≥13215	≥12507	≥5191	≥2596	≥2124	≥1652	≥1180	≥708
1A, 2A, 3A, 4A, 5A, 6A	≥12271	≥7551	≥2596	≥2124	≥1652	≥944	≥472	>0
7,8	≥2124	≥1888	≥1180	≥472	>0	>0	>0	>0

NR—Not required

TABLE 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, L/s							
3C	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 3B, 4C, 5C	NR	≥9203	≥4248	≥2360	≥1888	≥1416	≥708	>0
1A, 2A, 3A, 4B, 5B	≥1180	≥944	≥472	≥236	>0	>0	>0	>0
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0

NR—Not required

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

Exception: Centrifugal open-circuit cooling towers that are ducted (inlet or discharge) or require external sound attenuation.

6.5.5.4 Tower Flow Turndown. Open-circuit cooling towers used on water-cooled chiller systems that are configured with multiple- or variable-speed condenser water pumps shall be designed so that all open-circuit cooling tower cells can be run in parallel with the larger of

a. the flow that is produced by the smallest pump at its minimum expected flow rate or
b. 50% of the design flow for the cell.

6.5.6 Energy Recovery

6.5.6.1 Exhaust Air Energy Recovery. Each fan system shall have an energy recovery system when the system's supply airflow rate exceeds the value listed in Tables 6.5.6.1-1 and 6.5.6.1-2, based on the climate zone and percentage of outdoor airflow rate at design conditions. Table 6.5.6.1-1 shall be used for all ventilation systems that operate less than 8000 hours per year, and Table 6.5.6.1-2 shall be used for all ventilation systems that operate 8000 or more hours per year.

Energy recovery systems required by this section shall have at least 50% energy recovery effectiveness. Fifty percent energy recovery effectiveness 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 enthalpies at design conditions. Provision shall be made to bypass or control the energy recovery system to permit air economizer operation as required by Section 6.5.1.1.

Exceptions:

1. Laboratory systems meeting Section 6.5.7.2
2. Systems serving spaces that are not cooled and that are heated to less than 16°C
3. Systems exhausting toxic, flammable, paint, or corrosive fumes or dust
4. Commercial kitchen hoods used for collecting and removing grease vapors and smoke
5. Where more than 60% of the outdoor air heating energy is provided from site-recovered or site solar energy
6. Heating energy recovery in Climate Zones 1 and 2.
7. Cooling energy recovery in Climate Zones 3c, 4c, 5b, 5c, 6b, 7, and 8

TABLE 6.5.7.1.3 Maximum Net Exhaust Flow Rate, L/s per Linear Metre of Hood Length

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted canopy	217	325	433	596
Single island	433	541	650	758
Double island (per side)	271	325	433	596
Eyebrow	271	271	NA	NA
Backshelf/pass-over	325	325	433	NA

NA = not allowed

8. Where the largest source of air exhausted at a single location at the building exterior is less than 75% of the design outdoor airflow rate.
9. Systems requiring dehumidification that employ energy recovery in series with the cooling coil
10. Systems expected to operate less than 20 hours per week at the outdoor air percentage covered by Table 6.5.6.1-1

6.5.6.2 Heat Recovery for Service Water Heating

6.5.6.2.1 Condenser heat recovery systems shall be installed for heating or preheating of service hot water provided all of the following are true:

a. The facility operates 24 hours a day.
b. The total installed heat rejection capacity of the water-cooled systems exceeds 1800 kW of heat rejection.
c. The design service water heating load exceeds 300 kW.

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 29°C.

Exceptions:

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 or site-recovered energy or from other sources

6.5.7 Exhaust Systems

6.5.7.1 Kitchen Exhaust Systems

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

6.5.7.1.2 Conditioned supply air delivered to any space with a kitchen hood shall not exceed the greater of

a. the supply flow required to meet the space heating or cooling load or
b. the hood exhaust flow minus the available transfer air from adjacent spaces. Available transfer air is that portion of outdoor ventilation air not required to satisfy other exhaust needs, such as restrooms, and not required to maintain pressurization of adjacent spaces

6.5.7.1.3 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 2360 L/s then each hood shall have an exhaust rate that complies with Table 6.5.7.1.3. 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 6.5.7.1.3 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: At least 75% of all the replacement air is transfer air that would otherwise be exhausted.

6.5.7.1.4 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 2360 L/s 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 system(s) on at least 75% of the exhaust air. Such systems shall be capable of 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 with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.

6.5.7.1.5 Performance Testing. An approved field test method shall be used to evaluate design airflow rates and demonstrate proper capture and containment performance of installed commercial kitchen exhaust systems. Where demand ventilation systems are utilized to meet Section 6.5.7.1.4, additional performance testing shall be required to demonstrate proper capture and containment at minimum airflow.

6.5.7.2 Laboratory Exhaust Systems. Buildings with laboratory exhaust systems having a total exhaust rate greater than 2360 L/s shall include at least one of the following features:

a. VAV laboratory exhaust and room supply system capable of reducing exhaust and makeup airflow rates and/or incorporate a heat recovery system to precondition makeup air from laboratory exhaust that shall meet the following:

$$A + B \times (E/M) \geq 50\%$$

where

A = percentage that the exhaust and makeup airflow rates can be reduced from design conditions

B = percentage sensible recovery effectiveness

E = exhaust airflow rate through the heat recovery device at design conditions

M = makeup airflow rate of the system at design conditions.

b. VAV laboratory exhaust and room supply systems that are required to have minimum circulation rates to comply with code or accreditation standards shall be capable of reducing zone exhaust and makeup airflow rates to the regulated minimum circulation values or the minimum required to maintain pressurization relationship requirements. Nonregulated zones shall be capable of reducing exhaust and makeup airflow rates to 50% of the zone design values or the minimum required to maintain pressurization relationship requirements.
c. Direct makeup (auxiliary) air supply equal to at least 75% of the exhaust airflow rate, heated no warmer than 1.1°C below room setpoint, cooled to no cooler than 1.7°C above room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control.

6.5.8 Radiant Heating Systems

6.5.8.1 Heating Unenclosed Spaces. Radiant heating shall be used when heating is required for unenclosed spaces.

Exception: Loading docks equipped with air curtains

6.5.8.2 Heating Enclosed Spaces. Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the standard, including, but not limited to, the following:

a. Radiant hydronic ceiling or floor panels (used for heating or cooling)
b. Combination or hybrid systems incorporating radiant heating (or cooling) panels
c. Radiant heating (or cooling) panels used in conjunction with other systems such as VAV or thermal storage systems

6.5.9 Hot Gas Bypass Limitation. Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table 6.5.9 for VAV units and single-zone VAV units. Hot gas bypass shall not be used on constant-volume units.

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,

TABLE 6.5.9 Hot-Gas Bypass Limitation

Rated Capacity	Maximum Hot-Gas Bypass, % of Total Capacity
≤70 kW	15%
>70 kW	10%

a. disable mechanical heating or reset the heating setpoint to 13°C or lower within five minutes of the door opening and
b. disable mechanical cooling or reset the cooling setpoint to 32°C or greater within five minutes of the door opening. Mechanical cooling may remain enabled if outdoor air temperature is below space temperature.

Exceptions:

1. Building entries with automatic closing devices
2. Any space without a thermostat
3. Alterations to existing buildings
4. Loading docks

6.5.11 Refrigeration Systems. Refrigeration systems that are comprised of refrigerated display cases, walk-in coolers, or walk-in freezers connected to remote compressors, remote condensers, or remote condensing units shall meet the requirements of Sections 6.5.11.1 through 6.5.11.2.

Exception: Systems utilizing transcritical refrigeration cycle or ammonia refrigerant

6.5.11.1 Condensers Serving Refrigeration Systems. Fan-powered condensers shall conform to the following requirements:

a. Design saturated condensing temperatures for air-cooled condensers shall be less than or equal to the design dry-bulb temperature plus 5.5°C for low-temperature refrigeration systems and less than or equal to the design dry-bulb temperature plus 8°C 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 75 kW shall use electronically commutated motors, permanent split capacitor-type motors, or three-phase motors.
c. All condenser fans for air-cooled condensers, evaporatively cooled condensers, and air- or water-cooled fluid coolers or cooling towers shall incorporate one of the following continuous variable-speed fan-control approaches and shall reduce fan motor demand to no more than 30% of design wattage at 50% of design air volume:
    1. Refrigeration system condenser control for air-cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature.
    2. Refrigeration system condenser control for evaporatively cooled condensers shall use variable setpoint

control logic to reset the condensing temperature setpoint in response to ambient wet-bulb temperature.

d. Multiple fan condensers shall be controlled in unison.

e. The minimum condensing temperature setpoint shall be no greater than 21.1°C.

6.5.11.2 Compressor Systems. Refrigeration compressor systems shall conform to the following requirements:

a. Compressors and multiple-compressor systems suction groups shall include control systems that use floating suction pressure control logic to reset the target suction pressure temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Exceptions:

1. Single-compressor systems that do not have variable capacity capability
2. Suction groups that have a design saturated suction temperature equal to or greater than –1.1°C, suction groups that comprise the high stage of a two-stage or cascade system, or suction groups that primarily serve chillers for secondary cooling fluids.

b. Liquid subcooling shall be provided for all low-temperature compressor systems with a design cooling capacity equal to or greater than 29.3 kW with a design saturated suction temperature equal to or less than –23.3°C. The subcooled liquid temperature shall be controlled at a maximum temperature setpoint of 10°C at the exit of the subcooler using either compressor economizer (interstage) ports or a separate compressor suction group operating at a saturated suction temperature equal to or greater than –7.8°C.

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 serving the heating, cooling, or ventilating needs of a computer room shall comply with Sections 6.1, 6.4, 6.6.1.1 or 6.6.1.2, 6.6.1.3, 6.7, and 6.8.

6.6.1.1 The computer room PUE_1 shall be less than or equal to the values listed in Table 6.6.1. Hourly simulation of the proposed design, for purposes of calculating PUE_1, shall be based on the ASHRAE Standard 90.1 Appendix G simulation methodology.

Exceptions: This compliance path is not allowed for a proposed computer room design utilizing a combined heat and power system.

6.6.1.2 The computer room PUE_0 is less than or equal to the values listed in Table 6.6.1, shall be the highest value determined at outdoor cooling design temperatures, and shall be limited to systems only utilizing electricity for an energy source. PUE_0 shall be calculated for two conditions: 100% design IT equipment energy and 50% design IT equipment energy.

TABLE 6.6.1 Power Usage Effectiveness (PUE) Maximum

Climate Zone	PUE[a]
1A	1.61
2A	1.49
3A	1.41
4A	1.36
5A	1.36
6A	1.34
1B	1.53
2B	1.45
3B	1.42
4B	1.38
5B	1.33
6B	1.33
3C	1.39
4C	1.38
5C	1.36
7	1.32
8	1.30

a. PUE_0 and PUE_1 shall not include energy for battery charging.

6.6.1.3 Documentation shall be provided, including a breakdown of energy consumption or demand by at least the following components: IT equipment, power distribution losses external to the IT equipment, HVAC systems, and lighting.

6.7 Submittals

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

6.7.2 Completion Requirements. The following requirements are mandatory provisions and are necessary for compliance with the standard.

6.7.2.1 Drawings. Construction documents shall require that, within 90 days after the date of system acceptance, record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include, as a minimum, the location and performance data on each piece of equipment; general configuration of the duct and pipe distribution system, including sizes; and the terminal air or water design flow rates.

6.7.2.2 Manuals. Construction documents shall require that an operating manual and a maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of system acceptance. These manuals shall be in accordance with industry-accepted standards (see Informative Appendix E) and shall include, at a minimum, the following:

a. Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.
b. Operation manuals and maintenance manuals for each piece of equipment and system requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.
c. Names and addresses of at least one service agency.
d. HVAC controls system maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field-determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, in programming comments.
e. A complete narrative of how each system is intended to operate, including suggested setpoints.

6.7.2.3 System Balancing

6.7.2.3.1 General. Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards (see Informative Appendix E). Construction documents shall require that a written balance report be provided to the building owner or the designated representative of the building owner for HVAC systems serving zones with a total conditioned area exceeding 460 m^2.

6.7.2.3.2 Air System Balancing. Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with fan system power greater than 0.75 kW, fan speed shall be adjusted to meet design flow conditions.

6.7.2.3.3 Hydronic System Balancing. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses; then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

Exceptions: Impellers need not be trimmed nor pump speed adjusted

1. for pumps with pump motors of 7.5 kW or less or
2. when throttling results in no greater than 5% of the nameplate kW draw, or 2.2 kW, whichever is greater, above that required if the impeller was trimmed.

6.7.2.4 System Commissioning. HVAC control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition. For projects larger than 4600 m^2 conditioned area, except warehouses and semiheated spaces, detailed instructions for commissioning HVAC systems (see Informative Appendix E) shall be provided by the designer in plans and specifications.

6.8 Minimum Equipment Efficiency Tables

6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions

6.8.2 Duct Insulation Tables

6.8.3 Pipe Insulation Tables

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air conditioners, air cooled	<19 kW[b]	All	Split system	3.81 $SCOP_C$	AHRI 210/240
			Single package	3.81 $SCOP_C$ (before 1/20/15) 4.10 $SCOP_C$ (as of 1/1/2015)	
Through the wall, air cooled	≤9 kW[b]	All	Split system	3.51 $SCOP_C$	
			Single package	3.51 $SCOP_C$	
Small duct high velocity, air cooled	<19 kW[b]	All	Split System	2.93 $SCOP_C$	
Air conditioners, air cooled	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	3.28 COP_C 3.34 $ICOP_C$ (before 1/1/2016) 3.78 $ICOP_C$ (as of 1/1/2016)	AHRI 340/360
		All other	Split system and single package	3.22 COP_C 3.28 $ICOP_C$ (before 1/1/2016) 3.76 $ICOP_C$ (as of 1/1/2016)	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	3.22 COP_C 3.28 $ICOP_C$ (before 1/1/2016) 3.75 $ICOP_C$ (as of 1/1/2016)	
		All other	Split system and single package	3.16 COP_C 3.22 $ICOP_C$ (before 1/1/2016) 3.72 $ICOP_C$ (as of 1/1/2016)	
	≥70 kW and <223 kW	Electric resistance (or none)	Split system and single package	2.93 COP_C 2.96 $ICOP_C$ (before 1/1/2016) 3.40 $ICOP_C$ (as of 1/1/2016)	
		All other	Split system and single package	2.87 COP_C 2.90 $ICOP_C$ (before 1/1/2016) 3.34 $ICOP_C$ (as of 1/1/2016)	
	≥223 kW	Electric resistance (or none)	Split system and single package	2.84 COP_C 2.87 $ICOP_C$ (before 1/1/2016) 3.28 $ICOP_C$ (as of 1/1/2016)	
		All other	Split system and single package	2.78 COP_C 2.81 $ICOP_C$ (before 1/1/2016) 3.22 $ICOP_C$ (as of 1/1/2016)	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air conditioners, water cooled	<19 kW	All	Split system and single package	3.54 COP_C 3.60 $ICOP_C$	AHRI 210/240
	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	3.54 COP_C 3.60 $ICOP_C$ (before 1/1/2016) 4.07 $ICOP_C$ (as of 1/1/2016)	AHRI 340/360
		All other	Split system and single package	3.48 COP_C 3.54 $ICOP_C$ (before 1/1/2016) 4.02 $ICOP_C$ (as of 1/1/2016)	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	3.66 COP_C 3.66 $ICOP_C$ (before 1/1/2016) 4.07 $ICOP_C$ (as of 1/1/2016)	
		All other	Split system and single package	3.60 COP_C 3.66 $ICOP_C$ (before 1/1/2016) 4.02 $ICOP_C$ (as of 1/1/2016)	
	≥70 kW and <223 kW	Electric resistance (or none)	Split system and single package	3.63 COP_C 3.69 $ICOP_C$ (before 1/1/2016) 3.99 $ICOP_C$ (as of 1/1/2016)	AHRI 340/360
		All other	Split system and single package	3.57 COP_C 3.63 $ICOP_C$ (before 1/1/2016) 3.93 $ICOP_C$ (as of 1/1/2016)	
	≥223 kW	Electric resistance (or none)	Split system and single package	3.57 COP_C 3.63 $ICOP_C$ (before 1/1/2016) 3.96 $ICOP_C$ (as of 1/1/2016)	AHRI 340/360
		All other	Split system and single package	3.51 COP_C 3.57 $ICOP_C$ (before 1/1/2016) 3.90 $ICOP_C$ (as of 1/1/2016)	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units— Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air conditioners, evaporatively cooled	<19 kW[b]	All	Split system and single package	3.54 COP_C 3.60 $ICOP_C$	AHRI 210/240
	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	3.54 COP_C 3.60 $ICOP_C$	AHRI 340/360
		All other	Split system and single package	3.48 COP_C 3.54 $ICOP_C$	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	3.51 COP_C 3.57 $ICOP_C$	
		All other	Split system and single package	3.46 COP_C 3.51 $ICOP_C$	
	≥70 kW and <223 kW	Electric resistance (or none)	Split system and single package	3.48 COP_C 3.54 $ICOP_C$	
		All other	Split system and single package	3.43 COP_C 3.48 $ICOP_C$	
	≥223 kW	Electric resistance (or none)	Split system and single package	3.43 COP_C 3.48 $ICOP_C$	
		All other	Split system and single package	3.37 COP_C 3.43 $ICOP_C$	
Condensing units, air cooled	≥40 kW			3.07 COP_C 3.46 $ICOP_C$	AHRI 365
Condensing units, water cooled	≥40 kW			3.95 COP_C 4.10 $ICOP_C$	
Condensing units, evaporatively cooled	≥40 kW			3.95 COP_C 4.10 $ICOP_C$	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-2 Electrically Operated Unitary and Applied Heat Pumps— Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air cooled (cooling mode)	<19 kW[b]	All	Split system	3.81 $SCOP_C$ (before 1/1/2015) 4.10 $SCOP_C$ (as of 1/1/2015)	AHRI 210/240
			Single package	3.81 $SCOP_C$ (before 1/1/2015) 4.10 $SCOP_C$ (as of 1/1/2015)	
Through the wall, air cooled (cooling mode)	≤9 kW[b]	All	Split system	3.52 $SCOP_C$	
			Single package	3.52 $SCOP_C$	
Small duct high velocity, air cooled	<19 kW[b]	All	Split System	2.93 $SCOP_C$	
Air cooled (cooling mode)	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	3.22 COP_C 3.28 $ICOP_C$ (before 1/1/2016) 3.57 $ICOP_C$ (as of 1/1/2016)	AHRI 340/360
		All other	Split system and single package	3.17 COP_C 3.22 $ICOP_C$ (before 1/1/2016) 3.52 $ICOP_C$ (as of 1/1/2016)	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	3.11 COP_C 3.13 $ICOP_C$ (before 1/1/2016) 3.40 $ICOP_C$ (as of 1/1/2016)	
		All other	Split system and single package	3.05 COP_C 3.08 $ICOP_C$ (before 1/1/2016) 3.34 $ICOP_C$ (as of 1/1/2016)	
	≥70 kW	Electric resistance (or none)	Split system and single package	2.78 COP_C 2.81 $ICOP_C$ (before 1/1/2016) 3.11 $ICOP_C$ (as of 1/1/2016)	
		All other	Split system and single package	2.72 COP_C 2.75 $ICOP_C$ (before 1/1/2016) 3.05 $ICOP_C$ (as of 1/1/2016)	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-2 Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Water to air, water loop (cooling mode)	<5 kW	All	30°C entering water	3.57 COP_C	ISO 13256-1
	≥5 kW and <19 kW	All	30°C entering water	3.81 COP_C	
	≥19 kW and <40 kW	All	30°C entering water	3.81 COP_C	
Water to air, groundwater (cooling mode)	<40 kW	All	15°C entering water	5.27 COP_C	
Brine to air, ground loop (cooling mode)	<40 kW	All	25°C entering water	4.13 COP_C	
Water to water, water loop (cooling mode)	<40 kW	All	30°C entering water	3.10 COP_C	ISO 13256-2
Water to water, groundwater (cooling mode)	<40 kW	All	15°C entering water	4.77 COP_C	
Brine to water, ground loop (cooling mode)	<40 kW	All	25°C entering water	3.55 COP_C	
Air cooled (heating mode)	<19 kW[b] (cooling capacity)	—	Split system	2.26 $SCOP_H$ (before 1/1/2015) 2.40 $SCOP_H$ (as of1/1/2015)	AHRI 210/240
			Single package	2.26 $SCOP_H$ (before 1/1/2015) 3.34 $SCOP_H$ (as of1/1/2015)	
Through the wall, air cooled (heating mode)	≤9 kW[b] (cooling capacity)	—	Split system	2.17 $SCOP_H$	
			Single package	2.17 $SCOP_H$	
Small duct high velocity, air cooled (heating mode)	<19 kW[b]	—	Split System	2.0 $SCOP_H$	
Air cooled (heating mode)	≥19 kW and <40 kW (cooling capacity)	—	8.3°C db/6.1°C wb outdoor air	3.3 COP_H	AHRI 340/360
			–8.3°C db/–9.4°C wb outdoor air	2.25 COP_H	
	≥40 kW (cooling capacity)	—	8.3°C db/6.1°C wb outdoor air	3.2 COP_H	
			8.3°C db/–9.4°C 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, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-2 Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Water to air, water loop (heating mode)	<40 kW (cooling capacity)	—	20°C entering water	4.3 COP_H	ISO 13256-1
Water to air, groundwater (heating mode)	<40 kW (cooling capacity)	—	10°C entering water	3.7 COP_H	
Brine to air, ground loop (heating mode)	<40 kW (cooling capacity)	—	0°C entering water	3.2 COP_H	
Water to water, water loop (heating mode)	<40 kW (cooling capacity)	—	20°C entering water	3.7 COP_H	ISO 13256-2
Water to water, groundwater (heating mode)	<40 kW (cooling capacity)	—	10°C entering water	3.1 COP_H	
Brine to water, ground loop (heating mode)	<40 kW (cooling capacity)	—	0°C entering water	2.5 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, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-3 Water-Chilling Packages—Efficiency Requirements[a,b,e]

Equipment Type	Size Category	Units	Effective 1/1/2010		Effective 1/1/2015		Test Procedure[c]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	<528 kW	COP (W/W)	≥2.826 FL	NA[d]	≥2.985FL	≥2.866 FL	
			≥3.694 IPLV		≥4.048 IPLV	≥4.669 IPLV	
	≥528 kW		≥2.826 FL	NA[d]	≥2.985 FL	≥2.866 FL	
			≥3.768 IPLV		≥4.137 IPLV	≥4.758 IPLV	
Air cooled without condenser, electrically operated	All capacities	COP (W/W)	Air-cooled chillers without condenser must be rated with matching condensers and comply with air-cooled chiller efficiency requirements				
Water cooled, electrically operated positive displacement	<264 kW	COP (W/W)	≥4.513 FL	≥4.400 FL	≥4.694 FL	≥4.513 FL	AHRI 551/591
			≥ 5.588 FL	≥5.867 IPLV	≥5.867 IPLV	≥7.041 IPLV	
	≥264 kW and <528 kW		≥4.542 FL	≥4.456 FL	≥4.889 FL	≥4.694 FL	
			≥ 5.724 IPLV	≥6.007 IPLV	≥6.286 IPLV	≥7.184 IPLV	
	≥528 kW and <1055 kW		≥5.177 FL	≥4.903 FL	≥5.334 FL	≥5.177 FL	
			≥6.070 IPLV	≥6.519 IPLV	≥6.519 IPLV	≥8.001 IPLV	
	≥1055kW and <2110 kW		≥5.678 FL	≥5.509 FL	≥5.771 FL	≥5.633 FL	
			≥6.519 IPLV	≥7.184 IPLV	≥6.770 IPLV	≥8.586IPLV	
	≥2100 kW		≥5.678 FL	≥ 5.509 FL	≥6.286 FL	≥6.018 FL	
			≥6.519 IPLV	≥7.184 IPLV	≥7.041 IPLV	≥9.264 IPLV	
Water cooled, electrically operated centrifugal	<528 kW	COP (W/W)	≥5.553 FL	≥5.509 FL	≥5.771 FL	≥5.065 FL	
			≥5.907 IPLV	≥7.823 IPLV	≥6.401 IPLV	≥8.001 IPLV	
	≥528 kW and <1055 kW		≥5.553 FL	≥5.509 FL	≥5.771 FL	≥5.544 FL	
			≥5.907 IPLV	≥7.823 IPLV	≥6.401 IPLV	≥8.801 IPLV	
	≥1055 kW and <1407kW		≥6.112 FL	≥5.867 FL	≥6.286 FL	≥5.917 FL	
			≥6.412 IPLV	≥8.801 IPLV	≥6.770 IPLV	≥9.027 IPLV	
	≥1407 kW and <2110 kW		≥6.112 FL	≥5.867 FL	≥6.286 FL	≥6.018 FL	
			≥6.412 IPLV	≥8.801 IPLV	≥7.041 IPLV	≥9.264 IPLV	
	≥2110 kW		≥6.176 FL	≥5.967 FL	≥6.286 FL	≥6.018 FL	
			≥6.531 IPLV	≥8.801 IPLV	≥7.041 IPLV	≥9.264 IPLV	
Air-cooled absorption, single effect	All capacities	COP (W/W)	≥0.600 FL	NA[d]	≥0.600 FL	NA[d]	AHRI 560
Water-cooled absorption, single effect	All capacities	COP (W/W)	≥0.700 FL	NA[d]	≥0.700 FL	NA[d]	
Absorption double effect, indirect fired	All capacities	COP (W/W)	≥1.000 FL	NA[d]	≥1.000 FL	NA[d]	
			≥1.050 IPLV		≥1.050 IPLV		
Absorption double effect, direct fired	All capacities	COP (W/W)	≥1.000 FL	NA[d]	≥1.000 FL	NA[d]	
			≥1.000 IPLV		≥1.000 IPLV		

a. The requirements for centrifugal chillers shall be adjusted for nonstandard rating conditions per Section 6.4.1.2.1 and are only applicable for the range of conditions listed there. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.
b. Both the full-load and IPLV requirements must be met or exceeded to comply with this standard. When there is a Path B, compliance can be with either Path A or Path B for any application.
c. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
d. NA means the requirements are not applicable for Path B, and only Path A can be used for compliance.
e. FL is the full-load performance requirements, and IPLV is for the part-load performance requirements.

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

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
PTAC (cooling mode) standard size	All capacities	35.0°Cdb outdoor air	4.04 – (0.300 × Cap/1000)[c] COP_C (before 1/1/2015) 4.10 – (0.300 × Cap/1000)[c] COP_C (as of 1/1/2015)	AHRI 310/380
PTAC (cooling mode) nonstandard size[a]	All capacities	35.0°C db outdoor air	3.19 – (0.213 × Cap/1000)[c] COP_C	
PTHP (cooling mode) standard size	All capacities	35.0°C db outdoor air	4.10 – (0.300 × Cap/1000)[c] COP_C	
PTHP (cooling mode) nonstandard size[b]	All capacities	35.0°C db outdoor air	3.16 – (0.213 × Cap/1000)[c] COP_C	
PTHP (heating mode) standard size	All capacities	—	3.7 – (0.052 × Cap/1000)[c] COP_H	
PTHP (heating mode) nonstandard size[b]	All capacities	—	2.9 – (0.026 × Cap/1000)[c] COP_H	
SPVAC (cooling mode)	<19 kW	35.0°C db/23.9°C wb outdoor air	2.93 COP_C	AHRI 390
	≥19 kW and <40 kW	35.0°C db/23.9°C wb outdoor air	2.61 COP_C	
	≥40 kW and <70 kW	35.0°C db/23.9°C wb outdoor air	2.93 COP_C	
SPVHP (cooling mode)	<19 kW	35.0°C db/23.9°C wb outdoor air	2.64 COP_C	
	≥19 kW and <40 kW	35.0°C db/23.9°C wb outdoor air	2.61 COP_C	
	≥40 kW and <70 kW	35.0°C db/23.9°C wb outdoor air	2.52 COP_C	
SPVHP (heating mode)	<19 kW	8.3°C db/6.1°C wb outdoor air	3.0 COP_H	
	≥19 kW and <40 kW	8.3°C db/6.1°C wb outdoor air	3.0 COP_H	
	≥40 kW and <70 kW	8.3°C db/6.1°C wb outdoor air	3.0 COP_H	
Room air conditioners with louvered sides	<1.8 kW	—	2.84 COP_C	ANSI/AHAM RAC-1
	≥1.8 kW and <2.3 kW		2.84 COP_C	
	≥2.3 kW and <4.1 kW		2.87 COP_C	
	≥4.1 kW and <5.9 kW		2.84 COP_C	
	≥5.9 kW		2.49 COP_C	

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 0.45 m high or less than 1.0 m wide and having a cross-sectional area less than 0.4 m^2.
c. "Cap" means the rated cooling capacity of the product in kW. If the unit's capacity is less than 2.1 kW, use 2.1 kW in the calculation. If the unit's capacity is greater than 4.4 kW, use 4.4 kW in the calculation.

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

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
SPVAC (cooling mode), nonweatherized space constrained	≤9 kW	35°C db/23.9°C wb outdoor air	2.69 COP_C	AHRI 390
	>9 kW and ≤11 kW	35°C db/23.9°C wb outdoor air	2.64 COP_C	
SPVHP (cooling mode), nonweatherized space constrained	≤9 kW	35°C db/23.9°C wb outdoor air	2.69 COP_C	
	>9 kW and ≤11 kW	35°C db/23.9°C wb outdoor air	2.64 COP_C	
SPVHP (heating mode), nonweatherized space constrained	≤9 kW	8.3°C db/6.1°C wb outdoor air	3.0 COP_H	
	>9 kW and ≤11 kW	8.3°C db/6.1°C wb outdoor air	3.0 COP_H	
Room air conditioners without louvered sides	<2.3 kW	—	2.64 COP_C	ANSI/AHAM RAC-1
	≥2.3 kW and <5.9 kW		2.49 COP_C	
	≥5.9 kW		2.49 COP_C	
Room air-conditioner heat pumps with louvered sides	<5.9 kW	—	2.65 COP_C	
	≥5.9 kW		2.49 COP_C	
Room air-conditioner heat pumps without louvered sides	<4.1 kW	—	2.49 COP_C	
	≥4.1 kW		2.34 COP_C	
Room air conditioner, casement only	All capacities	—	2.55 COP_C	
Room air conditioner, casement slider	All capacities	—	2.78 COP_C	

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 0.45 m high or less than 1.0 m wide and having a cross-sectional area less than 0.4 m^2.

c. "Cap" means the rated cooling capacity of the product in kW. If the unit's capacity is less than 2.1 kW, use 2.1 kW in the calculation. If the unit's capacity is greater than 4.4 kW, use 4.4 kW in the calculation.

TABLE 6.8.1-5 Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Warm-air furnace, gas fired	<66 kW	Maximum capacity[c]	78% AFUE or 80% E_t [b,d]	DOE 10 CFR Part 430 or Section 2.39, Thermal Efficiency, ANSI Z21.47
	≥66 kW	Maximum capacity[c]	80% E_t[d]	Section 2.39, Thermal Efficiency, ANSI Z21.47
Warm-air furnace, oil fired	<66 kW	Maximum capacity[c]	78% AFUE or 80% E_t[b,d]	DOE 10 CFR Part 430 or Section 42, Combustion, UL 727
	≥66 kW	Maximum capacity[c]	81% E_t[d]	Section 42, Combustion, UL 727
Warm-air duct furnaces, gas fired	All capacities	Maximum capacity[c]	80% E_c[e]	Section 2.10, Efficiency, ANSI Z83.8
Warm-air unit heaters, gas fired	All capacities	Maximum capacity[c]	80% E_c[e,f]	Section 2.10, Efficiency, ANSI Z83.8
Warm-air unit heaters, oil fired	All capacities	Maximum capacity[c]	80% E_c[e,f]	Section 40, Combustion, UL 731

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Combination units not covered by NAECA (three-phase power or cooling capacity greater than or equal to 19 kW) may comply with either rating.
c. Compliance of multiple firing rate units shall be at the maximum firing rate.
d. E_t = thermal efficiency. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
e. E_c = combustion efficiency (100% less flue losses). See test procedure for detailed discussion.
f. As of August 8, 2008, according to the Energy Policy Act of 2005, units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an automatic flue damper.

TABLE 6.8.1-6 Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements

Equipment Type[a]	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency	Efficiency as of 3/2/2020	Test Procedure
Boilers, hot water	Gas fired	<88 kW[f,g]	82% AFUE	82% AFUE	10 CFR Part 430
		≥88 kW and ≤733 kW	80% E_t	80% E_t	10 CFR Part 431
		>733 kW[a]	82% E_c	82% E_c	
	Oil fired[e]	<88 kW[g]	84% AFUE	84% AFUE	10 CFR Part 430
		≥88 kW and ≤733 kW	82% E_t	82% E_t	10 CFR Part 431
		>733 kW[a]	84% E_c	84% E_c	
Boilers, steam	Gas fired	<88 kW[f]	80% AFUE	80% AFUE	10 CFR Part 430
	Gas fired—all, except natural draft	≥88 kW and ≤733 kW	79% E_t	79% E_t	10 CFR Part 431
		>733 kW[a]	79% E_t	79% E_t	
	Gas fired—natural draft	≥88 kW and ≤733 kW	77% E_t	79% E_t	
		>733 kW[a]	77% E_t	79% E_t	
	Oil fired[e]	<88 kW	82% AFUE	82% AFUE	10 CFR Part 430
		≥88 kW and ≤733 kW	81% E_t	81% E_t	10 CFR Part 431
		>733 kW[a]	81% E_t	81% E_t	

a. These requirements apply to boilers with rated input of 2346 kW or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.
b. E_c = combustion efficiency (100% less flue losses). See reference document for detailed information.
c. E_t = thermal efficiency. See reference document for detailed information.
d. Maximum capacity—minimum and maximum ratings as provided for and allowed by the unit's controls.
e. Includes oil-fired (residual).
f. Boilers shall not be equipped with a constant burning pilot light.
g. A boiler not equipped with a tankless domestic water heating coil shall be equipped with an automatic means for adjusting the temperature of the water such that an incremental change in inferred heat load produces a corresponding incremental change in the temperature of the water supplied.

TABLE 6.8.1-7 Performance Requirements for Heat Rejection Equipment

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition[h]	Performance Required[a,b,c,d,f,g]	Test Procedure[e]
Propeller or axial fan open-circuit cooling towers	All	35.0°C entering water 29.4°C leaving water 23.9°C entering wb	≥3.40 L/s·kW	CTI ATC-105 and CTI STD-201
Centrifugal fan open-circuit cooling towers	All	35.0°C entering water 29.4°C leaving water 23.9°C entering wb	≥1.7 L/s·kW	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed-circuit cooling towers	All	38.9°C entering water 32.2°C leaving water 23.9°C entering wb	≥1.18 L/s·kW	CTI ATC-105S and CTI STD-201
Centrifugal closed-circuit cooling towers	All	38.9°C entering water 32.2°C leaving water 23.9°C entering wb	≥0.59 L/s·kW	CTI ATC-105S and CTI STD-201
Propeller or axial fan evaporative condensers	All	R-507A test fluid 73.9°C entering gas temperature 40.6°C condensing temperature 23.9°F entering wb	≥61.6 COP	CTI ATC-106
Propeller or axial fan evaporative condensers	All	Ammonia test fluid 60°C entering gas temperature 35.7°C condensing temperature 23.9°C entering wb	≥52.6 COP	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-507A test fluid 73.9°C entering gas temperature 40.6°C condensing temperature 23.9°F entering wb	≥53.0 COP	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia test fluid 60°C entering gas temperature 35.7°C condensing temperature 23.9°C entering wb	≥43.2 COP	CTI ATC-106
Air cooled condensers	All	52°C condensing temperature 88°C entering gas temperature 8°C subcooling 35°C entering db	≥69 COP	AHRI 460

a. For purposes of this table, open-circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 6.8.1-7 divided by the fan motor nameplate power.
b. For purposes of this table, closed-circuit cooling tower performance is defined as the process water flow rating of the tower at the thermal rating condition listed in Table 6.8.1-7 divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.
c. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan motor nameplate power.
d. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
e. The efficiencies and test procedures for both open- and closed-circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of separate wet and dry heat exchange sections. The certification requirements do not apply to field-erected cooling towers.
f. All cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.
g. For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table, divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.
h. Requirements for evaporative condensers are listed with ammonia (R-717) and R-507A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-507A must meet the minimum efficiency requirements listed above with R-507A as the test fluid.

TABLE 6.8.1-8 Heat Transfer Equipment

Equipment Type	Subcategory	Minimum Efficiency[a]	Test Procedure[b]
Liquid-to-liquid heat exchangers	Plate type	NR	AHRI 400

a. NR = No requirement
b. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1-9 Electrically Operated Variable-Refrigerant-Flow Air Conditioners— Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF air conditioners, air cooled	<19 kW	All	VRF multisplit system	3.81 $SCOP_C$	AHRI 1230
	≥19 kW and <40 kW	Electric resistance (or none)	VRF multisplit system	3.28 COP_C 3.84 $ICOP_C$	
	≥40 kW and <70 kW	Electric resistance (or none)	VRF multisplit system	3.22 COP_C 3.75 $ICOP_C$	
	≥70 kW	Electric resistance (or none)	VRF multisplit system	2.93 COP_C 3.40 $ICOP_C$	

TABLE 6.8.1-10 Electrically Operated Variable-Refrigerant-Flow Air-to-Air 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)	<19 kW	All	VRF multisplit system	3.81 $SCOP_C$	AHRI 1230
	≥19 kW and <40 kW	Electric resistance (or none)	VRF multisplit system	3.22 COP_C 3.60 $ICOP_C$	
	≥19 kW and <40 kW	Electric resistance (or none)	VRF multisplit system with heat recovery	3.16 COP_C 3.55 $ICOP_C$	
	≥40 kW and <70 kW	Electric resistance (or none)	VRF multisplit system	3.11 COP_C 3.46 $ICOP_C$	
	≥40 kW and <70 kW	Electric resistance (or none)	VRF multisplit system with heat recovery	3.05 COP_C 3.40 $ICOP_C$	
	≥70 kW	Electric resistance (or none)	VRF multisplit system	2.78 COP_C 3.11 $ICOP_C$	
	≥70 kW	Electric resistance (or none)	VRF multisplit system with heat recovery	2.73 COP_C 3.05 $ICOP_C$	
VRF water source (cooling mode)	<19 kW	All	VRF multisplit systems 30°C entering water	3.52 COP_C	AHRI 1230
	<19 kW	All	VRF multisplit systems with heat recovery 30°C entering water	3.46 COP_C	
	≥19 kW and <40 kW	All	VRF multisplit system 30°C entering water	3.52 COP_C	
	≥19 kW and <40 kW	All	VRF multisplit system with heat recovery 30°C entering water	3.46 COP_C	
	≥40 kW	All	VRF multisplit system 30°C entering water	2.93 COP_C	
	≥40 kW	All	VRF multisplit system with heat recovery 30°C entering water	2.87 COP_C	
VRF groundwater source (cooling mode)	<40 kW	All	VRF multisplit system 15°C entering water	4.75 COP_C	AHRI 1230
	<40 kW	All	VRF multisplit system with heat recovery 15°C entering water	4.69 COP_C	
	≥40 kW	All	VRF multisplit system 15°C entering water	4.04 COP_C	
	≥40 kW	All	VRF multisplit system with heat recovery 15°C entering water	3.98 COP_C	

TABLE 6.8.1-10 Electrically Operated Variable-Refrigerant-Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements *(Continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF ground source (cooling mode)	<40 kW	All	VRF multisplit system 25°C entering water	3.93 COP_C	AHRI 1230
	<40 kW	All	VRF multisplit system with heat recovery 25°C entering water	3.87 COP_C	
	≥40 kW	All	VRF multisplit system 25°C entering water	3.22 COP_C	
	≥40 kW	All	VRF multisplit system with heat recovery 25°C entering water	3.16 COP_C	
VRF air cooled (heating mode)	<19 kW (cooling capacity)	—	VRF multisplit system	2.25 $SCOP_H$	AHRI 1230
	≥19 kW and <40 kW	—	VRF multisplit system 8.3°C db/6.1°C wb outdoor air	3.3 COP_H	
			–8.3°C db/–9.4°C wb outdoor air	2.25 COP_H	
	≥40 kW (cooling capacity)	—	VRF multisplit system 8.3°C db/6.1°C wb outdoor air	3.2 COP_H	
			–8.3°C db/–9.4°C wb outdoor air	2.05 COP_H	
VRF water source (heating mode)	<40 kW (cooling capacity)	—	VRF multisplit system 20°C entering water	4.2 COP_H	AHRI 1230
	≥40 kW (cooling capacity)	—	VRF multisplit system 20°C entering water	3.9 COP_H	
VRF groundwater source (heating mode)	<40 kW (cooling capacity)	—	VRF multisplit system 10°C entering water	3.6 COP_H	AHRI 1230
	≥40 kW (cooling capacity)	—	VRF multisplit system 10°C entering water	3.3 COP_H	
VRF ground source (heating mode)	<40 kW (cooling capacity)	—	VRF multisplit system 0°C entering water	3.1 COP_H	AHRI 1230
	≥40 kW (cooling capacity)	—	VRF multisplit system 0°C entering water	2.8 COP_H	

TABLE 6.8.1-11 Air Conditioners and Condensing Units Serving Computer Rooms

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

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

TABLE 6.8.1-12 Commercial Refrigerator and Freezers

Equipment Type	Application	Energy Use Limits, kWh/day	Test Procedure
Refrigerator with solid doors	Holding temperature	$3.53 \times V + 2.04$	AHRI 1200
Refrigerator with transparent doors		$4.24 \times V + 3.34$	
Freezers with solid doors		$14.13 \times V + 1.38$	
Freezers with transparent doors		$26.49 \times V + 4.10$	
Refrigerators/freezers with solid doors		the greater of $4.24 \times V + 3.34$ or 0.70	
Commercial refrigerators	Pulldown	$4.45 \times V + 3.51$	

V = the chiller or frozen compartment volume (m^3) as defined in Association of Home Appliance Manufacturers Standard HRF-1.

TABLE 6.8.1-13 Commercial Refrigeration—Minimum Efficiency Requirements

Equipment Type				Energy Use Limits as of 1/1/2012,[b,c] kWh/day	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical open	Remote condensing	Medium temperature	8.83 × TDA + 4.07	AHRI 1200
SVO.RC.M	Semivertical open	Remote condensing	Medium temperature	8.93 × TDA + 3.18	
HZO.RC.M	Horizontal open	Remote condensing	Medium temperature	3.77 × TDA + 2.88	
VOP.RC.L	Vertical open	Remote condensing	Low temperature	24.43 × TDA + 6.85	
HZO.RC.L	Horizontal open	Remote condensing	Low temperature	6.14 × TDA + 6.88	
VCT.RC.M	Vertical transparent door	Remote condensing	Medium temperature	2.37 × TDA + 1.95	
VCT.RC.L	Vertical transparent door	Remote condensing	Low temperature	6.03 × TDA + 2.61	
SOC.RC.M	Service over counter	Remote condensing	Medium temperature	5.49 × TDA + 0.11	
VOP.SC.M	Vertical open	Self contained	Medium temperature	18.73 × TDA + 4.71	
SVO.SC.M	Semivertical open	Self contained	Medium temperature	18.62 × TDA + 4.59	
HZO.SC.M	Horizontal open	Self contained	Medium temperature	8.29 × TDA + 5.55	
HZO.SC.L	Horizontal open	Self contained	Low temperature	20.67 × TDA + 7.08	
VCT.SC.I	Vertical transparent door	Self contained	Ice cream	7.21 × TDA + 3.29	
VCS.SC.I	Vertical solid door	Self contained	Ice cream	13.42 × V + 0.88	
HCT.SC.I	Horizontal transparent door	Self contained	Ice cream	6.03 × TDA + 0.43	
SVO.RC.L	Semivertical open	Remote condensing	Low temperature	24.43 × TDA + 6.85	
VOP.RC.I	Vertical open	Remote condensing	Ice cream	31.11 × TDA + 8.7	
SVO.RC.I	Semivertical open	Remote condensing	Ice cream	31.11 × TDA + 8.7	
HZO.RC.I	Horizontal open	Remote condensing	Ice cream	7.75 × TDA + 8.74	
VCT.RC.I	Vertical transparent door	Remote condensing	Ice cream	7.10 × TDA + 3.05	

a. Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of the following:
(AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical transparent doors, VCS = vertical solid doors, HCT = horizontal transparent doors, HCS = horizontal solid doors, and SOC = service over counter); (BB)—An operating mode code (RC = remote condensing and SC = self contained); and (C)—A rating temperature code (M = medium temperature [3.3°C], L = low temperature [–17.8°C], or I = ice cream temperature [–9.4°C]). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.

b. V is the volume of the case (m^3) as measured in AHRI Standard 1200, Appendix C.

c. TDA is the total display area of the case (m^3) as measured in AHRI Standard 1200, Appendix D.

TABLE 6.8.1-13 Commercial Refrigeration—Minimum Efficiency Requirements *(Continued)*

Equipment Type				Energy Use Limits as of 1/1/2012,[b,c] kWh/day	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
HCT.RC.M	Horizontal transparent door	Remote condensing	Medium temperature	1.72 × TDA + 0.13	
HCT.RC.L	Horizontal transparent door	Remote condensing	Low temperature	3.66 × TDA + 0.26	
HCT.RC.I	Horizontal transparent door	Remote condensing	Ice cream	4.31 × TDA + 0.31	
VCS.RC.M	Vertical solid door	Remote condensing	Medium temperature	3.88 × V + 0.26	
VCS.RC.L	Vertical solid door	Remote condensing	Low temperature	8.12 × V + 0.54	
VCS.RC.I	Vertical solid door	Remote condensing	Ice cream	9.53 × V + 0.63	
HCS.RC.M	Horizontal solid door	Remote condensing	Medium temperature	3.88 × V + 0.26	
HCS.RC.L	Horizontal solid door	Remote condensing	Low temperature	8.12 × V + 0.54	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	9.53 × V + 0.63	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	9.53 × V + 0.63	AHRI 1200
SOC.RC.L	Service over counter	Remote condensing	Low temperature	11.63 × TDA + 0.22	
SOC.RC.I	Service over counter	Remote condensing	Ice cream	13.56 × TDA + 0.26	
VOP.SC.L	Vertical open	Self contained	Low temperature	47.04 × TDA + 11.82	
VOP.SC.I	Vertical open	Self contained	Ice cream	59.74 × TDA + 15.02	
SVO.SC.L	Semivertical open	Self contained	Low temperature	46.72 × TDA + 11.51	
SVO.SC.I	Semivertical open	Self contained	Ice cream	5.52 × TDA + 14.63	
HZO.SC.I	Horizontal open	Self contained	Ice cream	59.42 × TDA + 9.0	
SOC.SC.I	Service over counter	Self contained	Ice cream	18.94 × TDA + 0.36	
HCS.SC.I	Horizontal solid door	Self contained	Ice cream	13.42 × TDA + 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 [3.3°C], L = low temperature [–17.8°C], or I = ice cream temperature [–9.4°C]). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.

b. V is the volume of the case (m^3) as measured in AHRI Standard 1200, Appendix C.

c. TDA is the total display area of the case (m^2) as measured in AHRI Standard 1200, Appendix D.

TABLE 6.8.2-1 Minimum Duct Insulation R-Value,[a] Cooling- and Heating-Only Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Heating-Only Ducts							
1, 2	None	None	None	None	None	None	None
3	R-0.62	None	None	None	None	None	None
4	R-0.62	None	None	None	None	None	None
5	R-1.06	R-0.62	None	None	None	None	R-0.62
6	R-1.06	R-1.06	R-0.62	None	None	None	R-0.62
7	R-1.41	R-1.06	R-1.06	None	R-0.62	None	R-0.62
8	R-1.41	R-1.41	R-1.06	None	R-1.06	None	R-1.06
Cooling-Only Ducts							
1	R-1.06	R-1.06	R-1.41	R-0.62	R-0.62	None	R-0.62
2	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	None	R-0.62
3	R-1.06	R-1.06	R-1.06	R-0.62	R-0.34	None	None
4	R-0.62	R-0.62	R-1.06	R-0.34	R-0.34	None	None
5, 6	R-0.62	R-0.34	R-0.62	R-0.34	R-0.34	None	None
7, 8	R-0.34	R-0.34	R-0.34	R-0.34	R-0.34	None	None
Return Ducts							
1 to 8	R-0.62	R-0.62	R-0.62	None	None	None	None

a. Insulation R-values, measured in $(m^2 \cdot K)/W$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 23.9°C at the installed thickness.
b. Includes crawlspaces, both ventilated and nonventilated.
c. Includes return air plenums with or without exposed roofs above.

TABLE 6.8.2-2 Minimum Duct Insulation R-Value,[a] Combined Heating and Cooling Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Supply Ducts							
1	R-1.06	R-1.06	R-1.41	R-0.62	R-0.62	None	R-0.62
2	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	None	R-0.62
3	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	None	R-0.62
4	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	None	R-0.62
5	R-1.06	R-1.06	R-1.06	R-0.34	R-0.62	None	R-0.62
6	R-1.41	R-1.06	R-1.06	R-0.34	R-0.62	None	R-0.62
7	R-1.41	R-1.06	R-1.06	R-0.34	R-0.62	None	R-0.62
8	R-1.41	R-1.41	R-1.41	R-0.34	R-1.06	None	R-1.06
Return Ducts							
1 to 8	R-0.62	R-0.62	R-0.62	None	None	None	None

a. Insulation R-values, measured in $(m^2 \cdot K)/W$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 23.9°C at the installed thickness.
b. Includes crawlspaces, both ventilated and nonventilated.
c. Includes return air plenums with or without exposed roofs above.

TABLE 6.8.3-1 Minimum Piping Insulation Thickness Heating and Hot Water Systems[a,b,c,d,e] (Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)

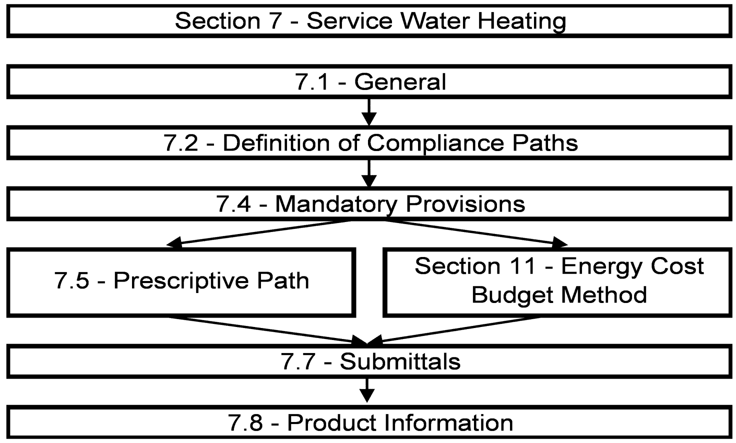
Fluid Operating Temperature Range (°C) and Usage	Insulation Conductivity		≥Nominal Pipe or Tube Size, mm				
	Conductivity, W/(m·°C)	Mean Rating Temperature, °C	<25	25 to <40	40 to <100	100 to <200	≥200
			Insulation Thickness, mm				
>177°C	0.046–0.049	121	115	125	125	125	125
122°C–177°C	0.042–0.046	93	80	100	115	115	115
94°C–121°C	0.039–0.043	66	65	65	80	80	80
61°C–93°C	0.036–0.042	52	40	40	50	50	50
41°C–60°C	0.032–0.040	38	25	25	40	40	40

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 (mm), r = actual outside radius of pipe (mm), 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 (W/(m°C)); 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 40 mm and located in partitions within conditioned spaces, reduction of these thicknesses by 25 mm shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 25 mm.
d. For direct-buried heating and hot-water system piping, reduction of these thicknesses by 40 mm shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 25 mm.
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 (°C) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size, mm				
	Conductivity, W/(m°C)	Mean Rating Temperature, °C	<25	25 to <40	40 to <100	100 to <200	≥200
			Insulation Thickness, mm				
4°C–16°C	0.030–0.039	24	15	15	25	25	25
<4°C	0.029–0.037	10	15	25	25	25	40

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 (mm), r = actual outside radius of pipe (mm), 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 (W/(m°C)); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.
b. These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.
c. For direct-buried cooling system piping, insulation is not required.
d. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.



7. SERVICE WATER HEATING

7.1 General

7.1.1 Service Water Heating Scope

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

7.1.1.2 Additions to Existing Buildings. Service water heating systems and equipment shall comply with the requirements of this section.

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

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

Exception: Compliance shall not be required where there is insufficient space or access to meet these requirements.

7.2 Compliance Paths

7.2.1 Compliance. Compliance shall be achieved by meeting the requirements of Section 7.1, "General"; Section 7.4, "Mandatory Provisions"; Section 7.5, "Prescriptive Path"; Section 7.7, "Submittals"; and Section 7.8, "Product Information."

7.2.2 Projects using the Energy Cost Budget Method (Section 11) for demonstrating compliance with the standard shall meet the requirements of Section 7.4, "Mandatory Provisions," in conjunction with Section 11, "Energy Cost Budget Method."

7.3 Simplified/Small Building Option (Not Used)

7.4 Mandatory Provisions

7.4.1 Load Calculations. Service water heating system design loads for the purpose of sizing systems and equipment shall be determined in accordance with manufacturers' published sizing guidelines or generally accepted engineering standards and handbooks acceptable to the adopting authority (e.g., *ASHRAE Handbook—HVAC Applications*).

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

Exceptions: All water heaters and hot-water supply boilers having more than 530 L of storage capacity are not required to meet the standby loss (SL) requirements of Table 7.8 when

a. the tank surface is thermally insulated to R-2.2,
b. a standing pilot light is not installed, and
c. gas- or oil-fired storage water heaters have a flue damper or fan-assisted combustion.

7.4.3 Service Hot-Water Piping Insulation. The following piping shall be insulated to levels shown in Section 6, Table 6.8.3-1:

a. Recirculating system piping, including the supply and return piping of a circulating tank type water heater
b. The first 2.4 m of outlet piping for a constant temperature nonrecirculating storage system
c. The inlet piping between the storage tank and a heat trap in a nonrecirculating storage system
d. Piping that is externally heated (such as heat trace or impedance heating)

7.4.4 Service Water Heating System Controls

7.4.4.1 Temperature Controls. Temperature controls shall be provided that allow for storage temperature adjustment from 49°C or lower to a maximum temperature compatible with the intended use.

Exception: When the manufacturers' installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion.

7.4.4.2 Temperature Maintenance Controls. Systems designed to maintain usage temperatures in hot-water pipes, such as recirculating hot-water systems or heat trace, shall be equipped with automatic time switches or other controls that can be set to switch off the usage temperature maintenance system during extended periods when hot water is not required.

7.4.4.3 Outlet Temperature Controls. Temperature controlling means shall be provided to limit the maximum temperature of water delivered from lavatory faucets in public facility restrooms to 43°C.

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 32°C shall have a pool cover with a minimum insulation value of R-2.1.

Exception: Pools deriving over 60% of the energy for heating from site-recovered energy or solar energy source.

7.4.5.3 Time Switches. Time switches shall be installed on swimming pool heaters and pumps.

Exceptions:

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

7.4.6 Heat Traps. Vertical pipe risers serving storage water heaters and storage tanks not having integral heat traps and serving a nonrecirculating system shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank. A heat trap is a means to counteract the natural convection of heated water in a vertical pipe run. The means is either a device specifically designed for the purpose or an arrangement of tubing that forms a loop of 360 degrees or piping that from the point of connection to the water heater (inlet or outlet) includes a length of piping directed downward before connection to the vertical piping of the supply water or hot-water distribution system, as applicable.

7.5 Prescriptive Path

7.5.1 Space Heating and Water Heating. The use of a gas-fired or oil-fired space-heating boiler system otherwise complying with Section 6 to provide the total space heating and water heating for a building is allowed when one of the following conditions is met:

a. The single space-heating boiler, or the component of a modular or multiple boiler system that is heating the service water, has a standby loss in kW not exceeding

$$(3.7 \times 10^6 \times \text{pmd} + 117)/n$$

where pmd is the probable maximum demand in m^3/s 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 18.3°C.

The standby loss is to be determined for a test period of 24 hours duration while maintaining a boiler water temperature of at least 50°C above ambient, with an ambient temperature between 16°C and 32°C. 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 44 kW.

7.5.2 Service Water Heating Equipment. Service water heating equipment used to provide the additional function of space heating as part of a combination (integrated) system shall satisfy all stated requirements for the service water heating equipment.

7.5.3 Buildings with High-Capacity Service Water Heating Systems. New buildings with gas service hot-water systems with a total installed gas water-heating input capacity of 293 kW or greater, shall have gas service water-heating equipment with a minimum thermal efficiency (E_t) of 90%. Multiple units of gas water-heating equipment are allowed to meet this requirement if the water-heating input provided by equipment with thermal efficiency (E_t) above and below 90% provides an input capacity-weighted average thermal efficiency of at least 90%.

The requirements of Section 7.5.3 are effective on July 30, 2015.

Exceptions:

1. Where 25% of the annual service water-heating requirement is provided by site-solar or site-recovered energy.
2. Water heaters installed in individual dwelling units.
3. Individual gas water heaters with input capacity not greater than 293 kW.

7.6 Alternative Compliance Path (Not Used)

7.7 Submittals

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

7.8 Product Information

TABLE 7.8 Performance Requirements for Water-Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure[b,c]
Electric table-top water heaters	≤12 kW	Resistance ≥75.7 L	0.93–0.00035V EF	DOE 10 CFR Part 430
Electric water heaters	≤12 kW	Resistance ≥75.7 L	0.97–0.00035V EF	DOE 10 CFR Part 430
	>12 kW	Resistance ≥75.7 L	0.3 + 27/Vm %/h	Section G.2 of ANSI Z21.10.3
	≤24 Amps and ≤250 Volts	Heat Pump	0.93–0.00035V EF	DOE 10 CFR Part 430
Gas storage water heaters	≤22.98 kW	≥75.7 L	0.67–0.0005V EF	DOE 10 CFR Part 430
	>22.98 kW	<309.75 W/L	80% E_t (Q/799 + 16.6$\sqrt{V}$) SL, W	Sections G.1 and G.2 of ANSI Z21.10.3
Gas instantaneous water heaters	>14.66 kW and <58.62 kW	≥309.75 W/L and <7.57 L	0.62–0.0005V EF	DOE 10 CFR Part 430
	≥58.62 kW[d]	≥309.75 W/L and <37.85 L	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
	≥58.62 kW	≥309.75 W/L and ≥37.85 L	80% E_t (Q/799 + 16.6$\sqrt{V}$) SL, W	
Oil storage water heaters	≤30.78 kW	≥75.7 L	0.59–0.0005V EF	DOE 10 CFR Part 430
	>30.78 kW	<309.75 W/L	80% E_t (Q/799 + 16.6$\sqrt{V}$) SL, W	Sections G.1 and G.2 of ANSI Z21.10.3
Oil instantaneous water heaters	≤61.55 kW	≥309.75 W/L and <7.57 L	0.59–0.0005V EF	DOE 10 CFR Part 430
	>61.55 kW	≥309.75 W/L and <37.85 L	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
	>61.55 kW	≥309.75 W/L and ≥37.85 L	78% E_t (Q/799 + 16.6$\sqrt{V}$) SL, W	
Hot-water supply boilers, gas and oil	≥61.55 kW and <3663.8 kW	≥309.75 W/L and <37.85 L	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
Hot-water supply boilers, gas		≥309.75 W/L and ≥37.85 L	80% E_t (Q/799 + 16.6$\sqrt{V}$) SL, W	
Hot-water supply boilers, oil		≥309.75 W/L and ≥37.85 L	78% E_t (Q/799 + 16.6$\sqrt{V}$) SL, W	
Pool heaters, oil and gas	All		78% E_t	ASHRAE 146
Heat-pump pool heaters	All		4.0 COP	AHRI 1160
Unfired storage tanks	All		R-2.2	(none)

a. Energy factor (EF) and thermal efficiency (E_t) are minimum requirements, while standby loss (SL) is maximum W based on a 38.9°C temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in litres. In the SL equation, V is the rated volume in litres and Q is the nameplate input rate in W. V_m is the measured volume in the tank

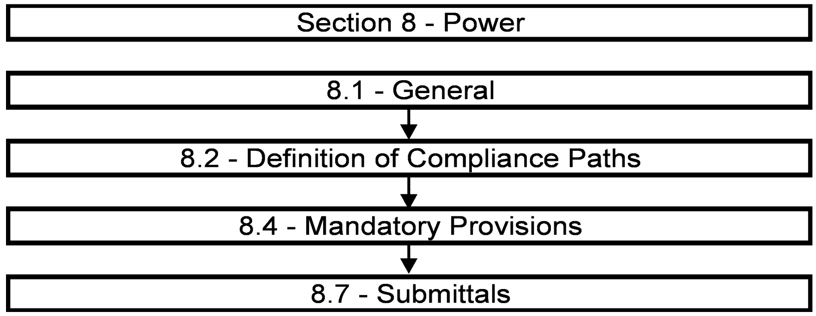
b. Section 12 contains a complete specification, including the year version, of the referenced test procedure.

c. Section G.1 is titled "Test Method for Measuring Thermal Efficiency" and Section G.2 is titled "Test Method for Measuring Standby Loss."

d. Instantaneous water heaters with input rates below 58.62 W must comply with these requirements if the water heater is designed to heat water to temperatures of 82.2°C or higher.

e. Electric water heaters with input rates below 12 kW must comply with these requirements if the water heater is designed to heat water to temperatures of 82.2°C or higher.

f. Refer to Section 7.5.3 for additional requirements for gas storage and instantaneous water heaters and gas hot-water supply boilers.



8. POWER

8.1 General

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

8.1.2 New Buildings. Equipment installed in new buildings shall comply with the requirements of this section.

8.1.3 Addition to Existing Buildings. Equipment installed in addition to existing buildings shall comply with the requirements of this section.

8.1.4 Alterations to Existing Buildings

Exception: Compliance shall not be required for the relocation or reuse of existing equipment at the same site.

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

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

8.2 Compliance Paths

8.2.1 Compliance. Power distribution systems in all projects shall comply with the requirements of Section 8.1, "General"; Section 8.4, "Mandatory Provisions"; and Section 8.7, "Submittals."

8.3 Simplified/Small Building Option (Not Used)

8.4 Mandatory Provisions

8.4.1 Voltage Drop

Exception: Feeder conductors and branch circuits that are dedicated to emergency services

8.4.1.1 Feeders. Feeder conductors shall be sized for a maximum voltage drop of 2% at design load.

8.4.1.2 Branch Circuits. Branch circuit conductors shall be sized for a maximum voltage drop of 3% at design load.

8.4.2 Automatic Receptacle Control. The following shall be automatically controlled:

a. At least 50% of all 125-volt 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 464.5 m^2 and not more than one floor (the occupant shall be able to manually override the control device for up to two hours),
b. an occupant sensor that shall turn receptacles off within 20 minutes of all occupants leaving a space, or
c. an automated signal from another control or alarm system that shall turn receptacles off within 20 minutes after determining that the area is unoccupied.

All controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles and are to be uniformly distributed throughout the space.

Plug-in devices shall not be used to comply with Section 8.4.2.

Exceptions: Receptacles for the following shall not require an automatic control device:

1. Receptacles specifically designated for equipment requiring continuous operation (24 hours/day, 365 days/year)
2. Spaces where an automatic control would endanger the safety or security of the room or building occupant(s).

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

8.4.3.2 Recording and Reporting. The electrical energy usage for all loads specified in Section 8.4.3.1 shall be

TABLE 8.4.4 Minimum Nominal Efficiency Levels for 10 CFR 431 Low-Voltage Dry-Type Distribution Transformers[a]

Single-Phase Transformers		Three-Phase Transformers	
kVA[b]	Efficiency,%[c]	kVA[b]	Efficiency,%[c]
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

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

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. The system shall be capable of maintaining all data collected for a minimum of 36 months.

Exceptions to 8.4.3.1 and 8.4.3.2:

1. Building less than 2322 m^2
2. Individual tenant spaces less than 929 m^2
3. Dwelling units
4. Residential buildings with less than 929 m^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.

Exceptions: 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, or
14. Testing transformer

8.5 Prescriptive Path (Not Used)

8.6 Alternative Compliance Path (Not Used)

8.7 Submittals

8.7.1 Drawings. Construction documents shall require that within 30 days after the date of system acceptance, record drawings of the actual installation shall be provided to the building owner, including

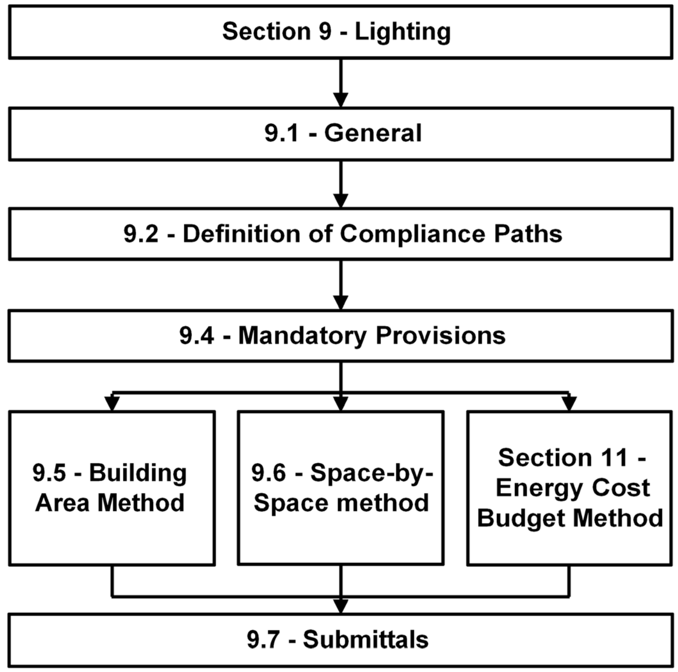
a. a single-line diagram of the building electrical distribution system and
b. floor plans indicating location and area served for all distribution.

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

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

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

8.8 Product Information (Not Used)



9. LIGHTING

9.1 General

9.1.1 Scope. This section shall apply to the following:

a. Interior spaces of buildings
b. Exterior building features, including façades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies
c. Exterior building grounds lighting provided through the building's electrical service

Exceptions:

1. Emergency lighting that is automatically off during normal building operation
2. Lighting within dwelling units
3. Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation
4. Decorative gas lighting systems

9.1.2 Lighting Alterations. For the alteration of any lighting system in an interior space, that space shall comply with the lighting power density (LPD) requirements of Section 9 applicable to that space and the automatic shutoff requirements of Section 9.4.1.1. For the alteration of any lighting system in an exterior building application, that lighting system shall comply with the lighting power density (LPD) requirements of Section 9 applicable to the area illuminated by that lighting system and the applicable control requirements of Sections 9.4.1.4(a) and 9.4.1.4(b). Such alterations shall include all luminaires that are added, replaced or removed. This requirement shall also be met for alterations that involve only the replacement of lamps plus ballasts. Alterations do not include routine maintenance or repair situations.

Exception: Alterations that involve less than 10% of the connected lighting load in a space or area need not comply with these requirements, provided that such alterations do not increase the installed LPD.

9.1.3 Installed Lighting Power. The luminaire wattage for all interior and exterior applications shall include all power used by the luminaires, including lamps, ballasts, transformers, and control devices, except as specifically exempted in Section 9.1.1, 9.2.2.3, or 9.4.2.

Exception: If two or more independently operating lighting systems in a space are capable of being controlled to prevent simultaneous user operation, the installed interior lighting power or the installed exterior lighting power shall be based solely on the lighting system with the highest wattage.

9.1.4 Interior and Exterior Luminaire Wattage. Luminaire wattage, when used to calculate either installed interior lighting power or installed exterior lighting power, shall be determined in accordance with the following criteria:

a. The wattage of line-voltage luminaires not containing permanently installed ballasts, transformers, or similar devices shall be the manufacturers' labeled maximum wattage of the luminaire.
b. The wattage of luminaires with permanently installed or remote ballasts, transformers, or similar devices shall be the operating input wattage of the maximum lamp/auxiliary combination based on values from the auxiliary manufacturers' literature or recognized testing laboratories or shall be the maximum labeled wattage of the luminaire.

Exception: Lighting power calculations for ballasts with adjustable ballast factors shall be based on the ballast factor that will be used in the space, provided that the ballast factor is not user changeable.

c. For line-voltage lighting track and plug-in busway designed to allow the addition and/or relocation of luminaires without altering the wiring of the system, the wattage shall be

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

d. The wattage of low-voltage lighting track, cable conductor, rail conductor, and other flexible lighting systems that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the specified wattage of the transformer supplying the system.

e. The wattage of all other miscellaneous lighting equipment shall be the specified wattage of the lighting equipment.

9.2 Compliance

9.2.1 Compliance Paths. Lighting systems and equipment shall comply with Section 9.1, "General"; Section 9.4, "Mandatory Provisions"; Section 9.7, "Submittals"; and the prescriptive requirements of either

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

9.2.2 Prescriptive Requirements

9.2.2.1 Building Area Method. This method for determining the interior lighting power allowance, described in Section 9.5, is a simplified approach for demonstrating compliance.

9.2.2.2 Space-by-Space Method. This method, described in Section 9.6, is an alternative approach that allows greater flexibility.

9.2.2.3 Interior Lighting Power. The interior lighting power allowance for a building or a separately metered or permitted portion of a building shall be determined by either the Building Area Method, described in Section 9.5, or the Space-by-Space Method, described in Section 9.6. Trade-offs of interior lighting power allowance among portions of the building for which a different method of calculation has been used are not permitted. The installed interior lighting power identified in accordance with Section 9.1.3 shall not exceed the interior lighting power allowance developed in accordance with Section 9.5 or 9.6.

Exceptions: The following lighting equipment and applications shall not be considered when determining the interior lighting power allowance developed in accordance with Section 9.5 or 9.6, nor shall the wattage for such lighting be included in the installed interior lighting power identified in accordance with Section 9.1.3. However, any such lighting shall not be exempt unless it is an addition to general lighting and is controlled by an independent control device.

1. Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments
2. Lighting that is integral to equipment or instrumentation and is installed by its manufacturer
3. Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical equipment
4. Lighting integral to both open and glass-enclosed refrigerator and freezer cases
5. Lighting integral to food warming and food preparation equipment
6. Lighting specifically designed for the life support of nonhuman life forms
7. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions
8. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark
9. Lighting that is an integral part of advertising or directional signage
10. Exit signs
11. Lighting that is for sale or lighting educational demonstration systems
12. Lighting for theatrical purposes, including performance, stage, and film and video production
13. Lighting for television broadcasting in sporting activity areas
14. Casino gaming areas
15. Furniture-mounted supplemental task lighting that is controlled by automatic shutoff and complies with Section 9.4.1.3(c)
16. Mirror lighting in dressing rooms and accent lighting in religious pulpit and choir areas
17. Parking garage transition lighting—lighting for covered vehicle entrances and exits from buildings and parking structures—that complies with Section 9.4.1.2(a) and 9.4.1.2(c); each transition zone shall not exceed a depth of 20 m inside the structure and a width of 15 m

9.3 (Not Used)

9.4 Mandatory Provisions

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

9.4.1.1 Interior Lighting Controls. For each space in the building, all of the lighting control functions indicated in Table 9.6.1, for the appropriate space type in column A, and as described below, shall be implemented. All control functions labeled with an "REQ" are mandatory and shall be implemented. If a space type has control functions labeled "ADD1" then at least one of those functions shall be implemented. If a space type has control functions labeled "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 for LPD requirements, the space type used for determining control requirements shall be the same space type used to determine the LPD.

a. *Local control:* There shall be one or more manual lighting controls in the space that controls all of the lighting in the space. Each control device shall control an area (1) no larger than $232 m^2$ if the space is ≤929 m^2 and (2) no larger than 929 m^2 otherwise. The device installed to comply with this provision shall be readily accessible and located so that the occupants can see the controlled lighting when using the control device.

Exception: Remote location of this local control device or devices shall be permitted for reasons of safety or security when each remote control device has an indicator pilot light as part of or next to the control device and the light is clearly labeled to identify the controlled lighting.

b. *Restricted to manual ON:* None of the lighting shall be automatically turned on.

Exception: Manual ON is not required where manual ON operation of the general lighting would endanger the safety or security of the room or building occupants.

c. *Restricted to partial automatic ON:* No more than 50% of the lighting power for the general lighting shall be allowed to be automatically turned on, and none of the remaining lighting shall be automatically turned on.

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

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 and secondary sidelighted areas is 300 W or greater, the general lighting in the primary sidelighted areas and secondary sidelighted areas shall be controlled by photocontrols.

The control system shall have the following characteristics:

1. The calibration adjustments shall be readily accessible.
2. At minimum, general lighting in the secondary sidelighted area shall be controlled independently of the general lighting in the primary sidelighted area.
3. The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.

Exceptions: The following areas are exempted from Section 9.4.1.1(e):

1. Primary sidelighted areas where the top of any existing adjacent structure is twice as high above the windows as its distance away from the windows
2. Sidelighted areas where the total glazing area is less than 1.9 m^2
3. Retail spaces

f. *Automatic daylight responsive controls for toplighting:* In any space where the combined input power for all general lighting completely or partially within daylight areas under skylights and daylight areas under roof monitors is 150 W or greater, general lighting in the daylight area shall be controlled by photocontrols having the following characteristics:

1. The calibration adjustments shall be readily accessible.
2. The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point that is between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.
3. General lighting in overlapping toplighted and sidelighted daylight areas shall be controlled together with general lighting in the daylight area under skylights or daylight areas under roof monitors.

Exceptions: The following areas are exempted from Section 9.4.1.1(f):

1. Daylight areas under skylights where it is documented that existing adjacent structures or natural objects block direct sunlight for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
2. Daylight areas where the skylight visual transmittance (VT) is less than 0.4
3. In each space within buildings in Climate Zone 8 where the input power of the general lighting within daylight areas is less than 200 W

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

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

1. The space has an LPD of no more than 8.6 W/m^2
2. The space is lighted by HID
3. The general lighting power in the space is automatically reduced by at least 30% within 20 minutes of all occupants leaving the space

h. *Automatic full OFF:* All lighting shall be automatically shut off within 20 minutes of all occupants leaving the space. A control device meeting this requirement shall control no more than 465 m^2.

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

1. General lighting and task lighting in shop and laboratory classrooms

2. General lighting and task lighting in spaces where automatic shutoff would endanger the safety or security of room or building occupants
3. Lighting required for 24/7 operation

i. *Scheduled shutoff:* All lighting in the space not exempted by Exception (1) to Section 9.1.1 shall be automatically shut off during periods when the space is scheduled to be unoccupied using either (1) a time-of-day operated control device that automatically turns the lighting off at specific programmed times or (2) a signal from another automatic control device or alarm/security system. The control device or system shall provide independent control sequences that (1) control the lighting for an area of no more than 2323 m^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 465 m^2.

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

1. Lighting in spaces where lighting is required for 24/7 continuous operation
2. Lighting in spaces where patient care is rendered
3. Lighting in spaces where automatic shutoff would endanger the safety or security of the room or building occupants

9.4.1.2 Parking Garage Lighting Control. Lighting for parking garages shall comply with the following requirements:

a. Parking garage lighting shall have automatic lighting shutoff per Section 9.4.1.1(i).
b. Lighting power of each luminaire shall be automatically reduced by a minimum of 30% when there is no activity detected within a lighting zone for 20 minutes. Lighting zones for this requirement shall be no larger than 334 m^2.

Exceptions: The following areas are exempt:

1. Daylight transitions zones and ramps without parking

c. Lighting for covered vehicle entrances and exits from buildings and parking structures shall be separately controlled by a device that automatically reduces the lighting by at least 50% from sunset to sunrise.
d. The power to luminaires within 1.9 m^2 of any perimeter wall structure that has a net opening-to-wall ratio of at least 40% and no exterior obstructions within 1.9 m^2, shall be automatically reduced in response to daylight.

Exceptions: Lighting in the following areas is exempt:

1. Lighting in daylight transitions zones and ramps without parking

9.4.1.3 Special Applications

a. The following lighting shall be separately controlled from the general lighting in all spaces:
   1. Display or accent lighting
   2. Lighting in display cases
   3. Nonvisual lighting, such as for plant growth or food warming
   4. Lighting equipment that is for sale or used for demonstrations in lighting education
b. Guestrooms
   1. All lighting and all switched receptacles in guestrooms and suites in hotels, motels, boarding houses, or similar buildings shall be automatically controlled such that the power to the lighting and switched receptacles in each enclosed space will be turned off within 20 minutes after all occupants leave that space.

   Exception: Enclosed spaces where the lighting and switched receptacles are controlled by captive key systems and bathrooms are exempt.

   2. Bathrooms shall have a separate control device installed to automatically turn off the bathroom lighting within 30 minutes after all occupants have left the bathroom.

   Exception: Night lighting of up to 5 W per bathroom is exempt.

c. All supplemental task lighting, including permanently installed undershelf or undercabinet lighting, shall be controlled from either (1) a control device integral to the luminaires or (2) by a wall-mounted control device that is readily accessible and located so that the occupant can see the controlled lighting.

9.4.1.4 Exterior Lighting Control. Lighting for exterior applications not exempted in Section 9.1 shall meet the following requirements:

a. Lighting shall be controlled by a device that automatically turns off the lighting when sufficient daylight is available.
b. All building façade and landscape lighting shall be automatically shut off between midnight or business closing, whichever is later, and 6 a.m. or business opening, whichever comes first, or between times established by the authority having jurisdiction.
c. Lighting not specified in Section 9.4.1.4(b) and lighting for signage shall be controlled by a device that automatically reduces the connected lighting power by at least 30% for at least one of the following conditions:
   1. From 12 midnight or within one (1) hour of the end of business operations, whichever is later, until 6 a.m. or business opening, whichever is earlier
   2. During any period when no activity has been detected for a time of no longer than 15 minutes

All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least ten hours.

Exceptions:

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

TABLE 9.4.2-1 Exterior Lighting Zones

Lighting Zone	Description
0	Undeveloped areas within national parks, state parks, forest land, rural areas, and other undeveloped areas as defined by the authority having jurisdiction
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas
4	High-activity commercial districts in major metropolitan areas as designated by the local jurisdiction

9.4.2 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 9.4.2-1 for the applicable lighting zone. The installed exterior lighting power identified in accordance with Section 9.1.3 shall not exceed the exterior lighting power allowance developed in accordance with this section. 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.

Exceptions:

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

9.4.3 Functional Testing. Lighting control devices and control systems shall be tested to ensure that control hardware and software are calibrated, adjusted, programmed, and in proper working condition in accordance with the construction documents and manufacturer's installation instructions. When occupant sensors, time switches, programmable schedule controls, or photosensors are installed, at a minimum, the following procedures shall be performed:

a. Occupant Sensors
    1. Certify that the sensor has been located and aimed in accordance with manufacturer recommendations.
    2. For projects with up to seven (7) occupancy sensors, all occupancy sensors shall be tested.
    3. For projects with more than seven (7) occupancy sensors, testing shall be done for each unique combination of sensor type and space geometry.
        (a) For each sensor to be tested, verify the following:
            (1) Status indicator (as applicable) operates correctly
            (2) Controlled lights turn off or down to the permitted level within the required time
            (3) For auto-on occupant sensors, the lights turn on to the permitted level when someone enters the space
            (4) For manual-on sensors, the lights turn on only when manually activated
            (5) The lights are not incorrectly turned on by movement in nearby areas or by HVAC operation

b. Automatic Time Switches
    1. Confirm that the automatic time-switch control is programmed with appropriate weekday, weekend, and holiday (as applicable) schedules.
    2. Document for the owner automatic time-switch programming, including weekday, weekend, and holiday schedules, as well as all setup and preference program settings.
    3. Verify that correct time and date are properly set in the time switch.
    4. Verify that any battery backup (as applicable) is installed and energized.

TABLE 9.4.2-2 Individual Lighting Power Allowances for Building Exteriors

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (base allowance may be used in tradable or non-tradable surfaces)					
	No base site in Zone 0	500 W	600 W	750 W	1300 W
Tradable Surfaces (LPDs for uncovered parking areas, building grounds, building entrances, exits and loading docks, canopies and overhangs, and outdoor sales areas may be traded.)					
Uncovered Parking Areas					
Parking areas and drives	No allowance	0.43 W/m^2	0.65 W/m^2	1.1 W/m^2	1.4 W/m^2
Building Grounds					
Walkways less than 3 m wide	No allowance	2.3 W/lin m	2.3 W/lin m	2.6 W/lin m	3.3 W/lin m
Walkways 3 m wide or greater Plaza areas Special feature areas	No allowance	1.5 W/m^2	1.5 W/m^2	1.7 W/m^2	2.2 W/m^2
Stairways	No allowance	8.1 W/m^2	10.8 W/m^2	10.8 W/m^2	10.8 W/m^2
Pedestrian tunnels	No allowance	1.6 W/m^2	1.6 W/m^2	2.2 W/m^2	3.2 W/m^2
Landscaping	No allowance	0.43 W/m^2	0.54 W/m^2	0.54 W/m^2	0.54 W/m^2
Building Entrances, Exits, and Loading Docks					
Main entries	No allowance	66 W/lin m of door width	66 W/lin m of door width	98 W/lin m of door width	98 W/lin m of door width
Other doors	No allowance	66 W/lin m of door width	66 W/lin m of door width	66 W/lin m of door width	66 W/lin m of door width
Entry canopies	No allowance	2.7 W/m^2	2.7 W/m^2	4.3 W/m^2	4.3 W/m^2
Loading docks	No allowance	5.4 W/m^2	5.4 W/m^2	5.4 W/m^2	5.4 W/m^2
Sales Canopies					
Free standing and attached	No allowance	6.5 W/m^2	6.5 W/m^2	8.6 W/m^2	10.8 W/m^2
Outdoor Sales					
Open areas (including vehicle sales lots)	No allowance	2.7 W/m^2	2.7 W/m^2	5.4 W/m^2	7.5 W/m^2
Street frontage for vehicle sales lots in addition to “open area” allowance	No allowance	No allowance	33 W/lin m	33 W/lin m	98 W/lin m
Nontradable Surfaces (LPD calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “Tradable Surfaces” section of this table.)					
Building facades	No allowance	No allowance	1.1 W/m^2 for each illuminated wall or surface or66 W/lin m for each illuminated wall or surface length	1.6 W/m^2 for each illuminated wall or surface or12.3 W/lin m for each illuminated wall or surface length	2.2 W/m^2 for each illuminated wall or surface or16.4 W/lin m for each illuminated wall or surface length
Automated teller machines and night depositories	No allowance	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location

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

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Entrances and gatehouse inspection stations at guarded facilities	No allowance	8.1 W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 8.1 W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 8.1 W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 8.1 W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles	No allowance	5.4 W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 5.4 W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 5.4 W/m^{2}of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 5.4 W/m^{2}of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Drive-through windows/ doors	No allowance	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
Parking near 24-hour retail entrances	No allowance	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry
Roadway/parking entry, trail head, and toilet facility, or other locations approved by the authority having jurisdiction.	A single luminaire of 60 W or less may be installed for each roadway/ parking entry, trail head, and toilet facility, or other locations approved by the authority having jurisdiction	No allowance	No allowance	No allowance	No allowance

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, field-calibrated, and set for appropriate setpoints and threshold light levels.
2. Daylight controlled lighting loads adjust to appropriate light levels in response to available daylight.
3. The location where calibration adjustments are made is readily accessible only to authorized personnel.

The individual(s) responsible for the functional testing shall not be directly involved in either the design or construction of the project and shall provide documentation certifying that the installed lighting controls meet or exceed all documented performance criteria.

9.5 Building Area Method Compliance Path

9.5.1 Building Area Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the Building Area Method:

a. Determine the appropriate building area type from Table 9.5.1 and the allowed LPD (watts per unit area) from the "Building Area Method" column. For building area types not listed, selection of a reasonably equivalent type shall be permitted.
b. Determine the gross lighted floor area (square metres) of the building area type.
c. Multiply the gross lighted floor areas of the building area type(s) times the LPD.
d. The interior lighting power allowance for the building is the sum of the lighting power allowances of all building area types. Trade-offs among building area types are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance.

9.6 Alternative Compliance Path: Space-by-Space Method

9.6.1 Space-by-Space Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the Space-by-Space Method:

a. For each space enclosed by partitions that are 80% of the ceiling height or taller, determine the appropriate space type from Table 9.6.1. If a space has multiple functions, where more than one space type is applicable, that space shall be broken up into smaller subspaces, each using its own space type from Table 9.6.1. Any of these subspaces that are smaller in floor area than 20% of the original space and less than 300 m^2 need not be broken out separately. Include the floor area of balconies and other projections in this calculation.
b. In calculating the area of each space and subspace, the limits of the area are defined by the centerline of interior walls, the dividing line between subspaces, and the outside surface of exterior walls.
c. Based on the space type selected for each space or subspace, determine the lighting power allowance of each space or subspace by multiplying the calculated area of the space or subspace by the appropriate LPD determined in Section 9.6.1(a). For space types not listed, selection of a reasonable equivalent category shall be permitted.
d. The interior lighting power allowance is the sum of lighting power allowances of all spaces and subspaces. 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 automatically controlled, separately from the general lighting, to be turned off during nonbusiness hours. This additional power shall be used only for the specified luminaires and shall not be used for any other purpose unless otherwise indicated.

An increase in the interior lighting power allowance is permitted in the following cases:

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	LPD, W/m^2
Automotive facility	8.6
Convention center	10.9
Courthouse	10.9
Dining: Bar lounge/leisure	10.7
Dining: Cafeteria/fast food	10.9
Dining: Family	10.2
Dormitory	6.1
Exercise center	9.0
Fire station	7.2
Gymnasium	10.1
Health-care clinic	9.7
Hospital	11.3
Hotel/Motel	9.4
Library	12.8
Manufacturing facility	12.6
Motion picture theater	8.2
Multifamily	5.5
Museum	11.0
Office	8.8
Parking garage	2.3
Penitentiary	8.7
Performing arts theater	15.0
Police station	9.4
Post office	9.4
Religious building	10.8
Retail	13.6
School/university	9.4
Sports arena	9.8
Town hall	9.6
Transportation	7.5
Warehouse	7.1
Workshop	12.8

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.

a. For spaces in which lighting is specified to be installed in addition to the general lighting for the purpose of decorative appearance or for highlighting art or exhibits, provided that the additional lighting power shall not exceed 10.8 W/m^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:

$$\text{Additional Interior Lighting Power Allowance} = 1000\text{ W} + (\text{Retail Area }1 \times 6.5\text{ W/m}^2)$$

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

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/m²	RCR Threshold	a: Local Control (See Section 9.4.1.1[a])	b: Restricted to Manual ON (See Section 9.4.1.1[b])	c: Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	d: Bilevel Lighting Control (See Section 9.4.1.1[d])	e: Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	f: Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	g: Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	h: Automatic Full OFF (See Section 9.4.1.1[h])	i: Scheduled Shutoff (See Section 9.4.1.1[i])
Atrium											
… that is <6.1 m in height	1.1/m total height	NA	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… that is ≥6.1 m and ≤12.2 m in height	1.1/m total height	NA	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… that is >12.2 m in height	4.3 + 0.7/m total height	NA	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Audience Seating Area											
... in an auditorium	6.8	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a convention center	8.9	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a gymnasium	7.1	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a motion picture theater	12.3	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a penitentiary	3.1	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
... in a performing arts theater	26.2	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a religious building	16.5	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a sports arena	4.7	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… all other audience seating areas	4.7	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Banking Activity Area	11.9	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Breakroom (See Lounge/Breakroom)											
Classroom/Lecture Hall/Training Room											
… in a penitentiary	14.5	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… all other classrooms/lecture halls/ training rooms	13.4	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 2.4 m 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 5.7 W/m^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m^2. The additional 5.7 W/m^2 allowance shall not be used for any other purpose.

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

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/m²	RCR Threshold	Local Control (See Section 9.4.1.1[a])	Restricted to Manual ON (See Section 9.4.1.1[b])	Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	Bilevel Lighting Control (See Section 9.4.1.1[d])	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	Automatic Full OFF (See Section 9.4.1.1[h])	Scheduled Shutoff (See Section 9.4.1.1[i])
			a	b	c	d	e	f	g	h	i
Conference/Meeting/Multipurpose Room	13.3	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Confinement Cells	8.8	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Copy/Print Room	7.8	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Corridor[2]											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	9.9	width <2.4 m	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… in a hospital	10.7	width <2.4 m	REQ	—	—	—	REQ	REQ	ADD2	ADD2	ADD2
… in a manufacturing facility	4.4	width <2.4 m	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… all other corridors	7.1	width <2.4 m	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
Courtroom	18.6	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Computer Room	18.4	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Dining Area											
… in a penitentiary	10.4	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a facility for the visually impaired (and not used primarily by the staff)[3]	28.5 W/m²	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in bar/lounge or leisure dining	11.6	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in cafeteria or fast food dining	7.0	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in family dining	9.6	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… all other dining areas	7.0	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 2.4 m 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 5.7 W/m² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m². The additional 5.7 W/m² allowance shall not be used for any other purpose.

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

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/m^2	RCR Threshold	Local Control (See Section 9.4.1.1[a]) a	Restricted to Manual ON (See Section 9.4.1.1[b]) b	Restricted to Partial Automatic ON (See Section 9.4.1.1[c]) c	Bilevel Lighting Control (See Section 9.4.1.1[d]) d	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6]) e	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6]) f	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies]) g	Automatic Full OFF (See Section 9.4.1.1[h]) h	Scheduled Shutoff (See Section 9.4.1.1[i]) i
Electrical/Mechanical Room[7]	4.6	6	REQ	—	—	—	REQ	REQ	—	—	—
Emergency Vehicle Garage	6.1	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Food Preparation Area	13.1	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Guest Room	9.8	6	See Section 9.4.1.3b.								
Laboratory											
… in or as a classroom	15.5	6	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
… all other laboratories	19.5	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Laundry/Washing Area	6.5	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Loading Dock, Interior	5.1	6	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Lobby											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	19.4	4	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… for an elevator	7.0	6	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… in a hotel	11.5	4	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… in a motion picture theater	6.4	4	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… in a performing arts theater	21.6	6	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… all other lobbies	9.7	4	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
Locker Room	8.1	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Lounge/Breakroom											
… in a healthcare facility	10.0	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… all other lounges/breakrooms	7.9	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 2.4 m 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 5.7 W/m^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m^2. The additional 5.7 W/m^2 allowance shall not be used for any other purpose.

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

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**			**The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.**								
			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/m²**	**RCR Threshold**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
Office											
… enclosed and ≤23.2 m²	12.0	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… enclosed and >23.2 m²	12.0	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… open plan	10.6	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Parking Area, Interior	2.1	4	See Section 9.4.1.2.								
Pharmacy Area	18.1	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Restroom											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	13.1	8	REQ	—	—	—	REQ	REQ	—	REQ	—
… all other restrooms	10.6	8	REQ	—	—	—	REQ	REQ	—	REQ	—
Sales Area[4]	15.5	6	REQ	ADD1	ADD1	REQ	—	REQ	—	ADD2	ADD2
Seating Area, General	5.9	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	7.4	10	REQ	—	—	REQ	REQ	REQ	REQ	ADD2	ADD2
Storage Room											
… <4.6 m²	6.8	6	REQ	—	—	—	—	—	—	ADD2	ADD2
… ≥4.6 m² and ≤ 305 m²	6.8	6	REQ	ADD1	ADD1	—	REQ	REQ	—	REQ	—
… all other storage rooms	6.8	6	REQ	ADD1	ADD1	—	REQ	REQ	REQ	ADD2	ADD2
Vehicular Maintenance Area	7.3	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Workshop	17.2	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 2.4 m 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 5.7 W/m² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m². The additional 5.7 W/m² allowance shall not be used for any other purpose.

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

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Building Type Specific/Space Types[1]	LPD, W/m^2	RCR Threshold	a: Local Control (See Section 9.4.1.1[a])	b: Restricted to Manual ON (See Section 9.4.1.1[b])	c: Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	d: Bilevel Lighting Control (See Section 9.4.1.1[d])	e: Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6])	f: Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6])	g: Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	h: Automatic Full OFF (See Section 9.4.1.1[h])	i: Scheduled Shutoff (See Section 9.4.1.1[i])
Facility for the Visually Impaired[3]											
… in a chapel (used primarily by residents)	23.8	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a recreation room/common living room (and not used primarily by staff)	26.0	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Automotive (See "Vehicular Maintenance Area")											
Convention Center—Exhibit Space	15.7	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Dormitory—Living Quarters	4.2	8	REQ	—	—	—	—	—	—	—	—
Fire Station—Sleeping Quarters	2.4	6	REQ	—	—	—	—	—	—	—	—
Gymnasium/Fitness Center											
… in an exercise area	7.8	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a playing area	13.0	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Healthcare Facility											
… in an exam/treatment room	18.0	8	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in an imaging room	16.3	6	REQ	—	—	REQ	—	—	—	ADD2	ADD2
….in a medical supply room	8.0	6	(See "Storage Room" under "Common Space Types" for control requirements)								
… in a nursery	9.5	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in a nurse's station	7.6	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 2.4 m 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 5.7 W/m^2 shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m^2. The additional 5.7 W/m^2 allowance shall not be used for any other purpose.

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

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

			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/m²**	**RCR Threshold**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
… in an operating room	26.8	6	REQ	—	—	REQ	—	—	—	ADD2	ADD2
… in a patient room	6.7	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in a physical therapy room	9.9	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
… in a recovery room	12.4	6	REQ	—	—	REQ	REQ	REQ	—	ADD2	ADD2
Library											
… in a reading area	11.5	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in the stacks	18.4	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Manufacturing Facility											
… in a detailed manufacturing area	13.9	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in an equipment room	8.0	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in an extra high bay area (15.2 m floor-to-ceiling height)	11.3	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a high bay area (7.6–15.2 m floor-to-ceiling height)	13.3	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a low bay area (< 7.6 m floor-to-ceiling height)	12.9	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Museum											
… in a general exhibition area	11.4	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a restoration room	11.0	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Performing Arts Theater—Dressing Room	6.6	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 2.4 m 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 5.7 W/m² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m². The additional 5.7 W/m² allowance shall not be used for any other purpose.

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

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The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

			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/m²**	**RCR Threshold**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
Post Office—Sorting Area	10.2	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
Religious Buildings											
… in a fellowship hall	6.9	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a worship/pulpit/choir area	16.5	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Retail Facilities											
… in a dressing/fitting room	7.7	8	REQ	ADD1	ADD1	REQ		REQ	—	REQ	—
… in a mall concourse	11.9	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Sports Arena—Playing Area											
… for a Class I facility	39.7	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… for a Class II facility	25.9	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… for a Class III facility	19.4	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… for a Class IV facility	13.0	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Transportation Facility											
… in a baggage/carousel area	5.7	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… in an airport concourse	3.9	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… at a terminal ticket counter	8.7	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Warehouse—Storage Area											
…for medium to bulky, palletized items	6.2	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	ADD2	ADD2
… for smaller, hand-carried items[5]	10.2	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 2.4 m 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 5.7 W/m² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 4.5 W/m². The additional 5.7 W/m² allowance shall not be used for any other purpose.

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
Automatic continuous daylight dimming in secondary sidelighted areas	0.10[c]	0.10[c]	0.10[c]	0.10[c]	0.10[c]

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 (b), 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.

c. Control factors may not be used if controls are used to satisfy exceptions to Section 5.5.4.2.3

$$+ (\text{Retail Area } 2 \times 6.5 \text{ W/m}^2)$$
$$+ (\text{Retail Area } 3 \times 15 \text{ W/m}^2)$$
$$+ (\text{Retail Area } 4 \times 27 \text{ W/m}^2),$$

where

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

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

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

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

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

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 is allowed for individual spaces where room cavity ratio (RCR) calculated for the empty room is documented to be greater than the RCR threshold for that space type shown in Table 9.6.1.

$$RCR = 2.5 \times \text{Room Cavity Height} \times \text{room perimeter length} / \text{room area}$$

where

Room Cavity Height = Luminaire mounting height – Workplane

For corridor/transition spaces, this adjustment is allowed when the corridor is less than 2.4 m wide, regardless of the RCR.

The LPD allowance for these spaces may be increased by the following amount:

$$\text{LPD increase} = \text{Base Space LPD} \times 0.20$$

where

Base space LPD = the applicable LPD from Table 9.6.1.

9.7 Submittals

9.7.1 General. Where required by the authority having jurisdiction, the submittal of compliance documentation and supplemental information shall be in accordance with Section 4.2.2.

9.7.2 Completion requirements. The following requirements are mandatory provisions and are necessary for compliance with this standard.

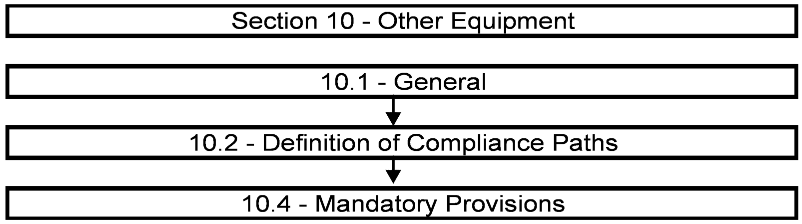
9.7.2.1 Drawings. Construction documents shall require that within 90 days after the date of system acceptance, record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include, as a minimum, the location, luminaire identifier, control, and circuiting for each piece of lighting equipment.

9.7.2.2 Manuals. Construction documents shall require for all lighting equipment and lighting controls, an operating and maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of system acceptance. These manuals shall include, at a minimum, the following:

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

9.7.2.3 Daylighting Documentation. The design documents shall identify all luminaires for general lighting that are located within daylight areas under skylights, daylight areas under roof monitors as well as primary sidelighted areas and secondary sidelighted areas.

9.8 Product Information (Not Used)



10. OTHER EQUIPMENT

10.1 General

10.1.1 Scope. This section applies only to the equipment described below.

10.1.1.1 New Buildings. Other equipment installed in new buildings shall comply with the requirements of this section.

10.1.1.2 Additions to Existing Buildings. Other equipment installed in additions to existing buildings shall comply with the requirements of this section.

10.1.1.3 Alterations to Existing Buildings

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

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

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

10.2 Compliance Paths

10.2.1 Compliance. Compliance with Section 10 shall be achieved by meeting all requirements of Section 10.1, "General"; Section 10.4, "Mandatory Provisions"; and Section 10.8, "Product Information."

10.2.2 Projects using the Energy Cost Budget Method (Section 11 of this standard) must comply with Section 10.4, the mandatory provisions of this section, as a portion of that compliance path.

10.3 Simplified/Small Building Option (Not Used)

10.4 Mandatory Provisions

10.4.1 Electric Motors. Electric motors manufactured alone or as a component of another piece of equipment with a power rating of 0.75 kW or more, and less than or equal to 150 kW, shall comply with the requirements of the Energy Independence and Security Act of 2007, as shown in Table 10.8-1 for general purpose electric motors (subtype I) and Table 10.8-2 for general purpose electric motors (subtype II).

General purpose electric motors with a power rating of more than 149.2 kW, but no more than 373 kW, shall have a minimum nominal full-load efficiency that is not less than as shown in Table 10.8-3.

Fire-pump electric motors shall have a minimum nominal full-load efficiency that is not less than that shown in Table 10.8-6.

Motors that are not included in the scope of the Energy Independence and Security Act of 2007, Section 313, have no performance requirements in this section.

10.4.2 Service Water Pressure Booster Systems. Service water pressure booster systems shall be designed such that

a. one or more pressure sensors shall be used to vary pump speed and/or start and stop pumps. The sensor(s) shall either be located near the critical fixture(s) that determine the pressure required, or logic shall be employed that adjusts the setpoint to simulate operation of remote sensor(s).
b. no device(s) shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster system pump or booster system, except for safety devices.
c. no booster system pumps shall operate when there is no service water flow.

10.4.3 Elevators. Elevator systems shall comply with the requirements of this section.

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

10.4.3.2 Ventilation Power Limitation. Cab ventilation fans for elevators without air conditioning shall not consume over 0.7 W·s/L at maximum speed.

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

10.4.4 Escalators and Moving Walks. Escalators and moving walks shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 or applicable local code when not conveying passengers.

10.4.5 Whole-Building Energy Monitoring. Measurement devices shall be installed at the building site to monitor the energy use of each new building.

10.4.5.1 Monitoring. Measurement devices shall be installed to monitor the building use of the following types of energy supplied by a utility, energy provider, or plant that is not within the building:

a. Natural gas
b. Fuel oil
c. Propane
d. Steam
e. Chilled water
f. Hot water

10.4.5.2 Recording and Reporting. The energy use of each building on the building site shall be recorded at a minimum of every 60 minutes and reported at least hourly, daily, monthly, and annually. The system shall be capable of maintaining all data collected for a minimum of 36 months and creating user reports showing at least hourly, daily, monthly, and annual energy consumption and demand.

Exceptions to 10.4.5.1 and 10.4.5.2:

1. Buildings or additions less than 2322 m^2
2. Individual tenant spaces less than 929 m^2
3. Dwelling units
4. Residential buildings with less than 929 m^2 of common area
5. Fuel used for on-site emergency equipment

10.5 Prescriptive Compliance Path (Not Used)

10.6 Alternative Compliance Path (Not Used)

10.7 Submittals (Not Used)

10.8 Product Information

TABLE 10.8-1 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype I), Except Fire-Pump Electric Motors[a]

Full-Load Efficiency, %						
	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Kilowatts						
0.8	77.0	85.5	82.5	77.0	85.5	82.5
1.1	84.0	86.5	86.5	84.0	86.5	87.5
1.5	85.5	86.5	87.5	85.5	86.5	88.5
2.2	85.5	89.5	88.5	86.5	89.5	89.5
3.7	86.5	89.5	89.5	88.5	89.5	89.5
5.6	88.5	91.0	90.2	89.5	91.7	91.0
7.5	89.5	91.7	91.7	90.2	91.7	91.0
11.1	90.2	93.0	91.7	91.0	92.4	91.7
14.9	91.0	93.0	92.4	91.0	93.0	91.7
18.7	91.7	93.6	93.0	91.7	93.6	93.0
22.4	91.7	94.1	93.6	91.7	93.6	93.0
29.8	92.4	94.1	94.1	92.4	94.1	94.1
37.3	93.0	94.5	94.1	93.0	94.5	94.1
44.8	93.6	95.0	94.5	93.6	95.0	94.5
56.0	93.6	95.0	94.5	93.6	95.4	94.5
74.6	93.6	95.4	95.0	94.1	95.4	95.0
93.3	94.1	95.4	95.0	95.0	95.4	95.0
111.9	94.1	95.8	95.4	95.0	95.8	95.8
149.2	95.0	95.8	95.4	95.4	96.2	95.8

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.

TABLE 10.8-2 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype II), Except Fire-Pump Electric Motors[a]

Full-Load Efficiency, %								
	Open Drip-Proof Motors				Totally Enclosed Fan-Cooled Motors			
Number of Poles ⇒	**2**	**4**	**6**	**8**	**2**	**4**	**6**	**8**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**900**	**3600**	**1800**	**1200**	**900**
Motor Kilowatts								
0.8	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.1	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
1.5	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
2.2	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
3.7	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
5.6	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
7.5	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
11.1	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
14.9	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
18.7	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
22.4	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
29.8	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
37.3	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
44.8	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
56.0	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
74.6	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
93.3	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
111.9	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
149.2	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement

TABLE 10.8-3 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype I and II), Except Fire-Pump Electric Motors[a]

Full-Load Efficiency, %								
	Open Drip-Proof Motors				Totally Enclosed Fan-Cooled Motors			
Number of Poles ⇒	**2**	**4**	**6**	**8**	**2**	**4**	**6**	**8**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**900**	**3600**	**1800**	**1200**	**900**
Motor Size (kW)								
186	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
224	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
261	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
298	95.4	95.4	NR	NR	95.4	95.4	NR	NR
336	95.8	95.8	NR	NR	95.4	95.4	NR	NR
373	95.8	95.8	NR	NR	95.4	95.8	NR	NR

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement

TABLE 10.8-4 Minimum Average Full-Load Efficiency for Polyphase Small Electric Motors[a]

Full-Load Efficiency for Motors Manufactured on or after March 9, 2015, %			
		Open Motors	
Number of Poles ⇒	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**
Motor Size (kW)			
0.19	65.6	69.5	67.5
0.25	69.5	73.4	71.4
0.37	73.4	78.2	75.3
0.56	76.8	81.1	81.7
0.75	77.0	83.5	82.5
1.1	84.0	86.5	83.8
1.5	85.5	86.5	N/A
2.2	85.5	86.9	N/A

a. Average full-load efficiencies shall be established in accordance with 10 CFR 431.

TABLE 10.8-5 Minimum Average Full-Load Efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run Small Electric Motors[a]

Full-Load Efficiency for Motors Manufactured on or after March 9, 2015, %			
		Open Motors	
Number of Poles ⇒	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**
Motor Size (kW)			
0.19	66.6	68.5	62.2
0.25	70.5	72.4	66.6
0.37	72.4	76.2	76.2
0.56	76.2	81.8	80.2
0.75	80.4	82.6	81.1
1.1	81.5	83.8	N/A
1.5	82.9	84.5	N/A
2.2	84.1	N/A	N/A

a. Average full-load efficiencies shall be established in accordance with 10 CFR 431.

TABLE 10.8-6 Minimum Nominal Full-Load Efficiency of 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 (kW)								
0.75	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.1	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
1.5	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
2.2	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
3.7	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
5.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
7.5	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
11	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
15	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
18.5	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
22	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
30	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
37	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
45	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
55	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
75	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
90	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
110	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
150	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
186	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
224	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
261	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
298	95.4	95.4	NR	NR	95.4	95.4	NR	NR
336	95.8	95.8	NR	NR	95.4	95.4	NR	NR

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement

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. Compliance with Section 11 will be achieved if

a. all requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met;
b. the design energy cost, as calculated in Section 11.5, does not exceed the energy cost budget as calculated by the simulation program described in Section 11.4; and
c. the energy efficiency level of components specified in the building design meet or exceed the efficiency levels used to calculate the design energy cost.

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 (a program such as, but not limited to, DOE-2 or BLAST). The simulation program shall include calculation methodologies for the building components being modeled.

Note to Adopting Authority: ASHRAE Standing Standard Project Committee 90.1 recommends that a compliance shell implementing the rules of a compliance supplement that controls inputs to and reports outputs from the required computer analysis program 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. A minimum of 1400 hours per year
b. Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays
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 cooling equipment
g. Air-side and water-side economizers with integrated control
h. The budget building design characteristics specified in Section 11.4.5

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 engine.

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 Standard 140, except Sections 7 and 8, and the results shall be furnished by the software provider.

11.4.2 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 city 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. Such 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, generated by systems included on the building permit, that is used directly by the building shall be subtracted from the proposed design energy consumption prior to calculating the design energy cost. 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.

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. Where no simulation program is available that adequately models a design, material, or device, the authority having jurisdiction may approve an exceptional calculation method to be used to demonstrate compliance with Section 11. Applications for approval of an exceptional method to include theoretical and empirical information verifying the method's accuracy shall include documentation to demonstrate that the exceptional calculation method and results

a. make no change in any input parameter values specified by this standard and the adopting authority,
b. provide input and output documentation that facilitates the enforcement agency's review and meets the formatting and content required by the adopting authority, and
c. are supported with instructions for using the method to demonstrate that the energy cost budget and design energy cost required by Section 11 are met.

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.

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. Components and parameters not listed in Figure 11.5.2 and Table 11.5.2-1 or otherwise specifically addressed in this subsection shall be identical to those in the proposed building design.

Exception: 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. All HVAC and service water heating equipment in the budget building 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. 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, 9, 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 a full- and part-load efficiency rating is provided in Tables 6.8.1-1 though 6.8.1-4, the full-load equation below shall be used:

$$COP_{nfcooling} = 9.13E\text{-}4 \times COP_C \times Q + 1.15 \times COP_C$$

$$COP_{nfcooling} = -0.0885 \times SCOP_C^2 + 1.295 \times SCOP_C$$
(applies to cooling efficiency only)

$$COP_{nfheating} = 5.05E\text{-}4 \times COP_{H8.3} \times Q + 1.062 \times COP_{H8.3}$$
(applies to heat-pump heating efficiency only)

$$COP_{nfheating} = -0.3446 \times SCOP_H^2 + 2.434 \times SCOP_H$$

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 kW.

COP_C, $SCOP_C$, $SCOP_{H8.3}$, and $SCOP_H$ 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 rates shall be the same for both the budget building design and proposed building design. Exhaust air heat recovery shall be modeled for the budget building design in accordance with Section 6.5.6.1.
e. Budget building systems as listed in Table 11.5.2-1 shall have outdoor air economizers or water economizers, the same as in the proposed building, in accordance with Section 6.5.1. The high-limit shutoff shall be in accordance with Table 11.5.2-4.
f. If the proposed building 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. System design supply air rates for the budget building design shall be based on a supply-air-to-room-air temperature difference of 11°C. If return or relief fans are specified in the proposed building design, the budget building design shall also be modeled with the same fan type 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.
h. Fan system efficiency (input kW per L/s of supply air including the effect of belt losses but excluding motor and motor drive losses) shall be the same as the proposed building 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 input kW until the limit is met. Fan electrical power shall then be determined by adjusting the calculated fan kW by the minimum motor efficiency prescribed by Section 10.4.1 for the appropriate motor size for each fan.

TABLE 11.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

No.	Proposed Building 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 building 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.	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 building design.
b.	All conditioned spaces in the proposed building design shall be simulated as being both heated and cooled, even if no cooling or heating system is being installed. Temperature and humidity control setpoints and schedules, as well as temperature control throttling range, shall be the same for proposed and baseline building designs.	
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 building 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.	
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:	Same as proposed building design
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 setpoints 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.	
3. Space Use Classification		
	The building 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-type or space-type categories but shall not combine the two types of categories within a single permit application. More than one building-type category may be used for a building if it is a mixed-use facility.	Same as proposed building 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 building type as determined by the designer and approved by the authority having jurisdiction. Required schedules shall be identical for the proposed building design and budget building design.	Same as proposed building design

TABLE 11.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

<table>
<tr><th>No.</th><th>Proposed Building Design (Column A)
Design Energy Cost (DEC)</th><th>Budget Building Design (Column B)
Energy Cost Budget (ECB)</th></tr>
<tr><td colspan="3">5. Building Envelope</td></tr>
<tr><td></td><td>All components of the building envelope in the proposed building design shall be modeled as shown on architectural drawings or as installed for existing building envelopes.
Exceptions: The following building elements are permitted to differ from architectural drawings.
1. Any envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described. If not separately described, the area of an 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 no more than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.
3. The exterior roof surface shall be modeled using the aged solar reflectance and thermal emittance determined in accordance with Section 5.5.3.1.1(a). Where aged test data is 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.</td><td>The budget building design shall have identical conditioned floor area and identical exterior dimensions and orientations as the proposed building 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 building 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 exterior wall or roof. If the fenestration area for new buildings or additions exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. If the vertical fenestration area facing west or east of the proposed building 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 5.5-1 through 5.5-8 for the appropriate climate, and the SHGC shall be equal to the criteria from Tables 5.5-1 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 envelope alterations shall reflect the limitations on area, U-factor, and SHGC as described in Section 5.1.3.
Exception: When trade-offs are made between an addition and an existing building, as described in the exception to Section 4.2.1.2, the 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.</td></tr>
</table>

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
6. Lighting		
	Lighting power in the proposed building design shall be determined as follows: a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model. b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building 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). e. The lighting schedules in the proposed building design shall reflect the mandatory automatic lighting control requirements in Section 9.4.1 (e.g., programmable controls or occupancy sensors). **Exception:** Automatic daylighting controls required by Section 9.4.1 shall be modeled directly in the proposed building design or through schedule adjustments determined by a separate daylighting analysis approved by the rating authority. f. Automatic lighting controls included in the proposed building design but not required by Section 9.4.1 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. As an alternative to modeling such lighting controls, the proposed building design lighting power density may be reduced by the sum of all additional allowances per Section 9.6.3 and Table 9.6.3, which are calculated individually as the lighting power under control multiplied by CF, where "CF" is the appropriate control factor given in Table 9.6.3 corresponding to the space type and the lighting controls designed to be used.	a. Lighting power in the budget building design shall be determined using the same categorization procedure (building area method or space-by-space method) and categories as the proposed building 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. b. Power for fixtures not included in the LPD calculation shall be modeled identically in the proposed building design and budget building design. c. Mandatory automatic lighting controls required by Section 9.4.1 shall be modeled the same as the proposed building 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 all of the following conditions are met: 1. The space-use classification is the same throughout the thermal block. 2. All HVAC zones in the thermal block that are adjacent to glazed exterior walls face the same orientation or their orientations are within 45 degrees of each other. 3. All of the zones are served by the same HVAC system or by the same kind of HVAC system.	Same as proposed building design

TABLE 11.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
8. Thermal Blocks—HVAC Zones Not Designed		
	Where the HVAC zones and systems have not yet been designed, thermal blocks shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following: a. Separate thermal blocks shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 15 ft from an exterior wall. Perimeter spaces shall be those located closer than 15 ft from an exterior wall. b. Separate thermal blocks shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except that orientations that differ by no more 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 building design
9. Thermal Blocks—Multifamily Residential Buildings		
	Residential spaces shall be modeled using one thermal block per space except that those 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 building design
10. HVAC Systems		
	The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed building 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 building. The proposed building 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 specified, the heating system shall be modeled as fossil fuel. The system characteristics shall be identical to the system modeled in the budget building design. d. Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air-cooled single-zone system, one unit per thermal block. The system characteristics shall be identical to the system modeled in the budget building design.	The HVAC system type and related performance parameters for the budget building design shall be determined from Figure 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)*

<table>
<tr><th>No.</th><th>Proposed Building Design (Column A)
Design Energy Cost (DEC)</th><th>Budget Building Design (Column B)
Energy Cost Budget (ECB)</th></tr>
<tr><td colspan="3">11. Service Hot-Water Systems</td></tr>
<tr><td colspan="2">The service hot-water system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed building design shall be determined as follows:
a. Where a complete service hot-water system exists, the model shall reflect the actual system type using actual component capacities and efficiencies.
b. Where a service hot-water system has been designed, the service hot-water model shall be consistent with design documents.
c. Where no service hot-water system exists or is specified, no service hot-water heating shall be modeled.</td><td>The service hot-water system type in the budget building design shall be identical to the proposed building design. The service hot-water system performance of the budget building design shall meet the requirements of Table 7.8.
Exceptions:
1. If the service hot water system type is not listed in Table 7.8, it shall be identical to the proposed building design.
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 or budget building design.</td></tr>
<tr><td colspan="3">12. Miscellaneous Loads</td></tr>
<tr><td colspan="2">Receptacle, motor, and process loads shall be modeled and estimated based on the building 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 Sections 13 and 14 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, refrigeration equipment, and cooking equipment.</td><td>Receptacle, motor, and process loads shall be modeled and estimated based on the building 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 Sections 13 and 14 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, refrigeration equipment, and cooking equipment.</td></tr>
</table>

TABLE 11.5.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(Continued)*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
13.	**Modeling Exceptions**	
	All elements of the proposed building design envelope, HVAC, service water heating, lighting, and electrical systems shall be modeled in the proposed building design in accordance with the requirements of Sections 1 through 12 of Table 11.5.1. **Exceptions:** Components and systems in the proposed building design may be excluded from the simulation model provided that 1. component energy usage does not affect the energy usage 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
14.	**Modeling Limitations to the Simulation Program**	
	If the simulation program cannot model a component or system included in the proposed building design, one of the following methods shall be used with the approval of the authority having jurisdiction: a. Ignore the component if the energy impact on the trade-offs being considered is not significant. b. Model the component substituting a thermodynamically similar component model. c. Model the HVAC system components or systems using the budget building design's HVAC system in accordance with Section 10 of Table 11.5.1. Whichever method is selected, the component shall be modeled identically for both the proposed building design and budget building design models.	Same as proposed building design

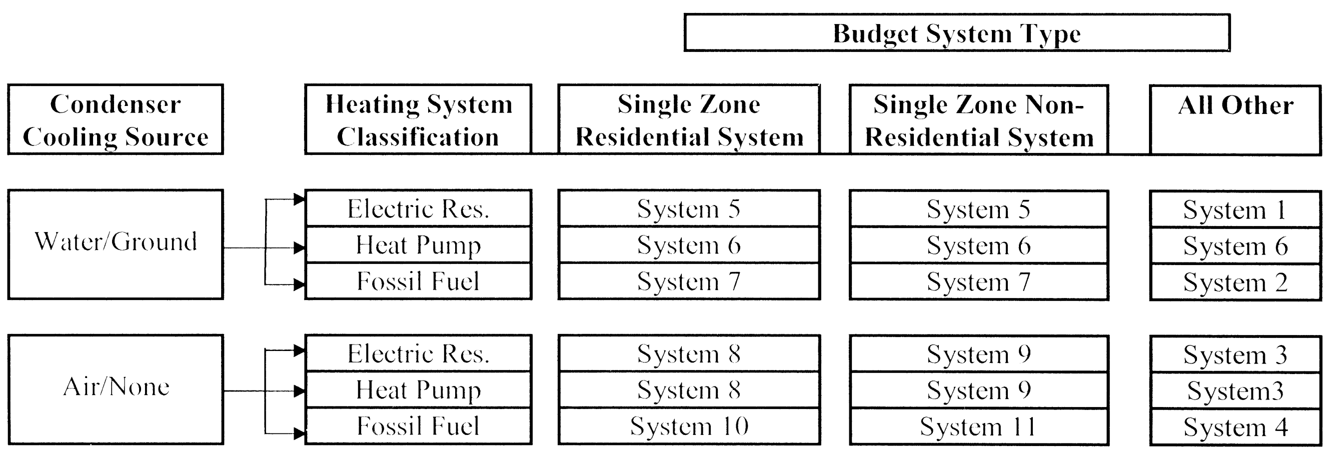


FIGURE 11.5.2 HVAC systems map.

i. The equipment capacities for the budget building design shall be sized proportionally to the capacities in the proposed building 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 building design and budget building design. Unmet load hours for the proposed design or baseline building designs shall not exceed 300. The unmet load hours for the proposed design shall not exceed the unmet load hours for the budget building. Alternatively, unmet load hours exceeding these limits may be accepted at the discretion 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.

j. Each HVAC system in a proposed building 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 building design system condenser is water or evaporatively

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 0.74 W per L/s fan power. Minimum volume setpoints 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 setpoint shall be constant at the design condition [see Section 11.5.2(g)].

b. **VAV with Reheat:** Minimum volume setpoints for VAV reheat boxes shall be 30% of zone peak airflow or the minimum ventilation rate, whichever is larger, consistent with Exception 1(a) to Section 6.5.2.1. The supply air temperature for cooling shall be reset higher by 2.8°C 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 building design.

d. **VAV:** Constant volume can be modeled if the system qualifies for Exception (2) to Section 6.5.2.1. Otherwise, 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 G.3.1.3.15. If the proposed building design's system has a DDC system at the zone level, static pressure setpoint 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 building design's chillers for each fuel type. Chilled-water supply temperature shall be modeled at 6.7°C design supply temperature and 13°C 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 building design; if the proposed building design has no chilled-water pumps, the budget building design pump power shall be 349 kW/1000 L/s (equal to a pump operating against a 23 m 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 5.6°C:

$Approach_{5.6°C Range} = 10.02 – (0.24 \times WB)$
where WB is the 0.4% evaporation design wet-bulb temperature in °C, valid for wet bulbs from 12.8°C to 32.2°C.

The tower shall be controlled to maintain a 21°C leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. Pump system power for each pumping system shall be the same as the proposed building design; if the proposed building design has no condenser water pumps, the budget building design pump power shall be 301 kW/1000 L/s (equal to a pump operating against a 18 m 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 building 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 176 kW or less and with two equally sized boilers for plant capacities exceeding 176 kW. Boilers shall be staged as required by the load. Hot-water supply temperature shall be modeled at 82°C design supply temperature and 54°C 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 building design; if the proposed building design has no hot-water pumps, the budget building design pump power shall be 301 kW/1000 L/s (equal to a pump operating against a 18 m 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 16°C and 32°C. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with two-speed fans if 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 building design and shall be natural draft. If no boilers exist in the proposed building 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 176 kW or less and with two equally sized boilers for plant capacities exceeding 176 kW. 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 building design; if the proposed building design has no pumps, the budget building design pump power shall be 349 kW/1000 L/s, which is equal to a pump operating against a 23 m 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 4°C.

i. **Fan System Operation:** Fans shall be controlled in the same manner as in the proposed building 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 building.

TABLE 11.5.2-2 Number of Chillers

Total Chiller Plant Capacity	Number of Chillers
≤1055 kW	One
>1055 kW, <2110 kW	Two sized equally
≥2110 kW	Two minimum with chillers added so that no chiller is larger than 2813 kW, all sized equally

TABLE 11.5.2-3 Water Chiller Types

Individual Chiller Plant Capacity	Electric Chiller Type	Fossil Fuel Chiller Type
≤352 kW	Reciprocating	Single-effect absorption, direct fired
>352 kW, <1055 kW	Screw	Double-effect absorption, direct fired
≥1055 kW	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
Water (integrated)	When its operation will no longer reduce HVAC system energy

cooled; enter at "Air" 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 building design does not require heat rejection, the system shall be treated as if the condenser water type were "Air." For proposed building 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 building 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. For kitchens with a total exhaust hood airflow rate greater than 2400 L/s, 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 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 6.5.7.1.3 for the numbers and types of hoods and appliances provided in the proposed design.

11.6 Alternative Compliance Path (Not Used)

11.7 Documentation Requirements. Compliance shall be documented and submitted to the authority having jurisdiction. 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. 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.

c. The input and output report(s) 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.

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

e. The reduction in design energy cost associated with onsite renewable energy.

11.8 Product Information (Not Used)

12. NORMATIVE REFERENCES

Reference	Title
Air Conditioning, Heating and Refrigeration Institute (AHRI) 2111 Wilson Blvd., Suite 500, Arlington, VA 22201	
AHRI 210/240-200 with Addendum 1 and 2	Unitary Air Conditioning and Air-Source Heat Pump Equipment
AHRI 310/380-2004	Packaged Terminal Air-Conditioners and Heat Pumps
AHRI 340/360-2007 with Addenda 1 and 2	Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
AHRI 365-2009	Commercial and Industrial Unitary Air-Conditioning Condensing Units
AHRI 390-2003	Performance Rating of Single Packaged Vertical Air-Conditioners and Heat Pumps
AHRI 400-2001 with Addendum 2	Liquid-to-Liquid Heat Exchangers
AHRI 460-2005	Remote Mechanical Draft Air Cooled Refrigerant Condensers
AHRI 550/590-2011 (I-P) with Addendum 1 and AHRI 551/591 (SI)	Performance Rating of Water-Chilling and Heat-Pump Water-Heating Packages Using the Vapor Compression Cycle
AHRI 560-2000	Absorption Water Chilling and Water Heating Packages
AHRI 1160-2009	Performance Rating of Heat Pump Pool Heaters
AHRI 1200-2010	Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets
AHRI 1230-2010 with Addendum 1	Performance Rating of Variable Refrigerant Flow (VRF) Multi-split Air-Conditioning and Heat Pump Equipment
BTS 2000	Testing Standard Method to Determine Efficiency of Commercial Space Heating Boilers
Air Movement and Control Association International (AMCA) 30 West University Drive, Arlington Heights, IL 60004-1806	
AMCA 205-12	Energy Efficiency Classification for Fans
ANSI/AMCA 500-D-12	Laboratory Methods of Testing Dampers for Rating
American Architectural Manufacturers Association (AAMA) 1827 Walden Office Square, Suite 550, Schaumburg, IL 60173-4268	
AAMA/WDMA/CSA 101/I.S.2/A440-08	Standard/Specification for Windows, Doors, and Unit Skylights
American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036	
ANSI Z21.10.3-2011	Gas Water Heater, Volume 3, Storage, with Input Ratings above 75,000 Btu/h, Circulating and Instantaneous Water Heaters
ANSI Z21.47-2012	Gas-Fired Central Furnaces
ANSI Z83.8-2009	Gas Unit Heaters and Duct Furnaces
American Society of Mechanical Engineers (ASME) Three Park Avenue, New York, NY 10016-5990	
ASME A17.1-2010/CSA B44-10	Safety Code for Elevators and Escalators

Reference	Title
ASHRAE **1791 Tullie Circle, NE, Atlanta, GA 30329**	
ANSI/ASHRAE/IESNA Standard 90.1-2007	Energy Standard for Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE/ACCA Standard 183-2007	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE Standard 62.1-2007	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE Standard 127-2007	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners
ANSI/ASHRAE Standard 140-2011	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
ANSI/ASHRAE Standard 154-2003	Ventilation for Commercial Cooking Operations
Briggs, R.S., R.G. Lucas, and Z.T. Taylor. 2003	Climate classification for building energy codes and standards: Part 1—Development process
ANSI/ASHRAE Standard 55-2010	Thermal Environmental Conditions for Human Occupancy
Association of Home Appliance Manufacturers (AHAM) **1111 19th Street NW, Suite 402, Washington, DC 20036**	
ANSI/AHAM HRF-1-2008	Energy and Internal Volume of Refrigerating Appliances (including errata issued November 17, 2009)
ANSI/AHAM RAC-1-R2008	Room Air Conditioners
ASTM International **100 Barr Harbor Dr., West Conshohocken, PA 19428-2959**	
ASTM C90-03	Standard Specification for Loadbearing Concrete Masonry Units
ASTM C177-97	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM C272-01	Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM C518-04	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus
ASTM C835-01	Standard Test Method for Total Hemispherical Emittance of Surfaces From 20°C to 1400°C
ASTM C1363-97	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM D1003-00	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
ASTM E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
ASTM E779-10	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
ASTM E972-96 (2002)	Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight
ASTM E1175-87 (2003)	Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere

Reference	Title
ASTM E1677-2005	Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls
ASTM E1680-95 (2003)	Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems
ASTM E1918 (2006)	Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-Sloped Surfaces in the Field
ASTM E1980 (2001)	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low Sloped Opaque Surfaces
ASTM E2178-03	Standard Test Method for Air Permeance of Building Materials
ASTM E2357-05	Standard Test Method for Determining Air Leakage of Air Barrier Assemblies
Canadian Standards Association (CSA) **5060 Spectrum Way, Mississauga, Ontario, Canada L4W 5N6**	
AAMA/WDMA/CSA 101/I.S.2/A440-08	Standard/Specification for Windows, Doors, and Unit Skylights
Cool Roof Rating Council (CRRC) **1610 Harrison Street, Oakland, CA 94612**	
ANSI/CRRC-1 Standard-2012	Cool Roof Rating Council—ANSI/CRRC-1 Standard
Cooling Technology Institute (CTI) **2611 FM 1960 West, Suite A-101, Houston, TX 77068-3730; P.O. Box 73383, Houston, TX 77273-3383**	
CTI ATC-105 (00)	Acceptance Test Code for Water Cooling Towers
CTI ATC-105S (11)	Acceptance Test Code for Closed-Circuit Cooling Towers
CTI ATC-106 (11)	Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers
CTI STD-201 (11)	Standard for Thermal Performance Certification of Evaporative Heat Transfer Equipment
Door and Access Systems Manufacturers Association (DASMA) **1300 Sumner Avenue, Cleveland, OH 44115-2851**	
ANSI/DASMA 105-92 (R 1998)	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors
Illuminating Engineering Society (IES) **120 Wall street, Floor 17, New York, NY 10005-4001**	
ANSI/IES RP-28-2007	Lighting and the Visual Environment for Senior Living
International Organization for Standardization (ISO) **1, rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland**	
ISO 13256-1 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps
ISO 13256-2 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 2: Water-to-Water and Brine-to-Water Heat Pumps
National Electrical Manufacturers Association (NEMA) **1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209**	
ANSI/NEMA MG 1-2006	Motors and Generators

Reference	Title
National Fenestration Rating Council (NFRC) 6305 Ivy Lane, Suite 140, Greenbelt, MD 20770-6323	
NFRC 100-2010	Procedure for Determining Fenestration Product U-Factors
NFRC 200-2010	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence
NFRC 300-2010	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems
NFRC 301-2010	Test Method for Emittance of Specular Surfaces Using Spectrometric Measurements
NFRC 400-2010	Procedure for Determining Fenestration Product Air Leakage
National Fire Protection Association (NFPA) 1 Battery March Park, P.O. Box 9101, Quincy, MA 02269-9101	
ANSI/NFPA 70-2008	National Electric Code
NFPA 70 Article 708-2011	Critical Operations Power Systems (COPS)
NFPA 96-12	Ventilation Control and Fire Protection of Commercial Cooking Operations
Telecommunications Industry Association (TIA) 2500 Wilson Boluevard, Arlington, VA 22201	
ANSI/TIA-942-2005	Telecommunication Infrastructure Standard for Data Centers
Underwriters Laboratories, Inc. (UL) 333 Pfingsten Rd., Northbrook, IL 60062	
UL 181A-2005	Closure Systems for Use with Rigid Air Ducts and Air Connectors
UL 181B-2005	Closure Systems for Use with Flexible Air Ducts and Air Connectors
UL 727-06	UL Standard for Safety—Oil Fired Central Furnaces
UL 731-12	UL Standard for Safety—Oil-Fired Unit Heaters
U.S. Department of Energy (DOE) 1000 Independence Avenue, SW, Washington, DC 20585	
10 CFR Part 430, App N	Uniform Test Method for Measuring the Energy Consumption of Furnaces
10 CFR 431 Subpart K, App A	Uniform Test Method for Measuring the Energy Consumption of Distribution Transformers
10 CFR Part 431, Subpart B, App B	Uniform Test Method for Measuring Nominal Full-Load Efficiency of Electric Motors
42 USC 6831, et seq., Public Law 102-486	Energy Policy Act of 1992
U.S. Security and Exchange Commission (SEC) 100 F Street, NE, Washington, DC 2-549	
The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System	The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System, April 7, 2003
Window and Door Manufacturers Association (WDMA) 2025 M Street, NW, Washington, DC 20036	
AAMA/WDMA/CSA 101/I.S.2/A440-08	North American Fenestration Standard/Specification for Windows, Doors, and Skylights

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

A1.2 Applicant-Determined Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. If the building official determines that the proposed construction assembly is not adequately represented in Sections A2 through A8, the applicant shall determine appropriate values for the assembly using the assumptions in Section A9. An assembly is deemed to be adequately represented if:

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

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

A2. ROOFS

A2.1 General. The buffering effect of suspended ceilings or attic spaces shall not be included in U-factor calculations.

A2.2 Roofs with Insulation Entirely Above Deck

A2.2.1 General. For the purpose of Section A1.2, the base assembly is continuous insulation over a structural deck. The U-factor includes R-0.03 for exterior air film, R-0 for metal deck, and R-0.11 for interior air film heat flow up. Added insulation is continuous and uninterrupted by framing. The framing factor is zero.

A2.2.2 Rated R-Value of Insulation. For roofs with insulation entirely above deck, the rated R-value of insulation is for continuous insulation.

Exception: Interruptions for framing and pads for mechanical equipment are permitted with a combined total area not exceeding one percent of the total opaque assembly area.

A2.2.3 U-Factor. U-factors for roofs with insulation entirely above deck shall be taken from Table A2.2.3. It is not acceptable to use these U-factors if the insulation is not entirely above deck or not continuous.

TABLE A2.2.3 Assembly U-Factors for Roofs with Insulation Entirely Above Deck

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
R-0.0	U-7.28
R-0.2	U-3.19
R-0.4	U-2.04
R-0.5	U-1.50
R-0.7	U-1.19
R-0.9	U-0.98
R-1.1	U-0.84
R-1.2	U-0.73
R-1.4	U-0.65
R-1.6	U-0.58
R-1.8	U-0.53
R-1.9	U-0.48
R-2.1	U-0.44
R-2.3	U-0.41
R-2.5	U-0.38
R-2.6	U-0.36
R-2.8	U-0.34
R-3.0	U-0.32
R-3.2	U-0.30
R-3.3	U-0.29
R-3.5	U-0.27
R-3.7	U-0.26
R-3.9	U-0.25
R-4.0	U-0.24
R-4.2	U-0.23
R-4.4	U-0.22
R-4.6	U-0.21
R-4.8	U-0.20
R-4.9	U-0.20
R-5.1	U-0.19
R-5.3	U-0.18
R-6.2	U-0.16
R-7.0	U-0.14
R-7.9	U-0.12
R-8.8	U-0.11
R-9.7	U-0.10
R-10.4	U-0.09

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 1.52 m 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-0.5 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

A2.3.2.2 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-0.5 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

A2.3.2.3 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-0.5. thermal spacer block between the purlins and the metal roof panels is required unless compliance is shown by the overall assembly U-factor.

A2.3.2.5 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-0.9 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

A2.3.3 U-factors for Metal Building Roofs. U-factors for metal building roofs shall be taken from Table A2.3.3 or determined in accordance with Section A9.2, provided the average purlin spacing for systems with compressed insulation is at least 1300 mm. U-factors for metal building roof assemblies with average purlin spacing less than 1300 mm shall be determined in accordance with Section A9.2. U-factors in Table A2.3.3 shall not be used where the insulation is substantially compressed by the bracing between the purlins.

A2.4 Attic Roofs with Wood Joists

A2.4.1 General. For the purpose of Section A1.2, the base attic roof assembly is a roof with nominal 100 mm deep wood as the lower chord of a roof truss or ceiling joist. The ceiling is attached directly to the lower chord of the truss and the attic space above is ventilated. Insulation is located directly on top of the ceiling, first filling the cavities between the wood and then later covering both the wood and cavity areas. No credit is given for roofing materials. The single-rafter roof is similar to the base attic roof, with the key difference being that there is a single, deep rafter to which both the roof and the ceiling are attached. The heat flow path through the rafter is calculated to be the same depth as the insulation. Additional assemblies include continuous insulation, uncompressed and uninterrupted by framing. The U-factors include R-0.08 for semi-exterior air film, R-0.10 for 16 mm gypsum board, and R-0.11 for interior air film heat flow up. U-factors are provided for the following configurations:

a. Attic roof, standard framing: insulation is tapered around the perimeter with a resultant decrease in thermal resistance. Weighting factors are 85% full-depth insulation, 5% half-depth insulation, and 10% joists.
b. Attic roof, advanced framing: full and even depth of insulation extending to the outside edge of exterior walls. Weighting factors are 90% full-depth insulation and 10% joists.
c. Single-rafter roof: an attic roof where the roof sheathing and ceiling are attached to the same rafter. Weighting factors are 90% full-depth insulation and 10% joists.

A2.4.2 Rated R-Value of Insulation

A2.4.2.1 For attics and other roofs, the rated R-value of insulation is for insulation installed both inside and outside the roof or entirely inside the roof cavity.

A2.4.2.2 Occasional interruption by framing members is allowed but requires that the framing members be covered with insulation when the depth of the insulation exceeds the depth of the framing cavity.

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-0.03 for exterior air film, R-0 for metal deck, and R-0.11 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 A2.3.3 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-1.1	R-1.7	R-2.3	R-2.8	R-3.3	R-3.9	R-4.4	R-5.6	R-6.7
Standing Seam Roofs with Thermal Spacer Blocks[a, b]											
Single Layer	None	7.27	0.780	0.54	0.41	0.34	0.29	0.25	0.22	0.17	0.15
	R-1.8	0.653	0.37	0.31	0.26	0.23	0.21	0.18	0.17	0.14	0.12
	R-1.9	0.608	0.36	0.30	0.25	0.23	0.20	0.18	0.17	0.14	0.12
	R-2.3	0.573	0.35	0.29	0.25	0.22	0.20	0.18	0.16	0.14	0.12
	R-2.8	0.55	0.34	0.28	0.24	0.22	0.19	0.17	0.16	0.13	0.12
	R-3.3	0.47	0.30	0.26	0.23	0.20	0.18	0.17	0.15	0.13	0.11
Double Layer	R-1.8 + R-1.8	0.50	0.32	0.27	0.23	0.21	0.19	0.17	0.16	0.13	0.12
	R-1.8 + R-1.9	0.49	0.31	0.26	0.23	0.21	0.19	0.17	0.16	0.13	0.11
	R-1.9 + R-1.9	0.48	0.31	0.26	0.23	0.21	0.18	0.17	0.15	0.13	0.11
	R-1.8 + R-2.3	0.48	0.31	0.26	0.23	0.20	0.18	0.17	0.15	0.13	0.11
	R-1.9 + R-2.3	0.47	0.30	0.26	0.23	0.20	0.18	0.17	0.15	0.13	0.11
	R-2.3 + R-2.3	0.43	0.28	0.25	0.22	0.19	0.18	0.16	0.15	0.13	0.11
	R-1.8 + R-3.3	0.42	0.28	0.24	0.22	0.19	0.17	0.16	0.15	0.12	0.11
	R-1.9 + R-3.3	0.41	0.28	0.24	0.21	0.19	0.17	0.16	0.15	0.12	0.11
	R-2.3 + R-3.3	0.39	0.27	0.23	0.20	0.19	0.17	0.15	0.14	0.12	0.11
	R-2.8 + R-3.3	0.37	0.26	0.23	0.20	0.18	0.17	0.15	0.14	0.12	0.11
	R-3.3 + R-3.3	0.34	0.25	0.21	0.19	0.17	0.16	0.15	0.14	0.12	0.10
Liner System	R-3.3 + R-1.9	0.21									
	R-4.4 +R-1.4	0.21									
	R-4.4 + R-1.9	0.18									
	R-5.3 + R-1.9	0.16									
	R-4.4 + R-1.9 + R-1.9	0.15									
Filled Cavity with Thermal Spacer Blocks[c]											
	R-1.8 + R-3.3	0.23	0.18	0.17	0.15	0.14	0.13	0.14	0.11	0.10	0.09
Standing Seam Roofs without Thermal Spacer Blocks											
Liner System	R-3.3 + R-1.9	0.23									
Through-Fastened Roofs without Thermal Spacer Blocks											
	R-1.8	1.04	0.48	0.37	0.31	0.27	0.23	0.21	0.19	0.15	0.13
	R-1.9	1.03	0.47	0.37	0.31	0.27	0.23	0.21	0.19	0.15	0.13
	R-2.3	0.988	0.46	0.37	0.30	0.26	0.23	0.20	0.18	0.15	0.13
	R-2.8	0.891	0.44	0.35	0.29	0.26	0.22	0.20	0.18	0.15	0.13
	R-3.3	0.857	0.43	0.35	0.29	0.25	0.22	0.20	0.18	0.15	0.13
Liner System	R-3.3 + R-1.9	0.25									
(Multiple R-values are listed in order from inside to outside)											

a. A standing seam roof clip that provides a minimum 3.8 cm distance between the top of the purlins and the underside of the metal roof panels is required.
b. A minimum R-0.5 thermal spacer block is required.
c. A minimum R-0.9 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 ≤ 200 mm	200 < *d* ≤ 250 mm	250 < *d* ≤ 300 mm
1–7	R-3.3/U-0.31	R-5.3/U-0.20	R-6.7/U-0.16
8	R-3.7/U-0.29	R-5.3/U-0.20	R-6.7/U-0.16

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-3.48			
R-1.9	U-0.52			
R-2.3	U-0.46			
R-3.3	U-0.30			
R-5.3	U-0.19			
R-6.7	U-0.15			
R-8.6	U-0.12			
R-10.6	U-0.10			
R-12.5	U-0.08			
R-14.4	U-0.07			
R-16.4	U-0.06			
R-18.3	U-0.06			
R-20.2	U-0.05			
R-22.2	U-0.05			
Wood-Framed Attic, Advanced Framing				
None	U-3.58			
R-1.9	U-0.50			
R-2.3	U-0.44			
R-3.3	U-0.29			
R-5.3	U-0.18			
R-6.7	U-0.15			
R-8.6	U-0.11			
R-10.6	U-0.09			
R-12.5	U-0.08			
R-14.4	U-0.07			
R-16.4	U-0.06			
R-18.3	U-0.05			
R-20.2	U-0.05			
R-22.2	U-0.04			
Wood Joists, Single-rafter Roof				
	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing)			
Cavity Insulation R-Value	Rated R-Value of Continuous Insulation			
	None	**R-0.8**	**R-1.8**	**R-2.6**
None	U-2.37	U-0.77	U-0.46	U-0.33
R-1.9	U-0.50	U-0.35	U-0.27	U-0.22
R-2.3	U-0.44	U-0.32	U-0.25	U-0.20
R-2.6	U-0.40	U-0.30	U-0.24	U-0.20
R-3.3	U-0.31	U-0.24	U-0.20	U-0.17
R-3.7	U-0.29	U-0.23	U-0.19	U-0.17
R-4.4	U-0.25	U-0.20	U-0.17	U-0.15
R-5.3	U-0.20	U-0.17	U-0.15	U-0.13
R-6.7	U-0.16	U-0.14	U-0.13	U-0.11

TABLE A2.5.2 Assembly U-Factors for Attic Roofs with Steel Joists (1.22 m on Center)

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
R-0.0	U-7.28
R-0.7	U-1.22
R-0.9	U-1.02
R-1.4	U-0.68
R-1.8	U-0.57
R-1.9	U-0.53
R-2.1	U-0.49
R-2.3	U-0.46
R-2.6	U-0.41
R-2.8	U-0.39
R-3.3	U-0.33
R-3.5	U-0.32
R-3.7	U-0.31
R-4.2	U-0.28
R-4.4	U-0.27
R-5.3	U-0.23
R-6.2	U-0.21
R-6.7	U-0.20
R-7.0	U-0.19
R-7.9	U-0.17
R-8.8	U-0.16
R-9.7	U-0.15

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-0.03 for exterior air film and R-0.12 for interior air film, vertical surfaces. For insulated walls, the U-factor also includes R-0.08 for 13 mm gypsum board. For the cavity wall, the U-factor includes R-0.13 for brick. U-factors are provided for the following configurations:

a. Concrete wall: 200 mm normal weight concrete wall with a density of 2320 kg/m^3.
b. Solid grouted concrete block wall: 200 mm medium weight ASTM C90 concrete block with a density of 1840 kg/m^3 and solid grouted cores.
c. Partially grouted concrete block wall: 200 mm medium weight ASTM C90 concrete block with a density of 1840 kg/m^3 having reinforcing steel every 800 mm vertically and every 1200 mm 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 25 mm metal clips spaced no closer than 600 mm on center horizontally and 400 mm on center vertically.

A3.1.2.3 Where other framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly U-factor.

A3.1.2.4 Where rated R-value of insulation is used for concrete sandwich panels, the insulation shall be continuous throughout the entire panel.

A3.1.3 Mass Wall U-Factor

A3.1.3.1 U-factors for mass walls shall be taken from Table A3.1-1 or determined by the procedure in this subsection. It is acceptable to use the U-factors in Table A3.1-1 for all mass walls, provided that the grouting is equal to or less than that specified. HC for mass walls shall be taken from Table A3.1-2 or A3.1-3.

A3.1.3.2 Determination of Mass Wall U-Factors. If not taken from Table A3.1-1, mass wall U-factors shall be determined from Tables A3.1-2, A3.1-3, or A3.1-4 using the following procedure:

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

A3.2 Metal Building Walls

A3.2.1 General. For the purpose of Section A1.2, the base assembly is a wall where the insulation is compressed between metal wall panels and the metal structure. Additional assemblies include continuous insulation, uncompressed and uninterrupted by framing. Insulation exposed to a conditioned space or semiheated space shall have a facing, and all insulation shall be continuously sealed to provide a continuous air barrier.

A3.2.2 Rated R-Value of Insulation for Metal Building Walls

A3.2.2.1 Single Layer. The first rated R-value of insulation is for insulation compressed between metal wall panels and the steel structure.

A3.2.2.2 Continuous Insulation. For assemblies with continuous insulation, the continuous insulation is installed on the outside or inside the girts, uncompressed and uninterrupted by the framing members.

A3.2.3 U-Factors for Metal Building Walls. U-factors for metal building walls shall be taken from Table A3.2.3 or determined in accordance with Section A9.2, provided the average girt spacing is at least 1300 mm. U-factors for metal building wall assemblies with average girt spacing less than 1300 mm 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 1.1 mm for 18 gage or 1.4 mm for 16 gage. The U-factors include R-0.03 for exterior air film, R-0.01 for stucco, R-0.10 for 16 mm gypsum board on on the exterior, R-0.10 for 16 mm gypsum board on the interior, and R-0.12 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 400 mm on center with cavities filled with 400 mm wide insulation for both 89 mm deep and 152 mm deep wall cavities.
b. Advanced framing: steel stud framing at 600 mm on center with cavities filled with 600 mm wide insulation for both 89mm deep and 152 mm 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 600 mm 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 600 to 800 mm 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 800 mm on center, use the metal building wall values in Table A3.2.

A3.4 Wood-Framed Walls

A3.4.1 General. For the purpose of Section A1.2, the base assembly is a wall where the insulation is installed between 51 mm nominal wood framing. Cavity insulation is full depth, but values are taken from Table A9.4.2 for R-3.35 insulation, which is compressed when installed in a 140 mm cavity. Headers are double 51 mm nominal wood framing. The U-factors include R-0.03 for exterior air film, R-0.01 for stucco, R-0.10 for 16 mm gypsum board on the exterior, R-0.10 for 16 mm gypsum board on the interior, and R-0.12 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 400 mm on center with cavities filled with 368 mm wide insulation for both 89 mm deep and 140 mm 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 600 mm on center with cavities filled with 572 mm wide insulation for both 89 mm deep and 140 mm 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 600 mm on center with cavities filled with 572 mm wide insulation for both 89 mm deep and 140 mm 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 600 mm 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 600 to 800 mm 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 800 mm 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 200 mm Normal Weight 2320 kg/m³ Solid Concrete Walls	Assembly U-Factors for 200 mm Medium Weight 1840 kg/m³ Concrete Block Walls: Solid Grouted	Assembly U-Factors for 200 mm Medium Weight 1840 kg/m³ Concrete Block Walls: Partially Grouted (cores uninsulated except where specified)
No Framing	**R-0**	**U-4.20**	**U-3.29**	**U-2.73**
	Ungrouted Cores Filled with Loose-Fill Insulation	**NA**	**NA**	**U-1.99**
Continuous Metal Framing at 600 mm on Center Horizontally				
25 mm	R-0.00	U-2.35	U-2.04	U-1.80
25 mm	R-0.67	U-1.84	U-1.64	U-1.49
25 mm	R-0.88	U-1.78	U-1.59	U-1.45
25 mm	R-1.15	U-1.73	U-1.55	U-1.41
38 mm	R-1.94	U-1.51	U-1.38	U-1.26
51 mm	R-1.34	U-1.30	U-1.20	U-1.12
51 mm	R-1.76	U-1.24	U-1.15	U-1.07
51 mm	R-2.29	U-1.19	U-1.11	U-1.03
76 mm	R-2.01	U-1.01	U-0.95	U-0.89
76 mm	R-2.65	U-0.95	U-0.90	U-0.84
76 mm	R-3.35	U-0.91	U-0.86	U-0.82
89 mm	R-1.94	U-0.95	U-0.90	U-0.85
89 mm	R-2.29	U-0.91	U-0.86	U-0.82
89 mm	R-2.64	U-0.88	U-0.83	U-0.80
114 mm	R-3.01	U-0.76	U-0.72	U-0.69
114 mm	R-3.96	U-0.70	U-0.68	U-0.65
114 mm	R-4.44	U-0.69	U-0.66	U-0.64
127 mm	R-3.35	U-0.69	U-0.66	U-0.64
127 mm	R-4.40	U-0.65	U-0.62	U-0.60
127 mm	R-4.93	U-0.64	U-0.61	U-0.59
127 mm	R-5.64	U-0.62	U-0.60	U-0.57
140 mm	R-3.35	U-0.67	U-0.64	U-0.62
140 mm	R-3.69	U-0.65	U-0.62	U-0.60
140 mm	R-3.70	U-0.64	U-0.62	U-0.60
140 mm	R-4.85	U-0.60	U-0.58	U-0.56
140 mm	R-5.43	U-0.59	U-0.57	U-0.55
152 mm	R-4.01	U-0.60	U-0.58	U-0.56
152 mm	R-5.28	U-0.56	U-0.54	U-0.52
152 mm	R-5.92	U-0.55	U-0.53	U-0.51
165 mm	R-4.36	U-0.56	U-0.55	U-0.52
178 mm	R-4.69	U-0.53	U-0.51	U-0.49
191 mm	R-5.03	U-0.50	U-0.48	U-0.47
203 mm	R-5.36	U-0.47	U-0.46	U-0.45
25 mm Metal Clips at 600 mm on Center Horizontally and 400 mm Vertically				
25 mm	R-0.67	U-1.19	U-1.11	U-1.03
25 mm	R-0.88	U-1.05	U-0.98	U-0.92
25 mm	R-0.99	U-0.99	U-0.93	U-0.87
38 mm	R-1.00	U-0.91	U-0.86	U-0.81
38 mm	R-1.32	U-0.78	U-0.74	U-0.71
38 mm	R-1.48	U-0.73	U-0.70	U-0.67
51 mm	R-1.34	U-0.73	U-0.70	U-0.67
51 mm	R-1.76	U-0.62	U-0.60	U-0.58

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 200 mm Normal Weight 2320 kg/m^3 Solid Concrete Walls	Assembly U-Factors for 200 mm Medium Weight 1840 kg/m^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 200 mm Medium Weight 1840 kg/m^3 Concrete Block Walls: Partially Grouted (cores uninsulated except where specified)
No Framing	R-0	U-4.20	U-3.29	U-2.73
	Ungrouted Cores Filled with Loose-Fill Insulation	NA	NA	U-1.99
51 mm	R-1.97	U-0.59	U-0.56	U-0.55
64 mm	R-1.68	U-0.62	U-0.59	U-0.57
64 mm	R-2.20	U-0.52	U-0.51	U-0.49
64 mm	R-2.46	U-0.49	U-0.47	U-0.45
76 mm	R-2.01	U-0.53	U-0.51	U-0.47
76 mm	R-2.64	U-0.44	U-0.43	U-0.42
76 mm	R-2.96	U-0.41	U-0.40	U-0.39
89 mm	R-2.34	U-0.47	U-0.45	U-0.44
89 mm	R-3.08	U-0.39	U-0.38	U-0.37
89 mm	R-3.45	U-0.36	U-0.35	U-0.35
102 mm	R-2.68	U-0.40	U-0.40	U-0.40
102 mm	R-3.52	U-0.34	U-0.33	U-0.33
102 mm	R-3.94	U-0.32	U-0.31	U-0.31
127 mm	R-4.93	U-0.26	U-0.26	U-0.26
152 mm	R-5.92	U-0.22	U-0.22	U-0.22
178 mm	R-6.90	U-0.19	U-0.19	U-0.19
203 mm	R-7.89	U-0.17	U-0.17	U-0.16
229 mm	R-8.87	U-0.15	U-0.15	U-0.15
254 mm	R-9.86	U-0.14	U-0.14	U-0.14
279 mm	R-10.8	U-0.12	U-0.12	U-0.12
Continuous Insulation Uninterrupted by Framing				
No Framing	R-0.18	U-2.41	U-2.08	U-1.84
No Framing	R-0.35	U-1.69	U-1.53	U-1.39
No Framing	R-0.53	U-1.31	U-1.20	U-1.12
No Framing	R-0.70	U-1.06	U-0.99	U-0.93
No Framing	R-0.88	U-0.89	U-0.85	U-0.80
No Framing	R-1.06	U-0.77	U-0.73	U-0.70
No Framing	R-1.23	U-0.68	U-0.65	U-0.62
No Framing	R-1.41	U-0.61	U-0.59	U-0.56
No Framing	R-1.58	U-0.55	U-0.53	U-0.51
No Framing	R-1.76	U-0.50	U-0.48	U-0.47
No Framing	R-1.94	U-0.46	U-0.45	U-0.43
No Framing	R-2.11	U-0.43	U-0.41	U-0.40
No Framing	R-2.29	U-0.40	U-0.39	U-0.37
No Framing	R-2.46	U-0.37	U-0.36	U-0.35
No Framing	R-2.64	U-0.35	U-0.34	U-0.34
No Framing	R-2.82	U-0.33	U-0.32	U-0.31
No Framing	R-2.99	U-0.31	U-0.30	U-0.30
No Framing	R-3.17	U-0.30	U-0.29	U-0.28
No Framing	R-3.35	U-0.28	U-0.27	U-0.27
No Framing	R-3.52	U-0.27	U-0.26	U-0.26
No Framing	R-3.70	U-0.26	U-0.25	U-0.24
No Framing	R-3.87	U-0.24	U-0.24	U-0.24

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 200 mm Normal Weight 2320 kg/m^3 Solid Concrete Walls	Assembly U-Factors for 200 mm Medium Weight 1840 kg/m^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 200 mm Medium Weight 1840 kg/m^3 Concrete Block Walls: Partially Grouted (cores uninsulated except where specified)
No Framing	**R-0**	**U-4.20**	**U-3.29**	**U-2.73**
	Ungrouted Cores Filled with Loose-Fill Insulation	**NA**	**NA**	**U-1.99**
No Framing	R-4.05	U-0.23	U-0.23	U-0.23
No Framing	R-4.23	U-0.22	U-0.22	U-0.22
No Framing	R-4.40	U-0.22	U-0.21	U-0.21
No Framing	R-5.28	U-0.18	U-0.18	U-0.18
No Framing	R-6.16	U-0.16	U-0.15	U-0.15
No Framing	R-7.04	U-0.14	U-0.14	U-0.14
No Framing	R-7.92	U-0.12	U-0.12	U-0.12
No Framing	R-8.80	U-0.11	U-0.11	U-0.11
No Framing	R-9.68	U-0.10	U-0.10	U-0.10
No Framing	R-10.56	U-0.09	U-0.09	U-0.09
Brick cavity wall with Continuous Insulation				
No Framing	R-0.00	U-1.91	U-1.70	U-1.53
No Framing	R-0.67	U-0.84	U-0.79	U-0.75
No Framing	R-0.88	U-0.71	U-0.68	U-0.65
No Framing	R-1.15	U-0.60	U-0.58	U-0.56
No Framing	R-1.34	U-0.54	U-0.52	U-0.50
No Framing	R-1.76	U-0.44	U-0.43	U-0.41
No Framing	R-1.85	U-0.45	U-0.44	U-0.43
No Framing	R-2.01	U-0.40	U-0.39	U-0.37
No Framing	R-2.65	U-0.32	U-0.31	U-0.30
No Framing	R-2.91	U-0.31	U-0.30	U-0.29
No Framing	R-3.35	U-0.26	U-0.25	U-0.25
No Framing	R-3.97	U-0.23	U-0.23	U-0.22
No Framing	R-5.03	U-0.19	U-0.18	U-0.18
Continuous Insulation Uninterrupted by Framing with Stucco and Continuous Metal Framing at 600 mm on Center Horizontally				
25 mm	R-0.00+R-3.35 c.i.	U-0.27	U-0.26	U-0.25
25 mm	R-0.67+R-3.35 c.i.	U-0.26	U-0.25	U-0.25
25 mm	R-0.88+R-3.35 c.i.	U-0.26	U-0.25	U-0.25
25 mm	R-1.15+R-3.35 c.i.	U-0.26	U-0.25	U-0.25
38 mm	R-1.34+R-3.35 c.i.	U-0.25	U-0.24	U-0.24
51mm	R-1.76+R-3.35 c.i.	U-0.24	U-0.24	U-0.23
51 mm	R-2.29+R-3.35 c.i.	U-0.24	U-0.23	U-0.23
51 mm	R-1.06+R-3.35 c.i.	U-0.24	U-0.23	U-0.23
76 mm	R-2.01+R-3.35 c.i.	U-0.23	U-0.23	U-0.22
76 mm	R-2.65+R-3.35 c.i.	U-0.23	U-0.22	U-0.22
76 mm	R-3.44+R-3.35 c.i.	U-0.23	U-0.22	U-0.22
89 mm	R-1.94+R-3.35 c.i.	U-0.23	U-0.22	U-0.22
89 mm	R-2.29+R-3.35 c.i.	U-0.23	U-0.22	U-0.22
127 mm	R-3.35+R-3.35 c.i.	U-0.21	U-0.21	U-0.20
127 mm	R-4.41+R-3.35 c.i.	U-0.20	U-0.20	U-0.20
127 mm	R-5.73+R-3.35 c.i.	U-0.20	U-0.20	U-0.20
140 mm	R-3.17+R-3.35 c.i.	U-0.20	U-0.20	U-0.20
140 mm	R-3.70+R-3.35 c.i.	U-0.20	U-0.20	U-0.20

TABLE A3.1-2 Assembly U-Factors, C-Factors, R_u, R_c, and HC for Concrete

Density, kg/m³	Properties	Thickness, mm 75	100	125	150	175	200	225	250	275	300
320	U-factor	1.24	0.97	0.80	0.68	0.59	0.52	0.47	0.43	0.39	0.36
	C-factor	1.52	1.14	0.91	0.76	0.65	0.57	0.51	0.46	0.41	0.38
	R_u	0.81	1.03	1.25	1.47	1.69	1.91	2.13	2.35	2.56	2.78
	R_c	0.66	0.88	1.10	1.32	1.54	1.76	1.98	2.20	2.42	2.63
	HC	20	27	34	41	48	54	61	68	75	82
480	U-factor	1.59	1.27	1.06	0.90	0.79	0.70	0.63	0.57	0.52	0.48
	C-factor	2.09	1.57	1.25	1.04	0.89	0.78	0.70	0.63	0.57	0.52
	R_u	0.63	0.79	0.95	1.11	1.27	1.43	1.59	1.75	1.91	2.07
	R_c	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60	1.76	1.92
	HC	31	41	51	61	71	82	92	102	112	123
640	U-factor	1.90	1.54	1.29	1.11	0.97	0.87	0.78	0.71	0.65	0.60
	C-factor	2.66	1.99	1.59	1.33	1.14	1.00	0.89	0.80	0.72	0.66
	R_u	0.53	0.65	0.78	0.90	1.03	1.15	1.28	1.40	1.53	1.66
	R_c	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.51
	HC	41	54	68	82	95	109	123	136	150	163
800	U-factor	2.18	1.78	1.50	1.30	1.15	1.02	0.93	0.85	0.78	0.72
	C-factor	3.23	2.42	1.94	1.61	1.38	1.21	1.08	0.97	0.88	0.81
	R_u	0.46	0.56	0.67	0.77	0.87	0.98	1.08	1.18	1.29	1.39
	R_c	0.31	0.41	0.52	0.62	0.72	0.83	0.93	1.03	1.14	1.24
	HC	51	68	85	102	119	136	153	170	187	204
1360	U-factor	3.66	3.19	2.83	5.52	2.29	2.10	1.93	1.79	1.67	1.56
	C-factor	8.11	6.11	4.90	4.06	3.48	3.05	2.72	2.44	2.22	2.04
	R_u	0.27	0.31	0.35	0.40	0.44	0.48	0.52	0.56	0.60	0.64
	R_c	0.12	0.16	0.20	0.25	0.29	0.33	0.37	0.41	0.45	0.49
	HC	87	116	145	174	203	232	261	290	319	348
1520	U-factor	4.09	3.64	3.26	2.96	2.70	2.49	2.31	2.15	2.02	1.90
	C-factor	10.52	8.00	6.38	5.31	4.54	3.97	3.53	3.17	2.90	2.65
	R_u	0.24	0.27	0.31	0.34	0.37	0.40	0.43	0.46	0.49	0.53
	R_c	0.10	0.13	0.16	0.19	0.22	0.25	0.28	0.32	0.35	0.38
	HC	97	129	162	194	227	259	291	324	356	389
1680	U-factor	4.47	4.03	3.66	3.34	3.09	2.87	2.68	2.51	2.37	2.57
	C-factor	16.71	10.14	8.11	6.68	5.74	5.03	4.47	4.03	3.66	4.18
	R_u	0.22	0.25	0.27	0.30	0.32	0.34	0.37	0.40	0.42	0.45
	R_c	0.07	0.10	0.12	0.15	0.17	0.20	0.22	0.25	0.27	0.30
	HC	107	143	179	215	251	286	322	358	394	429

TABLE A3.1-2 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete *(Continued)*

Density, kg/m³	Properties	Thickness, mm									
		75	100	125	150	175	200	225	250	275	300
1840	U-factor	4.77	4.37	4.00	3.71	3.44	3.23	3.04	2.85	2.70	2.57
	C-factor	16.71	12.62	9.96	8.35	7.10	6.24	5.57	4.98	4.54	4.18
	R_u	0.21	0.23	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.39
	R_c	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24
	HC	118	157	196	235	274	313	353	392	431	470
2000	U-factor	5.03	4.66	4.34	4.03	3.79	3.57	3.38	3.19	3.04	2.90
	C-factor	20.29	15.35	12.35	10.14	8.74	7.68	6.84	6.11	5.57	5.12
	R_u	0.20	0.21	0.23	0.25	0.26	0.28	0.30	0.31	0.33	0.35
	R_c	0.06	0.07	0.08	0.10	0.11	0.13	0.15	0.16	0.18	0.20
	HC	128	170	213	256	298	341	383	426	469	511
2160	U-factor	5.31	4.94	4.66	4.37	4.15	3.92	3.74	3.55	3.40	3.25
	C-factor	25.82	18.93	15.35	12.62	10.92	9.47	8.48	7.57	6.93	6.31
	R_u	0.19	0.20	0.21	0.23	0.24	0.26	0.27	0.28	0.29	0.31
	R_c	0.04	0.05	0.07	0.08	0.09	0.11	0.12	0.13	0.14	0.16
	HC	138	184	230	276	322	368	414	460	506	552
2304	U-factor	5.46	5.16	4.90	4.62	4.40	4.21	4.03	3.84	3.69	3.55
	C-factor	29.89	22.72	18.32	14.95	12.91	11.36	10.14	9.02	8.23	7.57
	R_u	0.18	0.19	0.20	0.22	0.23	0.24	0.25	0.26	0.27	0.28
	R_c	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.13
	HC	147	196	245	294	344	393	442	491	540	589

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: 76 mm thick concrete with densities of 1360, 1520, 1680, and 1840 kg/m^3.

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls

Product Size, mm	Density, kg/m^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
150 mm Block	1360	U-factor	3.24	2.61	1.91	2.25	1.11
		C-factor	6.30	4.28	2.68	3.40	1.33
		R_u	0.31	0.38	0.52	0.44	0.90
		R_c	0.16	0.23	0.37	0.29	0.75
		HC	224	138	143	86	95
	1520	U-factor	3.44	2.76	2.07	2.39	1.23
		C-factor	7.07	4.71	2.99	3.71	1.51
		R_u	0.29	0.36	0.48	0.42	0.81
		R_c	0.14	0.21	0.33	0.27	0.66
		HC	233	147	153	95	104
	1680	U-factor	3.61	2.91	2.22	2.51	1.36
		C-factor	7.86	5.15	3.32	4.02	1.71
		R_u	0.29	0.36	0.48	0.42	0.81
		R_c	0.14	0.21	0.33	0.27	0.66
		HC	243	156	162	105	114
	1840	U-factor	3.77	3.40	2.36	2.63	1.50
		C-factor	8.66	5.58	3.64	4.34	1.93
		R_u	0.27	0.33	0.42	0.38	0.67
		R_c	0.12	0.18	0.27	0.23	0.52
		HC	252	166	171	114	123
	2000	U-factor	3.95	3.20	2.55	2.78	1.68
		C-factor	9.65	6.14	4.12	4.75	2.25
		R_u	0.25	0.31	0.39	0.36	0.59
		R_c	0.10	0.16	0.24	0.21	0.45
		HC	262	175	181	124	132
	2160	U-factor	4.16	3.41	2.81	2.99	1.97
		C-factor	11.05	6.96	4.84	5.40	2.78
		R_u	0.24	0.29	0.36	0.33	0.51
		R_c	0.09	0.14	0.21	0.19	0.36
		HC	271	185	190	133	142

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls *(Continued)*

Product Size, mm	Density, kg/m^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
200 mm Block	1360	U-factor	2.80	2.34	1.60	2.08	0.86
		C-factor	4.82	3.60	2.11	3.03	0.98
		R_u	0.36	0.43	0.62	0.48	1.17
		R_c	0.21	0.28	0.47	0.33	1.02
		HC	306	184	192	111	123
	1520	U-factor	2.98	2.49	1.74	2.21	0.96
		C-factor	5.39	3.96	2.35	3.30	1.12
		R_u	0.34	0.40	0.57	0.43	5.92
		R_c	0.19	0.25	0.43	0.28	0.89
		HC	318	196	204	123	136
	1680	U-factor	3.15	2.62	1.87	2.33	1.07
		C-factor	5.95	4.32	2.60	3.57	1.27
		R_u	0.32	0.38	0.53	0.43	0.84
		R_c	0.17	0.23	0.38	0.28	0.69
		HC	330	0.8	216	135	160
	1840	U-factor	3.29	2.74	2.00	2.44	1.19
		C-factor	6.50	4.66	2.86	3.85	1.44
		R_u	0.30	0.36	0.50	0.41	0.84
		R_c	0.15	0.21	0.35	0.26	0.69
		HC	342	220	228	147	160
	2000	U-factor	3.46	2.90	2.17	2.58	1.35
		C-factor	7.20	5.12	3.22	4.20	1.69
		R_u	0.29	0.35	0.46	0.39	0.74
		R_c	0.14	0.20	0.31	0.24	10.59
		HC	354	233	240	159	172
	2160	U-factor	3.68	3.10	2.41	2.77	1.60
		C-factor	8.19	5.78	3.78	4.74	2.11
		R_u	0.27	0.32	0.41	0.36	0.62
		R_c	0.12	0.17	0.26	0.21	0.47
		HC	367	245	253	172	184

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls *(Continued)*

Product Size, mm	Density, kg/m^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
250 mm Block	1360	U-factor	2.48	2.17	1.40	2.00	0.72
		C-factor	3.95	3.22	1.77	2.85	0.81
		R_u	0.40	0.46	0.71	0.50	1.39
		R_c	0.25	0.31	0.56	0.35	1.24
		HC	388	229	239	134	150
	1520	U-factor	2.65	2.31	1.52	2.12	0.82
		C-factor	4.38	3.53	1.97	3.11	0.93
		R_u	0.38	0.43	0.66	0.47	1.22
		R_c	0.23	0.28	0.51	0.32	1.07
		HC	402	244	254	149	165
	1680	U-factor	2.79	2.44	1.65	2.24	0.92
		C-factor	4.80	3.84	2.19	3.36	1.07
		R_u	0.36	0.41	0.61	0.45	1.09
		R_c	0.21	0.26	0.46	0.30	0.94
		HC	417	259	269	163	180
250 mm Block	1840	U-factor	2.93	2.56	1.77	2.35	1.03
		C-factor	5.22	4.14	2.40	3.63	1.22
		R_u	0.34	0.39	0.57	0.43	0.97
		R_c	0.19	0.24	0.42	0.28	0.82
		HC	432	273	284	178	194
	2000	U-factor	3.09	2.70	1.93	2.49	1.18
		C-factor	5.75	4.53	2.71	3.96	1.44
		R_u	0.32	0.37	0.52	0.40	0.85
		R_c	0.17	0.22	0.37	0.25	0.70
		HC	447	288	298	193	209
	2160	U-factor	3.29	2.89	2.15	2.68	1.42
		C-factor	6.50	5.11	3.17	4.46	1.80
		R_u	0.30	0.35	0.46	0.37	0.70
		R_c	0.15	0.20	0.32	0.22	0.55
		HC	462	303	313	208	224

TABLE A3.1-3 Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls *(Continued)*

Product Size, mm	Density, kg/m^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
300 mm Block	1360	U-factor	2.24	2.05	1.24	1.94	0.60
		C-factor	3.38	2.96	1.52	2.73	0.66
		R_u	0.45	0.49	0.81	0.52	1.66
		R_c	0.30	0.34	0.66	0.34	1.51
		HC	472	273	285	153	174
	1520	U-factor	2.39	2.18	1.35	2.06	0.68
		C-factor	3.72	3.24	1.69	2.97	0.76
		R_u	0.42	0.46	0.74	0.49	1.47
		R_c	0.27	0.31	0.59	0.34	1.32
		HC	489	290	302	170	191
	1680	U-factor	2.52	2.30	1.46	2.17	0.77
		C-factor	4.05	3.51	1.86	3.21	0.87
		R_u	0.40	0.43	0.69	0.46	1.29
		R_c	0.25	0.28	0.54	0.31	1.14
		HC	506	307	319	187	208
	1840	U-factor	2.65	2.41	1.56	2.28	0.87
		C-factor	4.38	3.77	2.04	3.46	1.00
		R_u	0.38	0.41	0.64	0.44	1.15
		R_c	0.23	0.27	0.49	0.29	1.00
		HC	523	323	336	204	225
	2000	U-factor	2.79	2.55	1.70	2.41	1.00
		C-factor	4.79	4.12	2.28	3.77	1.18
		R_u	0.36	0.39	0.59	0.42	1.00
		R_c	0.21	0.24	0.44	0.27	0.85
		HC	540	340	353	221	242
	2160	U-factor	2.98	2.73	1.91	2.59	1.22
		C-factor	5.37	4.62	2.67	4.23	1.49
		R_u	0.34	0.37	0.52	0.39	0.82
		R_c	0.19	0.22	0.37	0.24	0.67
		HC	557	357	370	238	259

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

Depth, mm	Framing Type	Rated R-Value of Insulation																									
		0	0.18	0.35	0.53	0.70	0.88	1.06	1.23	1.41	1.58	1.76	1.94	2.11	2.29	2.46	2.64	2.82	2.99	3.17	3.35	3.52	3.70	3.87	4.05	4.23	4.40
Effective R-value if Continuous Insulation Uninterrupted by Framing (Includes Gypsum Board)																											
	None	0.08	0.26	0.43	0.61	0.78	0.96	1.14	1.31	1.49	1.66	1.84	2.02	2.19	2.37	2.54	2.72	2.90	3.07	3.25	3.42	3.60	3.78	3.95	4.13	4.30	4.48
Effective R-value if Insulation is Installed in Cavity between Framing (Includes Gypsum Board)																											
13	Wood	0.22	0.24	0.34	0.41	0.47	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.16	0.16	0.19	0.20	0.21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Wood	0.24	0.25	0.38	0.47	0.55	0.61	0.66	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.18	0.18	0.22	0.24	0.26	0.27	0.27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Wood	0.23	0.26	0.40	0.51	0.60	0.68	0.75	0.81	0.86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.18	0.19	0.25	0.28	0.30	0.31	0.32	0.33	0.34	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
38	Wood	0.24	0.26	0.42	0.55	0.67	0.77	0.87	0.95	1.02	1.08	1.14	1.20	1.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.19	0.21	0.28	0.33	0.36	0.39	0.41	0.42	0.44	0.45	0.45	0.46	0.47	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
51	Wood	0.24	0.27	0.43	0.58	0.71	0.83	0.94	1.04	1.13	1.21	1.29	1.36	1.42	1.48	1.54	1.59	1.64	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Metal	0.20	0.22	0.31	0.37	0.41	0.45	0.48	0.50	0.52	0.53	0.55	0.56	0.57	0.58	0.58	0.59	0.60	NA	NA	NA	NA	NA	NA	NA	NA	NA
64	Wood	0.24	0.27	0.44	0.60	0.74	0.87	0.99	1.10	1.21	1.30	1.39	1.47	1.55	1.62	1.69	1.76	1.82	1.87	1.93	1.98	2.03	NA	NA	NA	NA	NA
	Metal	0.21	0.22	0.32	0.40	0.45	0.50	0.53	0.56	0.59	0.61	0.63	0.64	0.66	0.67	0.68	0.69	0.70	0.71	0.71	0.72	0.73	NA	NA	NA	NA	NA
76	Wood	0.24	0.27	0.45	0.61	0.76	0.90	1.03	1.15	1.26	1.37	1.47	1.56	1.65	1.73	1.81	1.89	1.96	2.03	2.09	2.15	2.21	2.26	NA	NA	NA	NA
	Metal	0.21	0.23	0.34	0.42	0.48	0.54	0.58	0.62	0.65	0.67	0.70	0.72	0.74	0.75	0.77	0.78	0.79	0.80	0.81	0.82	0.83	0.84	NA	NA	NA	NA
89	Wood	0.25	0.27	0.45	0.62	0.77	0.92	1.06	1.19	1.31	1.42	1.53	1.64	1.73	1.83	1.91	2.00	2.08	2.15	2.23	2.30	2.36	2.43	2.49	2.55	2.60	2.66
	Metal	0.21	0.23	0.35	0.44	0.51	0.57	0.62	0.66	0.70	0.73	0.76	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97
102	Wood	0.25	0.27	0.45	0.63	0.79	0.94	1.08	1.22	1.35	1.47	1.58	1.69	1.80	1.90	2.00	2.09	2.18	2.26	2.34	2.42	2.49	2.56	2.63	2.70	2.76	2.82
	Metal	0.22	0.23	0.36	0.45	0.53	0.60	0.66	0.71	0.76	0.76	0.82	0.85	0.87	0.90	0.92	0.94	0.95	0.97	0.99	1.00	1.01	1.02	1.04	1.05	10.6	1.06
114	Wood	0.25	0.27	0.46	0.63	0.80	0.95	1.10	1.24	1.38	1.50	1.63	1.74	1.86	1.96	2.07	2.16	2.26	2.35	2.44	2.52	2.60	2.68	2.76	2.83	2.90	2.97
	Metal	0.22	0.24	0.36	0.47	0.55	0.62	0.69	0.74	0.79	0.83	0.87	0.90	0.93	0.96	0.98	1.01	1.03	1.05	1.06	1.08	1.10	1.11	1.12	1.14	1.15	1.16
127	Wood	0.25	0.27	0.46	0.64	0.80	0.96	1.12	1.26	1.40	1.53	1.66	1.79	1.90	2.02	2.13	2.23	2.33	2.43	2.52	2.61	2.70	2.78	2.87	2.94	3.02	3.09
	Metal	0.22	0.24	0.37	0.48	0.57	0.65	0.71	0.77	0.83	0.87	0.91	0.95	0.99	1.02	1.05	1.07	1.09	1.12	1.14	1.16	1.17	1.19	1.21	1.22	1.23	1.25
140	Wood	0.25	0.27	0.46	0.64	0.81	0.97	1.13	1.28	1.42	1.56	1.69	1.82	1.94	2.06	2.18	2.29	2.39	2.50	2.60	2.69	2.78	2.87	2.96	3.05	3.13	3.21
	Metal	0.22	0.24	0.37	0.49	0.58	0.67	0.74	0.80	0.86	0.91	0.96	1.00	1.04	1.07	1.10	1.13	1.16	1.18	1.21	1023	1.25	1.27	1.28	1.30	1.31	1.33

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-1.1	R-1.7	R-2.3	R-2.8	R-3.3	R3.9	R-4.4	R-5.6	R-6.7
Single Layer of Mineral Fiber											
	None	6.70	0.773	0.53	0.41	0.34	0.29	0.25	0.22	0.17	0.15
	R-1.8	1.06	0.48	0.37	0.31	0.27	0.23	0.21	0.19	0.15	0.13
	R-1.9	1.05	0.48	0.37	0.31	0.27	0.23	0.21	0.19	0.15	0.13
	R-2.3	0.920	0.45	0.36	0.30	0.26	0.23	0.20	0.18	0.15	0.13
	R-2.8	0.880	0.44	0.35	0.29	0.26	0.22	0.20	0.18	0.15	0.13
	R-3.3	0.835	0.43	0.34	0.28	0.25	0.22	0.20	0.18	0.15	0.13

TABLE A3.3.3.1 Assembly U-Factors for Steel-Frame Walls

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed [see Table A9.2B])	Overall U-Factor for Entire Base Wall Assembly	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing) — Rated R-Value of Continuous Insulation																			
			R-0.18	R-0.35	R-0.53	R-0.71	R-0.88	R-1.06	R-1.23	R-1.41	R-1.59	R-1.76	R-1.94	R-2.12	R-2.29	R-2.47	R-2.65	R-3.53	R-4.41	R-5.29	R-6.17	R-7.05
Steel Framing at 400 mm on Center																						
89 mm depth	None (0.0)	2.00	1.48	1.17	0.97	0.83	0.72	0.64	0.58	0.52	0.48	0.44	0.41	0.38	0.36	0.34	0.32	0.25	0.20	0.17	0.15	0.13
	R-1.9 (1.0)	0.75	0.66	0.59	0.54	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.21	0.17	0.15	0.13	0.12
	R-2.3 (1.1)	0.70	0.63	0.56	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.25	0.20	0.17	0.15	0.13	0.12
	R-2.6 (1.1)	0.67	0.60	0.54	0.50	0.46	0.42	0.39	0.37	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.20	0.17	0.15	0.13	0.12
152 mm depth	R-3.3 (1.3)	0.62	0.56	0.51	0.47	0.43	0.40	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.24	0.23	0.19	0.17	0.14	0.13	0.12
	R-3.7 (1.3)	0.60	0.54	0.50	0.46	0.42	0.39	0.37	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.19	0.16	0.14	0.13	0.11
Steel Framing at 600 mm on Center																						
89 mm depth	None (0.0)	1.92	1.43	1.14	0.95	0.81	0.71	0.63	0.57	0.52	0.47	0.44	0.41	0.38	0.36	0.33	0.32	0.25	0.20	0.17	0.15	0.13
	R-1.9 (1.2)	0.66	0.59	0.53	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.20	0.17	0.15	0.13	0.12
	R-2.3 (1.3)	0.61	0.55	0.50	0.46	0.43	0.40	0.37	0.35	0.33	0.31	0.29	0.28	0.27	0.25	0.24	0.23	0.19	0.17	0.14	0.13	0.12
	R-2.6 (1.4)	0.58	0.52	0.48	0.44	0.41	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.19	0.16	0.14	0.13	0.11
152 mm depth	R-3.3 (1.5)	0.53	0.49	0.45	0.42	0.39	0.36	0.34	0.32	030	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.18	0.16	0.14	0.12	0.11
	R-3.7 (1.6)	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.18	0.16	0.14	0.12	0.11

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 A9.4C])	Overall U-Factor for Entire Base Wall Assembly	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation																			
			R-0.18	R-0.35	R-0.53	R-0.71	R-0.88	R-1.06	R-1.23	R-1.41	R-1.59	R-1.76	R-1.94	R-2.12	R-2.29	R-2.47	R-2.65	R-3.53	R-4.41	R-5.29	R-6.17	R-7.05
Wood Studs at 400 mm on Center																						
89 mm depth	None (0.0)	1.66	1.26	1.03	0.86	0.75	0.66	0.59	0.53	0.49	0.45	0.41	0.39	0.36	0.34	0.32	0.30	0.24	0.20	0.17	0.15	0.13
	R-1.9 (1.9)	0.55	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.18	0.16	0.14	0.12	0.11
	R-2.3 (2.3)	0.50	0.46	0.42	0.39	0.36	0.34	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.22	0.21	0.17	0.15	0.13	0.12	0.11
	R-2.6 (2.6)	0.47	0.43	0.39	0.36	0.34	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.21	0.21	0.20	0.17	0.15	0.13	0.12	0.11
140 mm depth	R-3.3 (3.2)	0.38	0.35	0.33	0.31	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.16	0.14	0.12	0.11	0.10
	R-3.7 (3.7)	0.35	0.33	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.18	0.18	0.17	0.15	0.13	0.12	0.11	0.10
+ R-1.8 headers	R-3.3 (3.2)	0.36	0.34	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.18	0.18	0.15	0.14	0.12	0.11	0.10
	R-3.7 (3.7)	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.15	0.13	0.12	0.10	0.10
Wood Studs at 600 mm on Center																						
89 mm depth	None (0.0)	1.69	1.28	1.04	0.87	0.76	0.66	0.59	0.54	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.30	0.24	0.20	0.17	0.15	0.13
	R-1.9 (1.9)	0.53	0.48	0.44	0.41	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.22	0.18	0.16	0.14	0.12	0.11
	R-2.3 (2.3)	0.49	0.44	0.41	0.38	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.17	0.15	0.13	0.12	0.11
	R-2.6 (2.6)	0.45	0.41	0.38	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.17	0.14	0.13	0.12	0.10
140 mm depth	R-3.3 (3.2)	0.37	0.34	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.19	0.18	0.15	0.14	0.12	0.11	0.11
	R-3.7 (3.7)	0.34	0.32	0.30	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.15	0.13	0.12	0.10	0.10
+ R-1.8 headers	R-3.3 (3.2)	0.35	0.33	0.31	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.15	0.13	0.12	0.11	0.10
	R-3.7 (3.79)	0.32	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.14	0.13	0.11	0.10	0.10

A4. BELOW-GRADE WALLS

A4.1 General. For the purpose of Section A1.2, The base assembly is 200 mm medium-weight concrete block with a density of 1840 kg/m^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-0.08 for 13 mm gypsum board.

A4.2 C-Factors for Below-Grade Walls

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

A4.2.2 It is acceptable to use the C-factors in Table A4.2.1 for all below-grade walls.

A4.2.3 If not taken from Table A4.2.1, below-grade wall C-factors shall be determined from Tables A3.1-2, A3.1-3, or A3.1-4 using the following procedure:

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

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

TABLE A4.2.1 Assembly C-Factors for Below-Grade Walls

Framing Type and Depth	Rated R-Value of Insulation Alone	Specified C-Factors (Wall Only, without Soil and Air Films)
No Framing	R-0	C-6.48
Exterior Insulation, Continuous and Uninterrupted by Framing		
No Framing	R-0.88	C-0.97
No Framing	R-1.32	C-0.68
No Framing	R-1.76	C-0.52
No Framing	R-2.20	C-0.43
No Framing	R-2.64	C-0.36
No Framing	R-3.08	C-0.31
No Framing	R-3.52	C-0.27
No Framing	R-4.40	C-0.22
No Framing	R-5.28	C-0.18
No Framing	R-6.16	C-0.16
No Framing	R-7.04	C-0.14
No Framing	R-7.92	C-0.12
No Framing	R-8.80	C-0.11
Continuous Metal Framing at 600 mm on Center Horizontally		
89 mm	R-1.94	C-1.03
89 mm	R-2.29	C-0.99
89 mm	R-2.64	C-0.95
140 mm	R-3.35	C-0.71
140 mm	R-3.70	C-0.68
25 mm Metal Clips at 600 mm on Center Horizontally and 400 mm Vertically		
25 mm	R-0.67	C-1.32
25 mm	R-0.88	C-1.14
25 mm	R-0.99	C-0.95
38 mm	R-1.00	C-0.98
38 mm	R-1.32	C-0.83
38 mm	R-1.48	C-0.78
51 mm	R-1.34	C-0.78
51 mm	R-1.76	C-0.66
51 mm	R-1.97	C-0.61
64 mm	R-1.67	C-0.65
64 mm	R-2.20	C-0.55
64 mm	R-2.46	C-0.51
76 mm	R-2.01	C-0.56
76 mm	R-2.64	C-0.47
76 mm	R-2.96	C-0.43
89 mm	R-2.34	C-0.48
89 mm	R-3.08	C-0.40
89 mm	R-3.45	C-0.37
102 mm	R-2.68	C-0.43
102 mm	R-3.52	C-0.36
102 mm	R-3.94	C-0.33

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-0.16 for interior air film-heat flow down, R-0.22 for carpet and rubber pad, R-0.09 for 203 mm concrete, and R-0.08 for semi-exterior air film. Added insulation is continuous and uninterrupted by framing. Framing factor is zero.

A5.2.2 Rated R-Value of Insulation for Mass Floors

A5.2.2.1 The rated R-value of insulation is for continuous insulation uninterrupted by framing.

A5.2.2.2 Where framing, including metal and wood joists, is used, compliance shall be based on the maximum assembly U-factor rather than the minimum rated R-value of insulation.

A5.2.2.3 For waffle-slab floors, the floor shall be insulated either on the interior above the slab or on all exposed surfaces of the waffle.

A5.2.2.4 For floors with beams that extend below the floor slab, the floor shall be insulated either on the interior above the slab or on the exposed floor and all exposed surfaces of the beams that extend 600 mm 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-0.16 for interior air film—heat flow down, R-0.22 for carpet and pad, R-0.04 for 102 mm concrete, R-0 for metal deck, and R-0.08 for semi-exterior air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2-1.

A5.3.2 Rated R-Value of Insulation for Steel-Joist Floors

A5.3.2.1 The first rated R-value of insulation is for uncompressed insulation installed in the cavity between steel joists or for spray-on insulation.

A5.3.2.2 It is acceptable for this insulation to also be continuous insulation uninterrupted by framing. All continuous insulation shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.3.3 U-Factors for Steel-Joist Floors

A5.3.3.1 The U-factors for steel-joist floors shall be taken from Table A5.3.3.1.

A5.3.3.2 It is acceptable to use these U-factors for any steel-joist floor.

A5.4 Wood-Framed and Other Floors

A5.4.1 General. For the purpose of Section A1.2, the base assembly is a floor attached directly to the top of the wood joist with insulation located directly below the floor and ventilated airspace below the insulation. The heat flow path through the joist is calculated to be the same depth as the insulation. The U-factors include R-0.16 for interior air film—heat flow down, R-0.22 for carpet and pad, R-0.17 for 19 mm wood subfloor, and R-0.08 for semi-exterior air film. The weighting factors are 91% insulated cavity and 9% framing.

A5.4.2 Rated R-Value of Insulation for Wood-Framed and Other Floors

A5.4.2.1 The first rated R-value of insulation is for uncompressed insulation installed in the cavity between wood joists.

A5.4.2.2 It is acceptable for this insulation to also be continuous insulation uninterrupted by framing. All continuous insulation shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.4.3 U-Factors for Wood-Framed Floors

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

A5.4.3.2 It is not acceptable to use these U-factors if the framing is not wood.

TABLE A5.2.3.1 Assembly U-Factors for Mass Floors

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed)	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (Uninterrupted by Framing) — Rated R-Value of Continuous Insulation																			
			R-0.18	R-0.35	R-0.53	R-0.71	R-0.88	R-1.06	R-1.23	R-1.41	R-1.59	R-1.76	R-1.94	R-2.12	R-2.29	R-2.47	R-2.65	R-3.53	R-4.41	R-5.29	R-6.17	R-7.05
Concrete Floor with Rigid Foam																						
	None (0.0)	1.82	1.38	1.11	0.93	0.80	0.70	0.62	0.56	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.25	0.20	0.17	0.15	0.13
Concrete Floor with Pinned Boards																						
	R-0.74 (0.74)	0.78	0.68	0.61	0.55	0.50	0.46	0.43	0.40	0.37	0.35	0.33	0.31	0.29	0.28	0.27	0.25	0.21	0.18	0.15	0.13	0.12
	R-1.11 (1.11)	0.61	0.55	0.50	0.46	0.42	0.39	0.37	0.35	0.33	0.31	0.29	0.28	0.27	0.25	0.24	0.23	0.19	0.16	0.14	0.13	0.11
	R-1.46 (1.46)	0.50	0.46	0.42	0.39	0.37	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.18	0.16	0.14	0.12	0.11
	R-1.83 (1.83)	0.42	0.39	0.36	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.17	0.15	0.13	0.12	0.11
	R-2.20 (2.20)	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.19	0.16	0.14	0.12	0.11	0.10
	R-2.57 (2.57)	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.15	0.13	0.12	0.11	0.10
	R-2.95 (2.95)	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.14	0.13	0.11	0.10	0.09
Concrete Floor with Spray-On Insulation																						
25 mm	R-0.71 (0.71)	0.80	0.70	0.62	0.56	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.21	0.18	0.15	0.13	0.12
51 mm	R-1.41 (1.41)	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.18	0.16	0.14	0.12	0.11
76 mm	R-2.12 (2.12)	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.16	0.14	0.13	0.11	0.10
102 mm	R-2.82 (2.82)	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.14	0.13	0.12	0.10	0.10
127 mm	R-3.53 (3.53)	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.13	0.12	0.11	0.10	0.10
152 mm	R-4.23 (4.23)	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.12	0.11	0.10	0.09	0.08

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-0.18	R-0.35	R-0.53	R-0.71	R-0.88	R-1.06	R-1.23	R-1.41	R-1.59	R-1.76	R-1.94	R-2.12	R-2.29	R-2.47	R-2.65	R-3.53	R-4.41	R-5.29	R-6.17	R-7.05
Steel Joist Floor with Rigid Foam																						
	None (0.0)	1.98	1.47	1.17	0.97	0.83	0.72	0.64	0.58	0.52	0.48	0.44	0.41	0.38	0.36	0.34	0.32	0.25	0.20	0.17	0.15	0.13
Steel Joist Floor with Spray-on Insulation																						
25 mm	R-0.70 (0.68)	0.84	0.73	0.65	0.58	0.53	0.48	0.45	0.41	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.21	0.18	0.15	0.14	0.12
51 mm	R-1.41 (1.32)	0.55	0.50	0.46	0.42	0.39	0.37	0.35	0.33	0.31	0.29	0.28	0.27	0.25	0.24	0.23	0.22	0.19	0.16	0.14	0.12	0.11
76 mm	R-2.11 (1.90)	0.42	0.39	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.17	0.15	0.13	0.12	0.11
102 mm	R-2.82 (2.45)	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.15	0.14	0.12	0.11	0.10
127 mm	R-3.52 (2.99)	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.14	0.13	0.11	0.10	0.09
152 mm	R-4.23 (3.46)	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.16	0.15	0.13	0.12	0.11	0.10	0.09
Steel Joist Floor with Batt Insulation																						
	None (0.0)	1.98	1.47	1.17	0.97	0.83	0.72	0.64	0.58	0.52	0.48	0.44	0.41	0.38	0.36	0.34	0.32	0.25	0.20	0.17	0.15	0.13
	R-1.94 (1.76)	0.44	0.41	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.17	0.15	0.13	0.12	0.11
	R-2.29 (2.06)	0.39	0.36	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.16	0.14	0.13	0.11	0.10
	R-2.64 (2.32)	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.16	0.14	0.12	0.11	0.10
	R-3.35 (2.88)	0.30	0.28	0.27	0.26	0.24	0.23	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.14	0.13	0.12	0.10	0.10
	R-3.70 (3.11)	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.14	0.12	0.11	0.10	0.09
	R-4.40 (3.57)	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.13	0.12	0.11	0.10	0.09
	R-5.3C (4.17)	0.21	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.12	0.11	0.10	0.09	0.09
	R-5.28 (4.17)	0.21	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.12	0.11	0.10	0.09	0.09
	R-6.7C (4.95)	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.11	0.10	0.09	0.09	0.08
	R-6.69 (4.95)	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.11	0.10	0.09	0.09	0.08

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-0.18	R-0.35	R-0.53	R-0.71	R-0.88	R-1.06	R-1.23	R-1.41	R-1.59	R-1.76	R-1.94	R-2.12	R-2.29	R-2.47	R-2.65	R-3.53	R-4.41	R-5.29	R-6.17	R-7.05
Wood Joists																						
140 mm	None (0.0)	1.60	1.25	1.02	0.87	0.75	0.66	0.59	0.54	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.31	0.24	0.20	0.17	0.15	0.13
	R-1.94 (1.94)	0.42	0.39	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.17	0.15	0.13	0.12	0.11
	R-2.29 (2.29)	0.38	0.35	0.33	0.31	0.29	0.28	0.27	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.19	0.16	0.14	0.12	0.11	0.10
	R-2.65 (2.65)	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.15	0.13	0.12	0.11	0.10
	R-3.35 (3.17)	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.14	0.13	0.11	0.10	0.09
	R-3.70 (3.70)	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.13	0.12	0.11	0.10	0.09
184 mm	R-4.41 (4.41)	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.12	0.11	0.10	0.09	0.08
	R-5.3C (5.29)	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.11	0.10	0.09	0.09	0.08
235 mm	R-5.29 (5.29)	0.19	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.11	0.10	0.09	0.09	0.08
286 mm	R-6.7C (6.70)	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.09	0.08	0.08	0.07
337 mm	R-6.70 (6.70)	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.09	0.08	0.08	0.07

A6. SLAB-ON-GRADE FLOORS

A6.1 General. For the purpose of Section A1.2, the base assembly is a slab floor of 150 mm concrete poured directly on to the earth, the bottom of the slab is at grade line, and soil conductivity is 1.30 $W/m^2 \cdot K$. In contrast to the U-factor for floors, the F-factor for slab-on-grade floors is expressed per linear foot of building perimeter. F-factors are provided for unheated slabs and for heated slabs. Unheated slab-on-grade floors do not have heating elements, and heated slab-on-grade floors do have heating elements within or beneath the slab. F-factors are provided for three insulation configurations:

a. Horizontal Insulation: continuous insulation is applied directly to the underside of the slab and extends inward horizontally from the perimeter for the distance specified or continuous insulation is applied downward from the top of the slab and then extends horizontally to the interior or the exterior from the perimeter for the distance specified.
b. Vertical Insulation: continuous insulation is applied directly to the slab exterior, extending downward from the top of the slab for the distance specified.
c. Fully Insulated Slab: continuous insulation extends downward from the top of the slab and along the entire perimeter and completely covers the entire area under the slab.

A6.2 Rated R-Value of Insulation for Slab-on-Grade Floors

A6.2.1 The rated R-value of insulation shall be installed around the perimeter of the slab-on-grade floor to the distance specified.

Exception: For a monolithic slab-on-grade floor, the insulation shall extend from the top of the slab-on-grade to the bottom of the footing.

A6.2.2 Insulation installed inside the foundation wall shall extend downward from the top of the slab a minimum of the distance specified or to the top of the footing, whichever is less.

A6.2.3 Insulation installed outside the foundation wall shall extend from the top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum of the distance specified. In all climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 250 mm thick.

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

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

A6.3.2 These F-factors are acceptable for all slab-on-grade floors.

TABLE A6.3.1 Assembly F-Factors for Slab-on-Grade Floors

Insulation Description	Rated R-Value of Insulation												
	R-0.0	R-0.9	R-1.3	R-1.8	R-2.6	R-3.5	R-4.4	R-5.3	R-6.2	R-7.0	R-7.9	R-8.8	R-9.7
Unheated Slabs													
None	1.26												
300 mm horizontal		1.24	1.23	1.23	1.23								
600 mm horizontal		1.21	1.21	1.20	1.19								
900 mm horizontal		1.18	1.17	1.15	1.14								
1200 mm horizontal		1.16	1.13	1.11	1.09								
300 mm vertical		1.05	1.03	1.01	0.99	0.98	0.98	0.98					
600 mm vertical		1.00	0.97	0.93	0.90	0.88	0.87	0.87					
900 mm vertical		0.97	0.93	0.88	0.84	0.82	0.80	0.80					
1200 mm vertical		0.93	0.88	0.83	0.78	0.75	0.73	0.72					
Fully insulated slab		0.80	0.71	0.62	0.52	0.45	0.40	0.37	0.34	0.32	0.30	0.29	0.28
Heated Slabs													
None	2.33												
300 mm horizontal		2.27	2.26	2.26	2.25								
600 mm horizontal		2.21	2.19	2.18	2.16								
900 mm horizontal		2.14	2.10	2.07	2.04								
1200 mm horizontal		2.08	2.02	1.96	1.92								
300 mm vertical		1.84	1.76	1.73	1.70	1.67	1.67	1.66					
600 mm vertical		1.72	1.64	1.57	1.50	1.46	1.44	1.43					
900 mm vertical		1.64	1.54	1.45	1.36	1.32	1.29	1.28					
1200 mm vertical		1.57	1.47	1.35	1.25	1.19	1.16	1.14					
Fully insulated slab		1.28	1.11	0.95	0.76	0.65	0.56	0.51	0.47	0.44	0.41	0.39	0.38

A7. OPAQUE DOORS

All opaque doors with U-factors determined, certified, and labeled in accordance with NFRC 100 shall be assigned those U-factors.

A7.1 Unlabeled Opaque Doors. Unlabeled opaque doors shall be assigned the following U-factors:

a. Uninsulated single-layer metal swinging doors or nonswinging doors, including single-layer uninsulated access hatches and uninsulated smoke vents: 8.2
b. Uninsulated double-layer metal swinging doors or nonswinging doors, including double-layer uninsulated access hatches and uninsulated smoke vents: 4.0
c. Insulated metal swinging doors, including fire-rated doors, insulated access hatches, and insulated smoke vents: 2.8
d. Wood doors, minimum nominal thickness of 44 mm, including panel doors with minimum panel thickness of 28 mm, solid core flush doors, and hollow core flush doors: 2.8
e. Any other wood door: 3.4

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 6 mm.

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	3 mm glass	11.24	10.73	9.96	8.34	7.73	7.09	7.09
2	6.4 mm acrylic/ polycarb	10.33	9.82	9.07	7.45	6.90	6.26	6.26
3	3 mm acrylic/ polycarb	10.79	10.27	9.52	7.89	7.31	6.67	6.67
	Double Glazing							
4	6.4 mm airspace	7.44	6.32	5.94	4.79	4.64	3.99	3.74
5	12.7 mm airspace	7.39	6.27	5.90	4.74	4.59	3.95	3.70
6	6.4 mm argon space	7.19	6.06	5.70	4.54	4.40	3.75	3.50
7	12.7 mm argon space	7.19	6.06	5.70	4.54	4.40	3.75	3.50
	Double Glazing, *e* = 0.60 on surface 2 or 3							
8	6.4 mm airspace	7.24	6.11	5.75	4.59	4.45	3.80	3.55
9	12.7 mm airspace	7.19	6.06	5.70	4.54	4.40	3.75	3.50
10	6.4 mm argon space	6.98	5.86	5.49	4.34	4.20	3.56	3.31
11	12.7 mm argon space	6.98	5.86	5.49	4.34	4.20	3.56	3.31
	Double Glazing, *e* = 0.40 on surface 2 or 3							
12	6.4 mm airspace	7.09	5.96	5.59	4.44	4.30	3.66	3.41
13	12.7 mm airspace	7.03	5.91	5.54	4.39	4.25	3.61	3.36
14	6.4 mm argon space	6.73	5.60	5.24	4.09	3.96	3.32	3.07
15	12.7 mm argon space	6.83	5.70	5.34	4.19	4.06	3.41	3.16
	Double Glazing, *e* = 0.20 on surface 2 or 3							
16	6.4 mm airspace	6.83	5.70	5.34	4.19	4.06	3.41	3.16
17	12.7 mm airspace	6.83	5.70	5.34	4.19	4.06	3.41	3.16
18	6.4 mm argon space	6.47	5.34	4.99	3.84	3.72	3.07	2.83
19	12.7 mm argon space	6.52	5.39	5.04	3.89	3.77	3.12	2.87
	Double Glazing, *e* = 0.10 on surface 2 or 3							
20	6.4 mm airspace	6.73	5.60	5.24	4.09	3.96	3.32	3.07
21	12.7 mm airspace	6.73	5.60	5.24	4.09	3.96	3.32	3.07
22	6.4 mm argon space	6.31	5.18	4.84	3.69	3.57	2.93	2.68
23	12.7 mm argon space	6.41	5.29	4.94	3.79	3.67	3.03	2.78
	Double Glazing, *e* = 0.05 on surface 2 or 3							
24	6.4 mm airspace	6.62	5.50	5.14	3.99	3.87	3.22	2.97

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							
25	12.7 mm airspace	6.67	5.55	5.19	4.04	3.91	3.27	3.02
26	6.4 mm argon space	6.21	5.08	4.73	3.58	3.48	2.83	2.58
27	12.7 mm argon space	6.31	5.18	4.84	3.69	3.57	2.93	2.68
	Triple Glazing							
28	6.4 mm airspaces	6.38	5.07	4.77	3.63	3.65	3.02	2.71
29	12.7 mm airspaces	6.22	4.92	4.62	3.48	3.51	2.88	2.56
30	6.4 mm argon spaces	6.17	4.86	4.56	3.43	3.46	2.83	2.51
31	12.7 mm argon spaces	6.07	4.76	4.46	3.33	3.36	2.73	2.41
	Triple Glazing, *e* = 0.20 on surface 2,3,4, or 5							
32	6.4 mm airspace	6.12	4.81	4.51	3.38	3.41	2.78	2.46
33	12.7 mm airspace	5.96	4.65	4.36	3.22	3.26	2.63	2.32
34	6.4 mm argon space	5.81	4.50	4.21	3.07	3.11	2.49	2.17
35	12.7 mm argon space	5.75	4.44	4.15	3.02	3.07	2.44	2.12
	Triple Glazing, *e* = 0.20 on surfaces 2 or 3 and 4 or 5							
36	6.4 mm airspace	5.86	4.55	4.26	3.12	3.16	2.53	2.22
37	12.7 mm airspace	5.75	4.44	4.15	3.02	3.07	2.44	2.12
38	6.4 mm argon space	5.60	4.29	4.00	2.86	2.92	2.29	1.97
39	12.7 mm argon space	5.49	4.18	3.90	2.76	2.82	2.19	1.87
	Triple Glazing, *e* = 0.10 on surfaces 2 or 3 and 4 or 5							
40	6.4 mm airspace	5.75	4.44	4.15	3.02	3.07	2.44	2.12
41	12.7 mm airspace	5.65	4.34	4.05	2.91	2.97	2.34	2.02
42	6.4 mm argon space	5.44	4.13	3.84	2.71	2.77	2.14	1.82
43	12.7 mm argon space	5.38	4.07	3.79	2.66	2.72	2.09	1.78
	Quadruple Glazing, *e* = 0.10 on surfaces 2 or 3 and 4 or 5							
44	6.4 mm airspace	5.49	4.18	3.90	2.76	2.82	2.19	1.87
45	12.7 mm airspace	5.33	4.02	3.74	2.60	2.67	2.04	1.73
46	6.4 mm argon space	5.28	3.97	3.69	2.55	2.62	1.99	1.68
47	12.7 mm argon space	5.17	3.86	3.59	2.45	2.52	1.90	1.58
48	6.4 mm krypton spaces	5.01	3.70	3.43	2.29	2.38	1.75	1.43

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, 3 mm glass	0.82	0.76	0.78	0.76	0.73	0.73
	Single glazing, 6 mm 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, 3 mm glass	0.70	0.58	0.66	0.58	0.62	0.56
	Single glazing, 6 mm glass	0.61	0.45	0.56	0.45	0.52	0.44
	Single glazing, acrylic/polycarbonate	0.46	0.27	0.46	0.27	0.46	0.27
	Double glazing	0.50	0.40	0.46	0.40	0.42	0.39
	Double glazing, *e* = 0.40 on surface 2 or 3	0.59	0.50	0.55	0.50	0.50	0.48
	Double glazing, *e* = 0.20 on surface 2 or 3	0.47	0.37	0.43	0.37	0.39	0.36
	Double glazing, *e* = 0.10 on surface 2 or 3	0.43	0.38	0.39	0.38	0.35	0.37
	Double glazing, acrylic/polycarbonate	0.37	0.25	0.37	0.25	0.37	0.25
	Triple glazing	0.42	0.22	0.37	0.22	0.34	0.21
	Triple glazing, *e* = 0.40 on surface 2, 3, 4, or 5	0.53	0.45	0.49	0.45	0.45	0.44
	Triple glazing, *e* = 0.20 on surface 2, 3, 4, or 5	0.42	0.33	0.38	0.33	0.35	0.32
	Triple glazing, *e* = 0.10 on surface 2, 3, 4, or 5	0.39	0.34	0.35	0.34	0.31	0.33
	Triple glazing, *e* = 0.40 on surfaces 3 and 5	0.51	0.43	0.47	0.43	0.43	0.42
	Triple glazing, *e* = 0.20 on surfaces 3 and 5	0.40	0.31	0.36	0.31	0.32	0.29
	Triple glazing, *e* = 0.10 on surfaces 3 and 5	0.34	0.32	0.30	0.32	0.27	0.31
	Triple glazing, acrylic/polycarbonate	0.30	0.23	0.30	0.23	0.30	0.23
	Quadruple glazing, *e* = 0.10 on surfaces 3 and 5	0.30	0.29	0.26	0.29	0.23	0.28
	Quadruple glazing, acrylic/polycarbonate	0.27	0.25	0.27	0.25	0.27	0.25

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

Frame Type	Glazing Type	Unlabeled Vertical Fenestration					
		Clear Glass			Tinted Glass		
		U-Factor	SHGC	VT	U-Factor	SHGC	VT
All frame types	Single glazing	7.1	0.82	0.76	7.1	0.70	0.58
	Glass block	3.4	0.56	0.56	NA	NA	NA
Wood, vinyl, or fiberglass frames	Double glazing	3.4	0.59	0.64	3.4	0.42	0.39
	Triple glazing	2.6	0.52	0.57	2.6	0.34	0.21
Metal and other frame types	Double glazing	5.1	0.68	0.66	5.1	0.50	0.40
	Triple glazing	4.0	0.60	0.59	4.0	0.42	0.22

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

A9.1 General. Component U-factors for other opaque assemblies shall be determined in accordance with Section A9 only if approved by the building official in accordance with Section A1.2. The procedures required for each class of construction are specified in Section A9.2. Testing shall be performed in accordance with Section A9.3. Calculations shall be performed in accordance with Section A9.4.

A9.2 Required Procedures. Two- or three-dimensional finite difference and finite volume computer models shall be an acceptable alternative method to calculating the thermal performance values for all assemblies and constructions listed below. The following procedures shall also be permitted to determine all alternative U-factors, F-factors, and C-factors.

a. Roofs
   1. Roofs with insulation entirely above deck: testing or series calculation method.
   2. Metal building roofs: testing, or for single-layer and double-layer systems, calculation method in Section A9.4.5.
   3. Attic roofs, wood joists: testing or parallel path calculation method.
   4. Attic roofs, steel joists: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2-1 or modified zone calculation method.
   5. Attic roofs, concrete joists: testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
   6. Other attic roofs and other roofs: testing or two-dimensional calculation method.

b. Above-Grade Walls
   1. Mass walls: testing or isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
   2. Metal building walls: testing, or for single-layer and double-layer systems, calculation method in Section A9.4.5.
   3. Steel-framed walls: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2-2 or the modified zone method.
   4. Wood-framed walls: testing or parallel path calculation method.
   5. Other walls: testing or two-dimensional calculation method.

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

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

e. Slab-on-Grade Floors
   No testing or calculations allowed.

A9.3 Testing Procedures

A9.3.1 Building Material Thermal Properties. If building material R-values or thermal conductivities are determined by testing, one of the following test procedures shall be used:

a. ASTM C177
b. ASTM C518
c. ASTM C1363

For concrete, the oven-dried conductivity shall be multiplied by 1.2 to reflect the moisture content as typically installed.

A9.3.2 Assembly U-Factors. If assembly U-factors are determined by testing, ASTM C1363 test procedures shall be used.

Product samples tested shall be production line material or representative of material as purchased by the consumer or contractor. If the assembly is too large to be tested at one time in its entirety, then either a representative portion shall be tested or different portions shall be tested separately and a weighted average determined. To be representative, the portion tested shall include edges of panels, joints with other panels, typical framing percentages, and thermal bridges.

A9.4 Calculation Procedures and Assumptions. The following procedures and assumptions shall be used for all calculations. R-values for air films, insulation, and building materials shall be taken from Sections A9.4.1 through A9.4.3, respectively. In addition, the appropriate assumptions listed in Sections A2 through A8, including framing factors, shall be used.

A9.4.1 Air Films. Prescribed R-values for air films shall be as follows:

R-Value	Condition
0.03	All exterior surfaces
0.08	All semi-exterior surfaces
0.11	Interior horizontal surfaces, heat flow up
0.17	Interior horizontal surfaces, heat flow down
0.12	Interior vertical surfaces

A9.4.1.1 Exterior surfaces are areas exposed to the wind.

A9.4.1.2 Semi-exterior surfaces are protected surfaces that face attics, crawlspaces, and parking garages with natural or mechanical ventilation.

A9.4.1.3 Interior surfaces are surfaces within enclosed spaces.

TABLE A9.2-1 Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (1.2 m 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	3.52	0.85	2.99
0.70	0.97	0.68	3.70	0.84	3.11
0.88	0.96	0.85	4.23	0.82	3.46
1.41	0.94	1.32	4.40	0.81	3.57
1.76	0.92	1.62	5.28	0.79	4.17
1.94	0.91	1.76	6.16	0.76	4.68
2.11	0.90	1.90	6.69	0.74	4.95
2.29	0.90	2.06	7.04	0.73	5.14
2.64	0.88	2.32	7.92	0.71	5.63
2.82	0.87	2.45	8.80	0.69	6.07
3.35	0.86	2.88	9.68	0.67	6.49

TABLE A9.2-2 Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity, mm	Actual Depth of Cavity, mm	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 400 mm on Center	Effective Framing/Cavity R-Value at 600 mm on Center
Empty Cavity, No Insulation				
100	89	R-0.16	0.14	0.16
Insulated Cavity				
100	89	R-1.9	1.0	1.2
100	89	R-2.3	1.1	1.3
100	89	R-2.6	1.1	1.4
150	152	R-3.3	1.3	1.5
150	152	R-3.7	1.3	1.6
200	203	R-4.4	1.4	1.7

A9.4.1.4 The R-value for cavity airspaces shall be taken from Table A9.4.1.4-1 based on the emissivity of the cavity from Table A9.4.1.4-2. No credit shall be given for airspaces in cavities that contain any insulation or are less than 13 mm. The values for 89 mm cavities shall be used for cavities of that width and greater.

A9.4.2 Insulation R-Values. Insulation R-values shall be determined as follows:

a. For insulation that is not compressed, the rated R-value of insulation shall be used.
b. For calculation purposes, the effective R-value for insulation that is uniformly compressed in confined cavities shall be taken from Table A9.4.2.
c. For calculation purposes, the effective R-value for insulation installed in cavities in attic roofs with steel joists shall be taken from Table A9.2-1.
d. For calculation purposes, the effective R-value for insulation installed in cavities in steel-framed walls shall be taken from Table A9.2-2.

A9.4.3 Building Material Thermal Properties. R-values for building materials shall be taken from Table A9.4.3-1. Concrete block R-values shall be calculated using the isothermal planes method or a two-dimensional calculation program, thermal conductivities from Table A9.4.3-2, and dimensions from ASTM C90. The parallel path calculation method is not acceptable.

Exception: R-values for building materials or thermal conductivities determined from testing in accordance with Section A9.3.

A9.4.4 Building Material Heat Capacities. The HC of assemblies shall be calculated using published values for the unit weight and specific heat of all building material components that make up the assembly.

A9.4.5 Metal Building U-Factor Equations. For single-layer metal building roof and wall systems, the calculation procedure outlined in Section A9.4.5.1 shall be used to calculate the assembly U-factor. For double-layer metal building roof and wall systems, the calculation procedure outlined in

TABLE A9.4.1.4-1 Values for Cavity Air Spaces

Component	Airspace Thickness, mm	R-Value Effective Emissivity				
		0.03	0.05	0.20	0.50	0.82
Roof	13	0.38	0.36	0.27	0.18	0.14
	19	0.41	0.39	0.29	0.19	0.14
	38	0.45	0.42	0.31	0.20	0.14
	89	0.50	0.47	0.33	0.21	0.15
Wall	13	0.45	0.43	0.31	0.20	0.14
	19	0.63	0.58	0.38	0.23	0.16
	38	0.69	0.64	0.40	0.24	0.16
	89	0.65	0.60	0.39	0.23	0.16
Floor	13	0.45	0.23	0.18	0.12	0.19
	19	0.25	0.24	0.19	0.13	0.10
	38	0.44	0.42	0.31	0.20	0.15
	89	0.54	0.51	0.35	0.22	0.16

TABLE A9.4.1.4-2 Emittance Values of Various Surfaces and Effective Emittances of Air Spaces

Surface	Average Emissivity *e*	Effective Emissivity — Effective Emissivity of Air Space	
		One Surface *e*; Other, 0.9	Both Surfaces Emissivity *e*
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (>0.5 g/m²)	0.30	0.29	—
Aluminum foil, with condensate clearly visible (>2.0 g/m²)	0.70	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galv., bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

Section A9.4.5.2 shall be used to calculate the assembly U-factor. The calculation procedures outlined in this section shall not be used for other metal building roof and wall systems.

A9.4.5.1 Single Layer. The U-factor of metal building roofs or walls that are insulated with a single layer of fiberglass insulation (see Figure A9.4.5.1) shall be calculated using the procedure outlined in this section. The procedure assumes the insulation is compressed over the purlin or girt. There may also be a thermal spacer block present.

There are six steps in the calculation process:

Step 1—Characterize the thermal conductivity of the fiberglass,

Step 2—Determine the U-factor for the insulation in the cavity,

Step 3—Determine the U-factor over the structural framing member,

Step 4—Area weight the U-factors calculated in steps 2 and 3,

Step 5—Determine the U-factor from the finite element analysis results,

Step 6—Determine the U-factor for any continuous insulation if present.

TABLE A9.4.2 Effective R-Values for Fiberglass

		Insulation R-Value at Standard Thickness							
Rated R-Value		**6.7**	**5.3**	**3.9**	**3.7**	**3.3**	**2.6**	**2.3**	**1.9**
Standard Thickness, mm		**300**	**240**	**170**	**140**	**155**	**90**	**90**	**90**
Nominal Lumber Size, mm	**Actual Depth of Cavity, mm**	**Effective Insulation R-Values when Installed in a Confined Cavity**							
50 × 300	286	6.5	—	—	—	—	—	—	—
50 × 250	235	5.6	5.3	—	—	—	—	—	—
50 × 200	184	4.8	4.6	3.9	3.7	3.3	—	—	—
50 × 150	140	—	3.7	3.5	3.7	3.2	—	—	—
50 × 100	89	—	—	2.5	—	2.3	2.6	2.3	1.9
	64	—	—	—	—	—	—	1.7	—
	38	—	—	—	—	—	—	1.1	1.0

TABLE A9.4.3-1 R-Values for Building Materials

Material	Nominal Size, mm	Actual Size, mm	R-Value
Carpet and rubber pad	—	–	0.22
Concrete at R-0.000434/mm	—	50	0.02
	—	100	0.04
	—	150	0.07
	—	200	0.09
	—	250	0.11
	—	300	0.13
Flooring, wood subfloor	—	19	0.17
Gypsum board	—	13	0.08
	—	16	0.10
Metal deck	—	—	0
Roofing, built-up	—	9.5	0.06
Sheathing, vegetable fiber board, 20 mm	—	20	0.36
Soil at R-0.000723/mm	—	300	0.22
Steel, mild		25.4	0.0005601
Stucco	—	19	0.01
Wood, 50 × 100 at R-0.0087/mm	100	89	0.77
Wood, 50 × 150 at R-0.0087/mm	150	140	1.21
Wood, 50 × 200 at R-0.0087/mm	200	184	1.60
Wood, 50 × 250 at R-0.0087/mm	250	235	2.04
Wood, 50 × 300 at R-0.0087/mm	300	286	2.48
Wood, 50 × 350 at R-0.0087/mm	350	337	2.92

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

$$k = A + B\rho + \frac{C}{\rho} \qquad \text{(A9.4-1)}$$

where

k = thermal conductivity, W/m·°C

ρ = density, kg/m^3

A = 0.00258168

B = 0.000047295

C = 0.157740033

Step 2—Assume the fiberglass batt forms a parabolic profile defined by Equation A9.4-2:

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

Determine the cavity U-factor (U_c) using Equation A9.4-3:

$$U_c = \frac{C}{\rho_o t_o} + \frac{B\rho_o t_o}{2Y_oY_m} + \left[A + \frac{B\rho_o t_o}{2Y_m}\right]\frac{1}{2(Y_m - Y_o)}\sqrt{\frac{Y_m - Y_o}{Y_m}}\ln\left(\frac{1 + \sqrt{\frac{Y_m - Y_o}{Y_m}}}{1 - \sqrt{\frac{Y_m - Y_o}{Y_m}}}\right) \qquad \text{(A9.4-3)}$$

where_

ρ_o = reference density of the fiberglass, kg/m^3

t_o = reference thickness of the fiberglass, m

The properties of fiberglass insulation are presented in Table A9.4.5.1.

TABLE A9.4.3-2 Thermal Conductivity of Concrete Block Material

Concrete Block Density, kg/m^3	Thermal Conductivity, W/m·°C
1280	0.53
1360	0.60
1440	0.68
1520	0.73
1600	0.79
1680	0.88
1760	0.96
1840	1.04
1920	1.12
2000	1.28
2080	1.44
2160	1.70
2240	1.94

TABLE A9.4.5.1 Fiberglass Reference Properties

R-Value, m^2·°C/W	Weight, kg/m^2	Density, kg/m^3	Thickness, m
1.76	0.727	9.680	0.075
1.94	0.820	10.080	0.081
2.29	0.971	10.048	0.097
2.82	1.186	10.144	0.117
3.34	1.449	10.448	0.138
4.40	2.084	11.872	0.175
5.28	2.538	12.256	0.207

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

$$U_{co} = \frac{1}{\frac{1}{U_c} + R_i + R_e} \quad \text{(A9.4-4)}$$

Step 3—Determine the U-factor (U_{fo}) over the structural framing member. The variable Y_o represents the total combined thickness of the thermal spacer block and the compressed insulation. The density of the compressed insulation is determined by Equation A9.4-5:

$$\rho_c = \frac{\rho_o t_o}{t_c} \quad \text{(A9.4-5)}$$

where

ρ_c = density of the compressed insulation over the framing member, kg/m^3

t_c = thickness of the compressed insulation over the framing member, m

Determine the thermal resistance of the compressed insulation (R_c) using Equation A9.4-6:

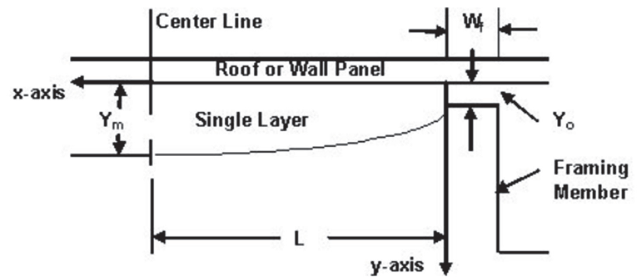


FIGURE A9.4.5.1 Geometry of single-layer fiberglass batt.

where

X = distance from edge of purlin or girt, m

Y = distance from edge of roof panel or wall panel, m

L = length from edge of purlin or girt to centerline of cavity, m

w$_f$ = width of purlin or girt flange, m

Y$_o$ = distance between purlin or girt and the roof panel or wall panel, m

Y$_m$ = distance from edge of roof panel or wall panel at the cavity centerline, m

$$R_c = \frac{t_c}{A + B\rho_c + C/\rho_c} \quad \text{(A9.4-6)}$$

Determine the overall framing U-factor (U_{fo}) at the structural framing member, including the air film resistances, using Equation A9.4-7:

$$U_{fo} = \frac{1}{R_{TB} + R_c + R_i + R_e} \quad \text{(A9.4-7)}$$

where

U_{fo} = U-factor over the structural framing member, W/m^2·°C

R_{TB} = R-value of the thermal spacer block, m^2·°C/W

R_c = R-value of the compressed insulation, m^2·°C/W

Step 4—Determine the overall area weighted U-factor for the entire system using Equation A9.4-8:

$$U_{es} = \frac{L \cdot U_{co} + (w_f/2) \cdot U_{fo}}{L + (w_f/2)} \quad \text{(A9.4-8)}$$

where

U_{es} = area weighted U-factor for the entire system, W/m^2·°C

w_f = width of purlin or girt flange, m

Step 5—Calculate the adjusted overall U-factor (U_{adj}) using Equation A9.4-9:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \quad \text{(A9.4-9)}$$

where

U_{adj} = adjusted overall U-factor represented by correlation with the finite element modeling, W/m^2·°C

Step 6—If there is any continuous insulation present, calculate the overall U-factor using Equation A9.4-10:

$$U = \frac{1}{\frac{1}{U_{adj}} + R_{ct}} \quad \text{(A9.4-10)}$$

A9.4.5.2 Double Layers. The U-factor of metal building roofs that are insulated with double layers of fiberglass insulation (see Figure A9.4.5.2-1) shall be calculated using the procedure outlined in this section. The procedure assumes the insulation is compressed over the purlin and there may be a thermal spacer block present.

There are six steps in the calculation process:

Step 1—Characterize the thermal conductivity of the fiberglass,

Step 2—Determine the U-factor for the insulation in the cavity,

Step 3—Determine the U-factor over the structural framing member,

Step 4—Area weight the U-factors calculated in steps 2 and 3,

Step 5—Determine the U-factor from the finite element analysis results,

Step 6—Determine the U-factor for any continuous insulation if present.

Step 1—The thermal conductivity of the fiberglass batt insulation is represented by a thermal curve of the form in Equation A9.4-11:

$$k = A + B\rho + \frac{C}{\rho} \quad \text{(A9.4-11)}$$

where

k = thermal conductivity, W/m^2·°C

ρ = density, kg/m^3

A = 0.0258168

B = 0.000047295

C = 0.157740033

Step 2—Assume the double-layer fiberglass batt forms a parabolic profile defined by Equation A9.4-12:

$$Y = Y_o + (Y_m - Y_o)\left(\frac{X}{2}\right)\left(2 - \frac{X}{2}\right) \quad \text{(A9.4-12)}$$

The presence of two layers of fiberglass adds complexity because each layer has distinct reference properties—see Table A9.4.5.1. As the double layers are compressed, the thickness of each layer needs to be determined by considering that each layer achieves the same compressive force. Instead of having a closed-form analytical solution that predicts the U-factor for the cavity, the double-layer system requires that the parabolic profile be numerically integrated. The compression of the double-layer system is presented in Figure A9.4.5.2-2.

The thickness of the second layer (Y_2) is described by Equation A9.4-13:

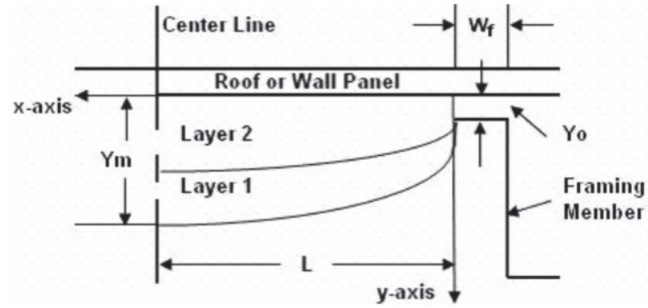


FIGURE A9.4.5.2-1 Geometry of double layers of fiberglass batts.

where

X = distance from edge of purlin or girt, m

Y = distance from edge of roof panel or wall panel, m

L = length from edge of purlin or girt to centerline of cavity, m

w_f = width of purlin or girt flange, m

Y_o = distance between purlin or girt and the roof panel or wall panel, m

Y_m = distance from edge of roof panel or wall panel at the cavity centerline, m

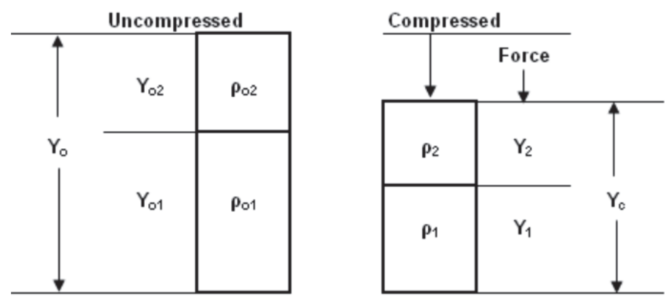


FIGURE A9.4.5.2-2 Compression of double layers of fiberglass insulation.

$$\left(\frac{Y_2}{Y_c}\right)^2 + \left[\frac{\rho o_1 W_1 + \rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)(Y_c/12)} - 1\right]\left(\frac{Y_2}{Y_c}\right) - \frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2)Y_c/12} = 0 \quad \text{(A9.4-13)}$$

where

Y_c = compressed thickness of the double layers, m

ρ_{o1} = reference density of first layer, kg/m^3

ρ_{o2} = reference density of second layer, kg/m^3

W_1 = reference weight of first layer, kg/m^2

W_2 = reference weight of second layer, kg/m^2

The solutions to Equation A9.4-13 are Equation A9.4-14a and A9.4-14b:

$$\frac{Y_{2,a}}{Y_c} = \left|\frac{-b + \sqrt{b^2 - 4ac}}{2a}\right| \quad \text{(A9.4-14a)}$$

$$\frac{Y_{2,b}}{Y_c} = \left|\frac{-b-\sqrt{b^2-4ac}}{2a}\right| \tag{A9.4-14b}$$

where

a = 1

b =

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

c =

$$\frac{\rho o_2 W_2}{(\rho o_1^2 - \rho o_2^2) Y_c}$$

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 0.0.127 m increments.

It is important to note that Equation A9.4-13 does not apply when the two layers of insulation are the same material. In this case, each compressed layer has the same thickness, which simplifies the U-factor calculations. The numerical integration still needs to be completed to determine the U_{co}.

Step 3—Determine the U-factor over the structural framing member. The variable (Y_o) represents the thickness of the thermal spacer block and the thickness of the compressed insulation. The density of the compressed insulation is determined by Equation A9.4-15:

$$\rho_c = \frac{\rho_o t_o}{t_c} \tag{A9.4-15}$$

where

ρ_c = density of the compressed insulation over the framing member, kg/m^3

t_c = thickness of the compressed insulation over the framing member, m

The thermal resistance of the compressed insulation is determined by Equation A9.4-16:

$$R_c = \frac{t_c}{A + B\rho_c + C/\rho_c} \tag{A9.4-16}$$

Determine the overall framing U-factor (U_{fo}) at the structural framing member including the air film resistances using Equation A9.4-17:

$$U_{f_o} = \frac{1}{R_{TB} + R_c + R_i + R_e} \tag{A9.4-17}$$

where

U_{fo} = U-factor over the structural framing member, W/m^2·°C

R_{TB} = R-value of the thermal spacer block, m^2·°C/W

R_c = R-value of the compressed insulation, m^2·°C/W

Step 4—Determine the overall area weighted U-factor for the entire system using Equation A9.4-18:

$$U_{es} = \frac{L \cdot U_{co} + (w_f/2) \cdot U_{fo}}{L + (w_f/2)} \tag{A9.4-18}$$

where

U_{es} = area weighted U-factor for the entire system, W/m^2·°C

Step 5—Calculate the adjusted overall U-factor (U_{adj}) using Equation A9.4-19:

$$U_{adj} = \frac{1}{0.8676/U_{es} + 1.1423} \tag{A9.4-19}$$

where

U_{adj}= adjusted overall U-factor represented by correlation with the finite element modeling, W/m^2·°C

Step 6—If there is any continuous insulation present, calculate the overall U-factor using Equation A9.4-20:

$$U_o = \frac{1}{\frac{1}{U_{ofe}} + R_{ci}} \tag{A9.4-20}$$

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX B
BUILDING ENVELOPE CLIMATE CRITERIA

B1. GENERAL

This normative appendix provides the information to determine both United States and international climate zones. For US locations, use either Figure B1-1 or Table B1-1 to determine the climate zone number and letter that are required for determining compliance regarding various sections and tables in this standard. Figure B1-1 contains the county-by-county climate zone map for the United States. Table B1-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

Table B1-2 shows the climate zone numbers for a wide variety of Canadian locations. When the climate zone letter is required to determine compliance with this standard, refer to Table B1-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

Table B1-3 shows the climate zone numbers for a wide variety of other international locations besides Canada. When the climate zone letter is required to determine compliance with this standard, refer to Table B1-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

For all international locations that are not listed either in Table B1-2 or B1-3, use Table B1-4 and the Major Climate Type Definitions in Section B2 to determine both the climate zone letter and number.

Informative Note: CDD50 and HDD65 values may be found in Normative Appendix D.

B2. MAJOR CLIMATE TYPE DEFINITIONS

Use the following information along with Table B-4 to determine climate zone numbers and letters for international climate zones.

Marine (C) definition—Locations meeting all four criteria:

1. *Mean temperature* of coldest month between –3°C and 18°C.
2. Warmest month mean <22°C.
3. At least four months with *mean temperatures* over 10°C.
4. Dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Dry (B) definition—Locations meeting the following criteria: not marine and

$$P_{cm} < 2.0 \times (TC + 7)$$

where

P = annual precipitation, cm

T = annual *mean temperature*, °C

Moist (A) definition—Locations that are not marine and not dry.

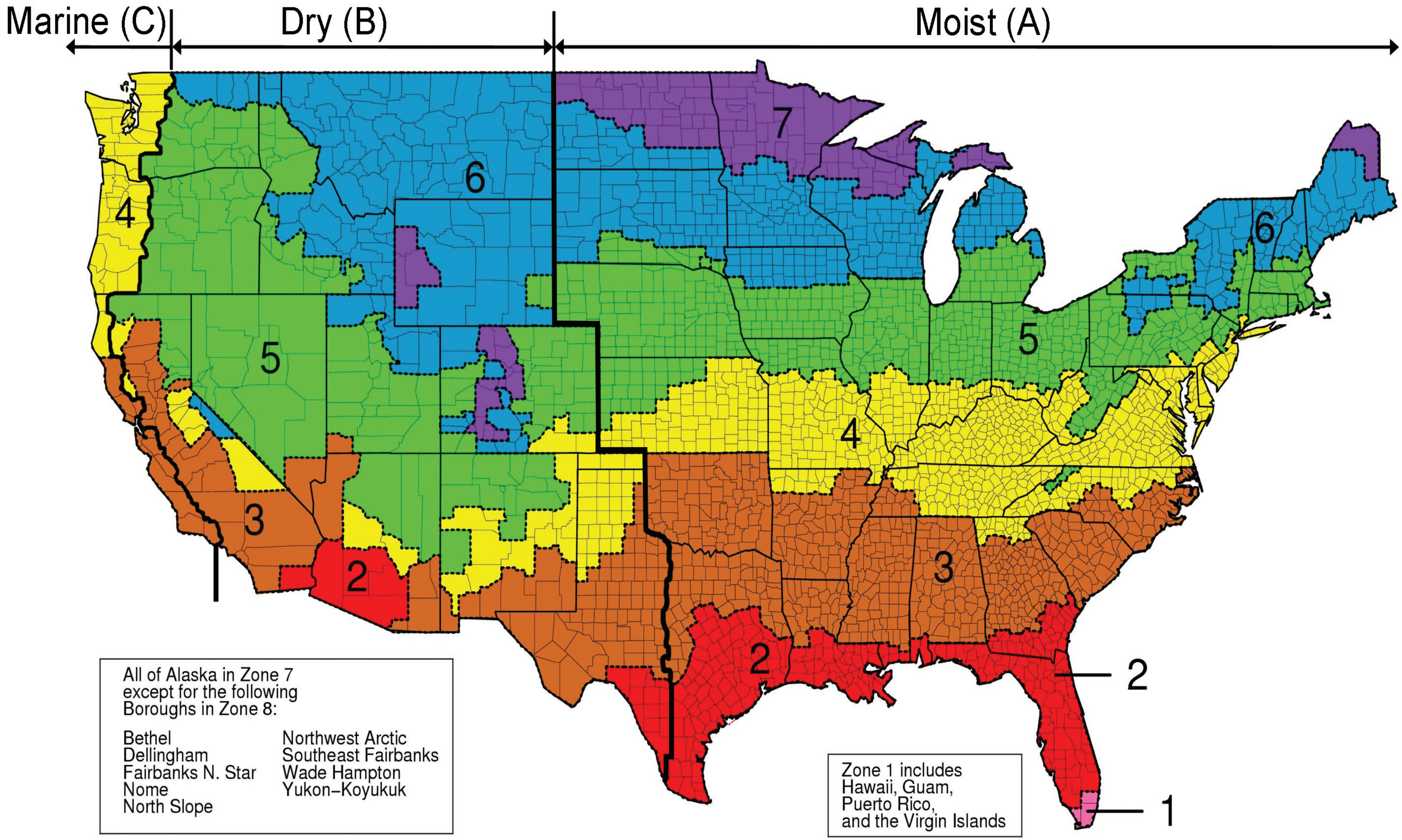


Figure B1-1 U.S. climate zone map (*ASHRAE Transactions*, Briggs et al., 2003).

TABLE B1-1 U.S. Climate Zones

Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk ‘*’ indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
Alabama	3A Limestone	8 Nome	3A Columbia*
3A Autauga*	3A Lowndes*	8 North Slope	3A Conway
2A Baldwin*	3A Macon*	8 Northwest Arctic	3A Craighead
3A Barbour*	3A Madison	7 Prince of Wales-Outer Ketchikan	3A Crawford
3A Bibb	3A Marengo*t	7 Sitka	3A Crittenden
3A Blount	3A Marion	7 Skagway-Hoonah-Angoon	3A Cross
3A Bullock*	3A Marshall	8 Southeast Fairbanks	3A Dallas
3A Butler*	2A Mobile*	7 Valdez-Cordova	3A Desha
3A Calhoun	3A Monroe*	8 Wade Hampton	3A Drew
3A Chambers	3A Montgomery*	7 Wrangell-Petersburg	3A Faulkner
3A Cherokee	3A Morgan	7 Yakutat	3A Franklin
3A Chilton	3A Perry*	8 Yukon-Koyukuk	4A Fulton
3A Choctaw*	3A Pickens	**Arizona**	3A Garland
3A Clarke*	3A Pike*	5B Apache	3A Grant
3A Clay	3A Randolph	3B Cochise	3A Greene
3A Cleburne	3A Russell*	5B Coconino	3A Hempstead*
3A Coffee*	3A Shelby	4B Gila	3A Hot Spring
3A Colbert	3A St. Clair	3B Graham	3A Howard
3A Conecuh*	3A Sumter	3B Greenlee	3A Independence
3A Coosa	3A Talladega	2B La Paz	4A Izard
3A Covington*	3A Tallapoosa	2B Maricopa	3A Jackson
3A Crenshaw*	3A Tuscaloosa	3B Mohave	3A Jefferson
3A Cullman	3A Walker	5B Navajo	3A Johnson
3A Dale*	3A Washington*	2B Pima	3A Lafayette*
3A Dallas*	3A Wilcox*	2B Pinal	3A Lawrence
3A DeKalb	3A Winston	3B Santa Cruz	3A Lee
3A Elmore*	**Alaska**	4B Yavapai	3A Lincoln
3A Escambia*	7 Aleutians East	2B Yuma	3A Little River*
3A Etowah	7 Aleutians West	**Arkansas**	3A Logan
3A Fayette	7 Anchorage	3A Arkansas	3A Lonoke
3A Franklin	8 Bethel	3A Ashley	4A Madison
3A Geneva*	7 Bristol Bay	4A Baxter	4A Marion
3A Greene	7 Denali	4A Benton	3A Miller*
3A Hale	8 Dillingham	4A Boone	3A Mississippi
3A Henry*	8 Fairbanks North Star	3A Bradley	3A Monroe
3A Houston*	7 Haines	3A Calhoun	3A Montgomery
3A Jackson	7 Juneau	4A Carroll	3A Nevada
3A Jefferson	7 Kenai Peninsula	3A Chicot	4A Newton
3A Lamar	7 Ketchikan Gateway	3A Clark	3A Ouachita
3A Lauderdale	7 Kodiak Island	3A Clay	3A Perry
3A Lawrence	7 Lake and Peninsula	3A Cleburne	3A Phillips
3A Lee	7 Matanuska- Susitna	3A Cleveland	3A Pike

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
3A Poinsett	4B Mariposa	4B Baca	7 Park
3A Polk	3C Mendocino	5B Bent	5B Phillips
3A Pope	3B Merced	5B Boulder	7 Pitkin
3A Prairie	5B Modoc	6B Chaffee	5B Prowers
3A Pulaski	6B Mono	5B Cheyenne	5B Pueblo
3A Randolph	3C Monterey	7 Clear Creek	6B Rio Blanco
3A Saline	3C Napa	6B Conejos	7 Rio Grande
3A Scott	5B Nevada	6B Costilla	7 Routt
4A Searcy	3B Orange	5B Crowley	6B Saguache
3A Sebastian	3B Placer	6B Custer	7 San Juan
3A Sevier*	5B Plumas	5B Delta	6B San Miguel
3A Sharp	3B Riverside	5B Denver	5B Sedgwick
3A St. Francis	3B Sacramento	6B Dolores	7 Summit
4A Stone	3C San Benito	5B Douglas	5B Teller
3A Union*	3B San Bernardino	6B Eagle	5B Washington
3A Van Buren	3B San Diego	5B Elbert	5B Weld
4A Washington	3C San Francisco	5B El Paso	5B Yuma
3A White	3B San Joaquin	5B Fremont	**Connecticut**
3A Woodruff	3C San Luis Obispo	5B Garfield	5A (all)
3A Yell	3C San Mateo	5B Gilpin	**Delaware**
California	3C Santa Barbara	7 Grand	4A (all)
3C Alameda	3C Santa Clara	7 Gunnison	**District of Columbia**
6B Alpine	3C Santa Cruz	7 Hinsdale	4A (all)
4B Amador	3B Shasta	5B Huerfano	**Florida**
3B Butte	5B Sierra	7 Jackson	2A Alachua*
4B Calaveras	5B Siskiyou	5B Jefferson	2A Baker*
3B Colusa	3B Solano	5B Kiowa	2A Bay*
3B Contra Costa	3C Sonoma	5B Kit Carson	2A Bradford*
4C Del Norte	3B Stanislaus	7 Lake	2A Brevard*
4B El Dorado	3B Sutter	5B La Plata	1A Broward*
3B Fresno	3B Tehama	5B Larimer	2A Calhoun*
3B Glenn	4B Trinity	4B Las Animas	2A Charlotte*
4C Humboldt	3B Tulare	5B Lincoln	2A Citrus*
2B Imperial	4B Tuolumne	5B Logan	2A Clay*
4B Inyo	3C Ventura	5B Mesa	2A Collier*
3B Kern	3B Yolo	7 Mineral	2A Columbia*
3B Kings	3B Yuba	6B Moffat	2A DeSoto*
4B Lake	**Colorado**	5B Montezuma	2A Dixie*
5B Lassen	5B Adams	5B Montrose	2A Duval*
3B Los Angeles	6B Alamosa	5B Morgan	2A Escambia*
3B Madera	5B Arapahoe	4B Otero	2A Flagler*
3C Marin	6B Archuleta	6B Ouray	2A Franklin*

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
2A Gadsden*	2A Suwannee*	2A Colquitt*	3A Irwin*
2A Gilchrist*	2A Taylor*	3A Columbia	3A Jackson
2A Glades*	2A Union*	2A Cook*	3A Jasper
2A Gulf*	2A Volusia*	3A Coweta	2A Jeff Davis*
2A Hamilton*	2A Wakulla*	3A Crawford	3A Jefferson
2A Hardee*	2A Walton*	3A Crisp*	3A Jenkins*
2A Hendry*	2A Washington*	4A Dade	3A Johnson*
2A Hernando*	**Georgia**	4A Dawson	3A Jones
2A Highlands*	2A Appling*	2A Decatur*	3A Lamar
2A Hillsborough*	2A Atkinson*	3A DeKalb	2A Lanier*
2A Holmes*	2A Bacon*	3A Dodge*	3A Laurens*
2A Indian River*	2A Baker*	3A Dooly*	3A Lee*
2A Jackson*	3A Baldwin	3A Dougherty*	2A Liberty*
2A Jefferson*	4A Banks	3A Douglas	3A Lincoln
2A Lafayette*	3A Barrow	3A Early*	2A Long*
2A Lake*	3A Bartow	2A Echols*	2A Lowndes*
2A Lee*	3A Ben Hill*	2A Effingham*	4A Lumpkin
2A Leon*	2A Berrien*	3A Elbert	3A Macon*
2A Levy*	3A Bibb	3A Emanuel*	3A Madison
2A Liberty*	3A Bleckley*	2A Evans*	3A Marion*
2A Madison*	2A Brantley*	4A Fannin	3A McDuffie
2A Manatee*	2A Brooks*	3A Fayette	2A McIntosh*
2A Marion*	2A Bryan*	4A Floyd	3A Meriwether
2A Martin*	3A Bulloch*	3A Forsyth	2A Miller*
1A Miami-Dade*	3A Burke	4A Franklin	2A Mitchell*
1A Monroe*	3A Butts	3A Fulton	3A Monroe
2A Nassau*	3A Calhoun*	4A Gilmer	3A Montgomery*
2A Okaloosa*	2A Camden*	3A Glascock	3A Morgan
2A Okeechobee*	3A Candler*	2A Glynn*	4A Murray
2A Orange*	3A Carroll	4A Gordon	3A Muscogee
2A Osceola*	4A Catoosa	2A Grady*	3A Newton
2A Palm Beach*	2A Charlton*	3A Greene	3A Oconee
2A Pasco*	2A Chatham*	3A Gwinnett	3A Oglethorpe
2A Pinellas*	3A Chattahoochee*	4A Habersham	3A Paulding
2A Polk*	4A Chattooga	4A Hall	3A Peach*
2A Putnam*	3A Cherokee	3A Hancock	4A Pickens
2A Santa Rosa*	3A Clarke	3A Haralson	2A Pierce*
2A Sarasota*	3A Clay*	3A Harris	3A Pike
2A Seminole*	3A Clayton	3A Hart	3A Polk
2A St. Johns*	2A Clinch*	3A Heard	3A Pulaski*
2A St. Lucie*	3A Cobb	3A Henry	3A Putnam
2A Sumter*	3A Coffee*	3A Houston*	3A Quitman*

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
4A Rabun	1A (all)*	6B Teton	5A Iroquois
3A Randolph*	**Idaho**	5B Twin Falls	4A Jackson
3A Richmond	5B Ada	6B Valley	4A Jasper
3A Rockdale	6B Adams	5B Washington	4A Jefferson
3A Schley*	6B Bannock	**Illinois**	5A Jersey
3A Screven*	6B Bear Lake	5A Adams	5A Jo Daviess
2A Seminole*	5B Benewah	4A Alexander	4A Johnson
3A Spalding	6B Bingham	4A Bond	5A Kane
4A Stephens	6B Blaine	5A Boone	5A Kankakee
3A Stewart*	6B Boise	5A Brown	5A Kendall
3A Sumter*	6B Bonner	5A Bureau	5A Knox
3A Talbot	6B Bonneville	5A Calhoun	5A Lake
3A Taliaferro	6B Boundary	5A Carroll	5A La Salle
2A Tattnall*	6B Butte	5A Cass	4A Lawrence
3A Taylor*	6B Camas	5A Champaign	5A Lee
3A Telfair*	5B Canyon	4A Christian	5A Livingston
3A Terrell*	6B Caribou	5A Clark	5A Logan
2A Thomas*	5B Cassia	4A Clay	5A Macon
3A Tift*	6B Clark	4A Clinton	4A Macoupin
2A Toombs*	5B Clearwater	5A Coles	4A Madison
4A Towns	6B Custer	5A Cook	4A Marion
3A Treutlen*	5B Elmore	4A Crawford	5A Marshall
3A Troup	6B Franklin	5A Cumberland	5A Mason
3A Turner*	6B Fremont	5A DeKalb	4A Massac
3A Twiggs*	5B Gem	5A De Witt	5A McDonough
4A Union	5B Gooding	5A Douglas	5A McHenry
3A Upson	5B Idaho	5A DuPage	5A McLean
4A Walker	6B Jefferson	5A Edgar	5A Menard
3A Walton	5B Jerome	4A Edwards	5A Mercer
2A Ware*	5B Kootenai	4A Effingham	4A Monroe
3A Warren	5B Latah	4A Fayette	4A Montgomery
3A Washington	6B Lemhi	5A Ford	5A Morgan
2A Wayne*	5B Lewis	4A Franklin	5A Moultrie
3A Webster*	5B Lincoln	5A Fulton	5A Ogle
3A Wheeler*	6B Madison	4A Gallatin	5A Peoria
4A White	5B Minidoka	5A Greene	4A Perry
4A Whitfield	5B Nez Perce	5A Grundy	5A Piatt
3A Wilcox*	6B Oneida	4A Hamilton	5A Pike
3A Wilkes	5B Owyhee	5A Hancock	4A Pope
3A Wilkinson	5B Payette	4A Hardin	4A Pulaski
3A Worth*	5B Power	5A Henderson	5A Putnam
Hawaii	5B Shoshone	5A Henry	4A Randolph

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
4A Richland	4A Dubois	5A Parke	6A Buchanan
5A Rock Island	5A Elkhart	4A Perry	6A Buena Vista
4A Saline	5A Fayette	4A Pike	6A Butler
5A Sangamon	4A Floyd	5A Porter	6A Calhoun
5A Schuyler	5A Fountain	4A Posey	5A Carroll
5A Scott	5A Franklin	5A Pulaski	5A Cass
4A Shelby	5A Fulton	5A Putnam	5A Cedar
5A Stark	4A Gibson	5A Randolph	6A Cerro Gordo
4A St. Clair	5A Grant	4A Ripley	6A Cherokee
5A Stephenson	4A Greene	5A Rush	6A Chickasaw
5A Tazewell	5A Hamilton	4A Scott	5A Clarke
4A Union	5A Hancock	5A Shelby	6A Clay
5A Vermilion	4A Harrison	4A Spencer	6A Clayton
4A Wabash	5A Hendricks	5A Starke	5A Clinton
5A Warren	5A Henry	5A Steuben	5A Crawford
4A Washington	5A Howard	5A St. Joseph	5A Dallas
4A Wayne	5A Huntington	4A Sullivan	5A Davis
4A White	4A Jackson	4A Switzerland	5A Decatur
5A Whiteside	5A Jasper	5A Tippecanoe	6A Delaware
5A Will	5A Jay	5A Tipton	5A Des Moines
4A Williamson	4A Jefferson	5A Union	6A Dickinson
5A Winnebago	4A Jennings	4A Vanderburgh	5A Dubuque
5A Woodford	5A Johnson	5A Vermillion	6A Emmet
Indiana	4A Knox	5A Vigo	6A Fayette
5A Adams	5A Kosciusko	5A Wabash	6A Floyd
5A Allen	5A Lagrange	5A Warren	6A Franklin
5A Bartholomew	5A Lake	4A Warrick	5A Fremont
5A Benton	5A La Porte	4A Washington	5A Greene
5A Blackford	4A Lawrence	5A Wayne	6A Grundy
5A Boone	5A Madison	5A Wells	5A Guthrie
4A Brown	5A Marion	5A White	6A Hamilton
5A Carroll	5A Marshall	5A Whitley	6A Hancock
5A Cass	4A Martin	**Iowa**	6A Hardin
4A Clark	5A Miami	5A Adair	5A Harrison
5A Clay	4A Monroe	5A Adams	5A Henry
5A Clinton	5A Montgomery	6A Allamakee	6A Howard
4A Crawford	5A Morgan	5A Appanoose	6A Humboldt
4A Daviess	5A Newton	5A Audubon	6A Ida
4A Dearborn	5A Noble	5A Benton	5A Iowa
5A Decatur	4A Ohio	6A Black Hawk	5A Jackson
5A De Kalb	4A Orange	5A Boone	5A Jasper
5A Delaware	5A Owen	6A Bremer	5A Jefferson

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
5A Johnson	6A Webster	5A Greeley	4A Reno
5A Jones	6A Winnebago	4A Greenwood	5A Republic
5A Keokuk	6A Winneshiek	5A Hamilton	4A Rice
6A Kossuth	5A Woodbury	4A Harper	4A Riley
5A Lee	6A Worth	4A Harvey	5A Rooks
5A Linn	6A Wright	4A Haskell	4A Rush
5A Louisa	**Kansas**	4A Hodgeman	4A Russell
5A Lucas	4A Allen	4A Jackson	4A Saline
6A Lyon	4A Anderson	4A Jefferson	5A Scott
5A Madison	4A Atchison	5A Jewell	4A Sedgwick
5A Mahaska	4A Barber	4A Johnson	4A Seward
5A Marion	4A Barton	4A Kearny	4A Shawnee
5A Marshall	4A Bourbon	4A Kingman	5A Sheridan
5A Mills	4A Brown	4A Kiowa	5A Sherman
6A Mitchell	4A Butler	4A Labette	5A Smith
5A Monona	4A Chase	5A Lane	4A Stafford
5A Monroe	4A Chautauqua	4A Leavenworth	4A Stanton
5A Montgomery	4A Cherokee	4A Lincoln	4A Stevens
5A Muscatine	5A Cheyenne	4A Linn	4A Sumner
6A O'Brien	4A Clark	5A Logan	5A Thomas
6A Osceola	4A Clay	4A Lyon	5A Trego
5A Page	5A Cloud	4A Marion	4A Wabaunsee
6A Palo Alto	4A Coffey	4A Marshall	5A Wallace
6A Plymouth	4A Comanche	4A McPherson	4A Washington
6A Pocahontas	4A Cowley	4A Meade	5A Wichita
5A Polk	4A Crawford	4A Miami	4A Wilson
5A Pottawattamie	5A Decatur	5A Mitchell	4A Woodson
5A Poweshiek	4A Dickinson	4A Montgomery	4A Wyandotte
5A Ringgold	4A Doniphan	4A Morris	**Kentucky**
6A Sac	4A Douglas	4A Morton	4A (all)
5A Scott	4A Edwards	4A Nemaha	**Louisiana**
5A Shelby	4A Elk	4A Neosho	2A Acadia*
6A Sioux	5A Ellis	5A Ness	2A Allen*
5A Story	4A Ellsworth	5A Norton	2A Ascension*
5A Tama	4A Finney	4A Osage	2A Assumption*
5A Taylor	4A Ford	5A Osborne	2A Avoyelles*
5A Union	4A Franklin	4A Ottawa	2A Beauregard*
5A Van Buren	4A Geary	4A Pawnee	3A Bienville*
5A Wapello	5A Gove	5A Phillips	3A Bossier*
5A Warren	5A Graham	4A Pottawatomie	3A Caddo*
5A Washington	4A Grant	4A Pratt	2A Calcasieu*
5A Wayne	4A Gray	5A Rawlins	3A Caldwell*

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
2A Cameron*	3A Tensas*	4A Howard	5A Gratiot
3A Catahoula*	2A Terrebonne*	4A Kent	5A Hillsdale
3A Claiborne*	3A Union*	4A Montgomery	7 Houghton
3A Concordia*	2A Vermilion*	4A Prince George's	6A Huron
3A De Soto*	3A Vernon*	4A Queen Anne's	5A Ingham
2A East Baton Rouge*	2A Washington*	4A Somerset	5A Ionia
3A East Carroll	3A Webster*	4A St. Mary's	6A Iosco
2A East Feliciana*	2A West Baton Rouge*	4A Talbot	7 Iron
2A Evangeline*	3A West Carroll	4A Washington	6A Isabella
3A Franklin*	2A West Feliciana*	4A Wicomico	5A Jackson
3A Grant*	3A Winn*	4A Worcester	5A Kalamazoo
2A Iberia*	**Maine**	**Massachusetts**	6A Kalkaska
2A Iberville*	6A Androscoggin	5A (all)	5A Kent
3A Jackson*	7 Aroostook	**Michigan**	7 Keweenaw
2A Jefferson*	6A Cumberland	6A Alcona	6A Lake
2A Jefferson Davis*	6A Franklin	6A Alger	5A Lapeer
2A Lafayette*	6A Hancock	5A Allegan	6A Leelanau
2A Lafourche*	6A Kennebec	6A Alpena	5A Lenawee
3A La Salle*	6A Knox	6A Antrim	5A Livingston
3A Lincoln*	6A Lincoln	6A Arenac	7 Luce
2A Livingston*	6A Oxford	7 Baraga	7 Mackinac
3A Madison*	6A Penobscot	5A Barry	5A Macomb
3A Morehouse	6A Piscataquis	5A Bay	6A Manistee
3A Natchitoches*	6A Sagadahoc	6A Benzie	6A Marquette
2A Orleans*	6A Somerset	5A Berrien	6A Mason
3A Ouachita*	6A Waldo	5A Branch	6A Mecosta
2A Plaquemines*	6A Washington	5A Calhoun	6A Menominee
2A Pointe Coupee*	6A York	5A Cass	5A Midland
2A Rapides*	**Maryland**	6A Charlevoix	6A Missaukee
3A Red River*	4A Allegany	6A Cheboygan	5A Monroe
3A Richland*	4A Anne Arundel	7 Chippewa	5A Montcalm
3A Sabine*	4A Baltimore	6A Clare	6A Montmorency
2A St. Bernard*	4A Baltimore (city)	5A Clinton	5A Muskegon
2A St. Charles*	4A Calvert	6A Crawford	6A Newaygo
2A St. Helena*	4A Caroline	6A Delta	5A Oakland
2A St. James*	4A Carroll	6A Dickinson	6A Oceana
2A St. John the Baptist*	4A Cecil	5A Eaton	6A Ogemaw
2A St. Landry*	4A Charles	6A Emmet	7 Ontonagon
2A St. Martin*	4A Dorchester	5A Genesee	6A Osceola
2A St. Mary*	4A Frederick	6A Gladwin	6A Oscoda
2A St. Tammany*	5A Garrett	7 Gogebic	6A Otsego
2A Tangipahoa*	4A Harford	6A Grand Traverse	5A Ottawa

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
6A Presque Isle	7 Hubbard	6A Sibley	3A Hinds*
6A Roscommon	6A Isanti	6A Stearns	3A Holmes
5A Saginaw	7 Itasca	6A Steele	3A Humphreys
6A Sanilac	6A Jackson	6A Stevens	3A Issaquena
7 Schoolcraft	7 Kanabec	7 St. Louis	3A Itawamba
5A Shiawassee	6A Kandiyohi	6A Swift	2A Jackson*
5A St. Clair	7 Kittson	6A Todd	3A Jasper
5A St. Joseph	7 Koochiching	6A Traverse	3A Jefferson*
5A Tuscola	6A Lac qui Parle	6A Wabasha	3A Jefferson Davis*
5A Van Buren	7 Lake	7 Wadena	3A Jones*
5A Washtenaw	7 Lake of the Woods	6A Waseca	3A Kemper
5A Wayne	6A Le Sueur	6A Washington	3A Lafayette
6A Wexford	6A Lincoln	6A Watonwan	3A Lamar*
Minnesota	6A Lyon	7 Wilkin	3A Lauderdale
7 Aitkin	7 Mahnomen	6A Winona	3A Lawrence*
6A Anoka	7 Marshall	6A Wright	3A Leake
7 Becker	6A Martin	6A Yellow Medicine	3A Lee
7 Beltrami	6A McLeod	**Mississippi**	3A Leflore
6A Benton	6A Meeker	3A Adams*	3A Lincoln*
6A Big Stone	7 Mille Lacs	3A Alcorn	3A Lowndes
6A Blue Earth	6A Morrison	3A Amite*	3A Madison
6A Brown	6A Mower	3A Attala	3A Marion*
7 Carlton	6A Murray	3A Benton	3A Marshall
6A Carver	6A Nicollet	3A Bolivar	3A Monroe
7 Cass	6A Nobles	3A Calhoun	3A Montgomery
6A Chippewa	7 Norman	3A Carroll	3A Neshoba
6A Chisago	6A Olmsted	3A Chickasaw	3A Newton
7 Clay	7 Otter Tail	3A Choctaw	3A Noxubee
7 Clearwater	7 Pennington	3A Claiborne*	3A Oktibbeha
7 Cook	7 Pine	3A Clarke	3A Panola
6A Cottonwood	6A Pipestone	3A Clay	2A Pearl River*
7 Crow Wing	7 Polk	3A Coahoma	3A Perry*
6A Dakota	6A Pope	3A Copiah*	3A Pike*
6A Dodge	6A Ramsey	3A Covington*	3A Pontotoc
6A Douglas	7 Red Lake	3A DeSoto	3A Prentiss
6A Faribault	6A Redwood	3A Forrest*	3A Quitman
6A Fillmore	6A Renville	3A Franklin*	3A Rankin*
6A Freeborn	6A Rice	3A George*	3A Scott
6A Goodhue	6A Rock	3A Greene*	3A Sharkey
7 Grant	7 Roseau	3A Grenada	3A Simpson*
6A Hennepin	6A Scott	2A Hancock*	3A Smith*
6A Houston	6A Sherburne	2A Harrison*	2A Stone*

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
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U.S. States	U.S. States	U.S. States	U.S. States
3A Sunflower	4A Cole	4A Moniteau	4A Warren
3A Tallahatchie	4A Cooper	4A Monroe	4A Washington
3A Tate	4A Crawford	4A Montgomery	4A Wayne
3A Tippah	4A Dade	4A Morgan	4A Webster
3A Tishomingo	4A Dallas	4A New Madrid	5A Worth
3A Tunica	5A Daviess	4A Newton	4A Wright
3A Union	5A DeKalb	5A Nodaway	**Montana**
3A Walthall*	4A Dent	4A Oregon	6B (all)
3A Warren*	4A Douglas	4A Osage	**Nebraska**
3A Washington	4A Dunklin	4A Ozark	5A (all)
3A Wayne*	4A Franklin	4A Pemiscot	**Nevada**
3A Webster	4A Gasconade	4A Perry	5B Carson City (city)
3A Wilkinson*	5A Gentry	4A Pettis	5B Churchill
3A Winston	4A Greene	4A Phelps	3B Clark
3A Yalobusha	5A Grundy	5A Pike	5B Douglas
3A Yazoo	5A Harrison	4A Platte	5B Elko
Missouri	4A Henry	4A Polk	5B Esmeralda
5A Adair	4A Hickory	4A Pulaski	5B Eureka
5A Andrew	5A Holt	5A Putnam	5B Humboldt
5A Atchison	4A Howard	5A Ralls	5B Lander
4A Audrain	4A Howell	4A Randolph	5B Lincoln
4A Barry	4A Iron	4A Ray	5B Lyon
4A Barton	4A Jackson	4A Reynolds	5B Mineral
4A Bates	4A Jasper	4A Ripley	5B Nye
4A Benton	4A Jefferson	4A Saline	5B Pershing
4A Bollinger	4A Johnson	5A Schuyler	5B Storey
4A Boone	5A Knox	5A Scotland	5B Washoe
5A Buchanan	4A Laclede	4A Scott	5B White Pine
4A Butler	4A Lafayette	4A Shannon	**New Hampshire**
5A Caldwell	4A Lawrence	5A Shelby	6A Belknap
4A Callaway	5A Lewis	4A St. Charles	6A Carroll
4A Camden	4A Lincoln	4A St. Clair	5A Cheshire
4A Cape Girardeau	5A Linn	4A Ste. Genevieve	6A Coos
4A Carroll	5A Livingston	4A St. Francois	6A Grafton
4A Carter	5A Macon	4A St. Louis	5A Hillsborough
4A Cass	4A Madison	4A St. Louis (city)	6A Merrimack
4A Cedar	4A Maries	4A Stoddard	5A Rockingham
5A Chariton	5A Marion	4A Stone	5A Strafford
4A Christian	4A McDonald	5A Sullivan	6A Sullivan
5A Clark	5A Mercer	4A Taney	**New Jersey**
4A Clay	4A Miller	4A Texas	4A Atlantic
5A Clinton	4A Mississippi	4A Vernon	5A Bergen

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
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U.S. States	U.S. States	U.S. States	U.S. States
4A Burlington	4B Roosevelt	4A New York	3A Brunswick*
4A Camden	5B Sandoval	5A Niagara	4A Buncombe
4A Cape May	5B San Juan	6A Oneida	4A Burke
4A Cumberland	5B San Miguel	5A Onondaga	3A Cabarrus
4A Essex	5B Santa Fe	5A Ontario	4A Caldwell
4A Gloucester	4B Sierra	5A Orange	3A Camden
4A Hudson	4B Socorro	5A Orleans	3A Carteret*
5A Hunterdon	5B Taos	5A Oswego	4A Caswell
5A Mercer	5B Torrance	6A Otsego	4A Catawba
4A Middlesex	4B Union	5A Putnam	4A Chatham
4A Monmouth	4B Valencia	4A Queens	4A Cherokee
5A Morris	**New York**	5A Rensselaer	3A Chowan
4A Ocean	5A Albany	4A Richmond	4A Clay
5A Passaic	6A Allegany	5A Rockland	4A Cleveland
4A Salem	4A Bronx	5A Saratoga	3A Columbus*
5A Somerset	6A Broome	5A Schenectady	3A Craven
5A Sussex	6A Cattaraugus	6A Schoharie	3A Cumberland
4A Union	5A Cayuga	6A Schuyler	3A Currituck
5A Warren	5A Chautauqua	5A Seneca	3A Dare
New Mexico	5A Chemung	6A Steuben	3A Davidson
4B Bernalillo	6A Chenango	6A St. Lawrence	4A Davie
5B Catron	6A Clinton	4A Suffolk	3A Duplin
3B Chaves	5A Columbia	6A Sullivan	4A Durham
4B Cibola	5A Cortland	5A Tioga	3A Edgecombe
5B Colfax	6A Delaware	6A Tompkins	4A Forsyth
4B Curry	5A Dutchess	6A Ulster	4A Franklin
4B DeBaca	5A Erie	6A Warren	3A Gaston
3B Dona Ana	6A Essex	5A Washington	4A Gates
3B Eddy	6A Franklin	5A Wayne	4A Graham
4B Grant	6A Fulton	4A Westchester	4A Granville
4B Guadalupe	5A Genesee	6A Wyoming	3A Greene
5B Harding	5A Greene	5A Yates	4A Guilford
3B Hidalgo	6A Hamilton	**North Carolina**	4A Halifax
3B Lea	6A Herkimer	4A Alamance	4A Harnett
4B Lincoln	6A Jefferson	4A Alexander	4A Haywood
5B Los Alamos	4A Kings	5A Alleghany	4A Henderson
3B Luna	6A Lewis	3A Anson	4A Hertford
5B McKinley	5A Livingston	5A Ashe	3A Hoke
5B Mora	6A Madison	5A Avery	3A Hyde
3B Otero	5A Monroe	3A Beaufort	4A Iredell
4B Quay	6A Montgomery	4A Bertie	4A Jackson
5B Rio Arriba	4A Nassau	3A Bladen	3A Johnston

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
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U.S. States	U.S. States	U.S. States	U.S. States
3A Jones	3A Washington	7 Pierce	5A Fairfield
4A Lee	5A Watauga	7 Ramsey	5A Fayette
3A Lenoir	3A Wayne	6A Ransom	5A Franklin
4A Lincoln	4A Wilkes	7 Renville	5A Fulton
4A Macon	3A Wilson	6A Richland	4A Gallia
4A Madison	4A Yadkin	7 Rolette	5A Geauga
3A Martin	5A Yancey	6A Sargent	5A Greene
4A McDowell	**North Dakota**	7 Sheridan	5A Guernsey
3A Mecklenburg	6A Adams	6A Sioux	4A Hamilton
5A Mitchell	7 Barnes	6A Slope	5A Hancock
3A Montgomery	7 Benson	6A Stark	5A Hardin
3A Moore	6A Billings	7 Steele	5A Harrison
4A Nash	7 Bottineau	7 Stutsman	5A Henry
3A New Hanover*	6A Bowman	7 Towner	5A Highland
4A Northampton	7 Burke	7 Traill	5A Hocking
3A Onslow*	6A Burleigh	7 Walsh	5A Holmes
4A Orange	7 Cass	7 Ward	5A Huron
3A Pamlico	7 Cavalier	7 Wells	5A Jackson
3A Pasquotank	6A Dickey	7 Williams	5A Jefferson
3A Pender*	7 Divide	**Ohio**	5A Knox
3A Perquimans	6A Dunn	4A Adams	5A Lake
4A Person	7 Eddy	5A Allen	4A Lawrence
3A Pitt	6A Emmons	5A Ashland	5A Licking
4A Polk	7 Foster	5A Ashtabula	5A Logan
3A Randolph	6A Golden Valley	5A Athens	5A Lorain
3A Richmond	7 Grand Forks	5A Auglaize	5A Lucas
3A Robeson	6A Grant	5A Belmont	5A Madison
4A Rockingham	7 Griggs	4A Brown	5A Mahoning
3A Rowan	6A Hettinger	5A Butler	5A Marion
4A Rutherford	7 Kidder	5A Carroll	5A Medina
3A Sampson	6A LaMoure	5A Champaign	5A Meigs
3A Scotland	6A Logan	5A Clark	5A Mercer
3A Stanly	7 McHenry	4A Clermont	5A Miami
4A Stokes	6A McIntosh	5A Clinton	5A Monroe
4A Surry	6A McKenzie	5A Columbiana	5A Montgomery
4A Swain	7 McLean	5A Coshocton	5A Morgan
4A Transylvania	6A Mercer	5A Crawford	5A Morrow
3A Tyrrell	6A Morton	5A Cuyahoga	5A Muskingum
3A Union	7 Mountrail	5A Darke	5A Noble
4A Vance	7 Nelson	5A Defiance	5A Ottawa
4A Wake	6A Oliver	5A Delaware	5A Paulding
4A Warren	7 Pembina	5A Erie	5A Perry

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
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U.S. States	U.S. States	U.S. States	U.S. States
5A Pickaway	3A Craig	3A Payne	4C Marion
4A Pike	3A Creek	3A Pittsburg	5B Morrow
5A Portage	3A Custer	3A Pontotoc	4C Multnomah
5A Preble	3A Delaware	3A Pottawatomie	4C Polk
5A Putnam	3A Dewey	3A Pushmataha	5B Sherman
5A Richland	3A Ellis	3A Roger Mills	4C Tillamook
5A Ross	3A Garfield	3A Rogers	5B Umatilla
5A Sandusky	3A Garvin	3A Seminole	5B Union
4A Scioto	3A Grady	3A Sequoyah	5B Wallowa
5A Seneca	3A Grant	3A Stephens	5B Wasco
5A Shelby	3A Greer	4B Texas	4C Washington
5A Stark	3A Harmon	3A Tillman	5B Wheeler
5A Summit	3A Harper	3A Tulsa	4C Yamhill
5A Trumbull	3A Haskell	3A Wagoner	**Pennsylvania**
5A Tuscarawas	3A Hughes	3A Washington	5A Adams
5A Union	3A Jackson	3A Washita	5A Allegheny
5A Van Wert	3A Jefferson	3A Woods	5A Armstrong
5A Vinton	3A Johnston	3A Woodward	5A Beaver
5A Warren	3A Kay	**Oregon**	5A Bedford
4A Washington	3A Kingfisher	5B Baker	5A Berks
5A Wayne	3A Kiowa	4C Benton	5A Blair
5A Williams	3A Latimer	4C Clackamas	5A Bradford
5A Wood	3A Le Flore	4C Clatsop	4A Bucks
5A Wyandot	3A Lincoln	4C Columbia	5A Butler
Oklahoma	3A Logan	4C Coos	5A Cambria
3A Adair	3A Love	5B Crook	6A Cameron
3A Alfalfa	3A Major	4C Curry	5A Carbon
3A Atoka	3A Marshall	5B Deschutes	5A Centre
4B Beaver	3A Mayes	4C Douglas	4A Chester
3A Beckham	3A McClain	5B Gilliam	5A Clarion
3A Blaine	3A McCurtain	5B Grant	6A Clearfield
3A Bryan	3A McIntosh	5B Harney	5A Clinton
3A Caddo	3A Murray	5B Hood River	5A Columbia
3A Canadian	3A Muskogee	4C Jackson	5A Crawford
3A Carter	3A Noble	5B Jefferson	5A Cumberland
3A Cherokee	3A Nowata	4C Josephine	5A Dauphin
3A Choctaw	3A Okfuskee	5B Klamath	4A Delaware
4B Cimarron	3A Oklahoma	5B Lake	6A Elk
3A Cleveland	3A Okmulgee	4C Lane	5A Erie
3A Coal	3A Osage	4C Lincoln	5A Fayette
3A Comanche	3A Ottawa	4C Linn	5A Forest
3A Cotton	3A Pawnee	5B Malheur	5A Franklin

TABLE B1-1 U.S. Climate Zones *(Continued)*

Key: A—Moist, B—Dry, C—Marine

(Absence of moisture designation indicates moisture regime is irrelevant.

Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
5A Fulton	3A Abbeville	3A Sumter	6A Kingsbury
5A Greene	3A Aiken	3A Union	6A Lake
5A Huntingdon	3A Allendale*	3A Williamsburg	6A Lawrence
5A Indiana	3A Anderson	3A York	6A Lincoln
5A Jefferson	3A Bamberg*	**South Dakota**	6A Lyman
5A Juniata	3A Barnwell*	6A Aurora	6A Marshall
5A Lackawanna	3A Beaufort*	6A Beadle	6A McCook
5A Lancaster	3A Berkeley*	5A Bennett	6A McPherson
5A Lawrence	3A Calhoun	5A Bon Homme	6A Meade
5A Lebanon	3A Charleston*	6A Brookings	5A Mellette
5A Lehigh	3A Cherokee	6A Brown	6A Miner
5A Luzerne	3A Chester	6A Brule	6A Minnehaha
5A Lycoming	3A Chesterfield	6A Buffalo	6A Moody
6A McKean	3A Clarendon	6A Butte	6A Pennington
5A Mercer	3A Colleton*	6A Campbell	6A Perkins
5A Mifflin	3A Darlington	5A Charles Mix	6A Potter
5A Monroe	3A Dillon	6A Clark	6A Roberts
4A Montgomery	3A Dorchester*	5A Clay	6A Sanborn
5A Montour	3A Edgefield	6A Codington	6A Shannon
5A Northampton	3A Fairfield	6A Corson	6A Spink
5A Northumberland	3A Florence	6A Custer	6A Stanley
5A Perry	3A Georgetown*	6A Davison	6A Sully
4A Philadelphia	3A Greenville	6A Day	5A Todd
5A Pike	3A Greenwood	6A Deuel	5A Tripp
6A Potter	3A Hampton*	6A Dewey	6A Turner
5A Schuylkill	3A Horry*	5A Douglas	5A Union
5A Snyder	3A Jasper*	6A Edmunds	6A Walworth
5A Somerset	3A Kershaw	6A Fall River	5A Yankton
5A Sullivan	3A Lancaster	6A Faulk	6A Ziebach
6A Susquehanna	3A Laurens	6A Grant	**Tennessee**
6A Tioga	3A Lee	5A Gregory	4A Anderson
5A Union	3A Lexington	6A Haakon	4A Bedford
5A Venango	3A Marion	6A Hamlin	4A Benton
5A Warren	3A Marlboro	6A Hand	4A Bledsoe
5A Washington	3A McCormick	6A Hanson	4A Blount
6A Wayne	3A Newberry	6A Harding	4A Bradley
5A Westmoreland	3A Oconee	6A Hughes	4A Campbell
5A Wyoming	3A Orangeburg	5A Hutchinson	4A Cannon
4A York	3A Pickens	6A Hyde	4A Carroll
Rhode Island	3A Richland	5A Jackson	4A Carter
5A (all)	3A Saluda	6A Jerauld	4A Cheatham
South Carolina	3A Spartanburg	6A Jones	3A Chester

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
4A Claiborne	3A Madison	2A Anderson*	3A Collin*
4A Clay	4A Marion	3B Andrews	3B Collingsworth
4A Cocke	4A Marshall	2A Angelina*	2A Colorado*
4A Coffee	4A Maury	2A Aransas*	2A Comal*
3A Crockett	4A McMinn	3A Archer	3A Comanche*
4A Cumberland	3A McNairy	4B Armstrong	3B Concho
4A Davidson	4A Meigs	2A Atascosa*	3A Cooke
4A Decatur	4A Monroe	2A Austin*	2A Coryell*
4A DeKalb	4A Montgomery	4B Bailey	3B Cottle
4A Dickson	4A Moore	2B Bandera*	3B Crane
3A Dyer	4A Morgan	2A Bastrop*	3B Crockett
3A Fayette	4A Obion	3B Baylor	3B Crosby
4A Fentress	4A Overton	2A Bee*	3B Culberson
4A Franklin	4A Perry	2A Bell*	4B Dallam
4A Gibson	4A Pickett	2A Bexar*	3A Dallas*
4A Giles	4A Polk	3A Blanco*	3B Dawson
4A Grainger	4A Putnam	3B Borden	4B Deaf Smith
4A Greene	4A Rhea	2A Bosque*	3A Delta
4A Grundy	4A Roane	3A Bowie*	3A Denton*
4A Hamblen	4A Robertson	2A Brazoria*	2A DeWitt*
4A Hamilton	4A Rutherford	2A Brazos*	3B Dickens
4A Hancock	4A Scott	3B Brewster	2B Dimmit*
3A Hardeman	4A Sequatchie	4B Briscoe	4B Donley
3A Hardin	4A Sevier	2A Brooks*	2A Duval*
4A Hawkins	3A Shelby	3A Brown*	3A Eastland
3A Haywood	4A Smith	2A Burleson*	3B Ector
3A Henderson	4A Stewart	3A Burnet*	2B Edwards*
4A Henry	4A Sullivan	2A Caldwell*	3A Ellis*
4A Hickman	4A Sumner	2A Calhoun*	3B El Paso
4A Houston	3A Tipton	3B Callahan	3A Erath*
4A Humphreys	4A Trousdale	2A Cameron*	2A Falls*
4A Jackson	4A Unicoi	3A Camp*	3A Fannin
4A Jefferson	4A Union	4B Carson	2A Fayette*
4A Johnson	4A Van Buren	3A Cass*	3B Fisher
4A Knox	4A Warren	4B Castro	4B Floyd
3A Lake	4A Washington	2A Chambers*	3B Foard
3A Lauderdale	4A Wayne	2A Cherokee*	2A Fort Bend*
4A Lawrence	4A Weakley	3B Childress	3A Franklin*
4A Lewis	4A White	3A Clay	2A Freestone*
4A Lincoln	4A Williamson	4B Cochran	2B Frio*
4A Loudon	4A Wilson	3B Coke	3B Gaines
4A Macon	**Texas**	3B Coleman	2A Galveston*

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
3B Garza	3B Jones	3A Montague	4B Sherman
3A Gillespie*	2A Karnes*	2A Montgomery*	3A Smith*
3B Glasscock	3A Kaufman*	4B Moore	3A Somervell*
2A Goliad*	3A Kendall*	3A Morris*	2A Starr*
2A Gonzales*	2A Kenedy*	3B Motley	3A Stephens
4B Gray	3B Kent	3A Nacogdoches*	3B Sterling
3A Grayson	3B Kerr	3A Navarro*	3B Stonewall
3A Gregg*	3B Kimble	2A Newton*	3B Sutton
2A Grimes*	3B King	3B Nolan	4B Swisher
2A Guadalupe*	2B Kinney*	2A Nueces*	3A Tarrant*
4B Hale	2A Kleberg*	4B Ochiltree	3B Taylor
3B Hall	3B Knox	4B Oldham	3B Terrell
3A Hamilton*	3A Lamar*	2A Orange*	3B Terry
4B Hansford	4B Lamb	3A Palo Pinto*	3B Throckmorton
3B Hardeman	3A Lampasas*	3A Panola*	3A Titus*
2A Hardin*	2B La Salle*	3A Parker*	3B Tom Green
2A Harris*	2A Lavaca*	4B Parmer	2A Travis*
3A Harrison*	2A Lee*	3B Pecos	2A Trinity*
4B Hartley	2A Leon*	2A Polk*	2A Tyler*
3B Haskell	2A Liberty*	4B Potter	3A Upshur*
2A Hays*	2A Limestone*	3B Presidio	3B Upton
3B Hemphill	4B Lipscomb	3A Rains*	2B Uvalde*
3A Henderson*	2A Live Oak*	4B Randall	2B Val Verde*
2A Hidalgo*	3A Llano*	3B Reagan	3A Van Zandt*
2A Hill*	3B Loving	2B Real*	2A Victoria*
4B Hockley	3B Lubbock	3A Red River*	2A Walker*
3A Hood*	3B Lynn	3B Reeves	2A Waller*
3A Hopkins*	2A Madison*	2A Refugio*	3B Ward
2A Houston*	3A Marion*	4B Roberts	2A Washington*
3B Howard	3B Martin	2A Robertson*	2B Webb*
3B Hudspeth	3B Mason	3A Rockwall*	2A Wharton*
3A Hunt*	2A Matagorda*	3B Runnels	3B Wheeler
4B Hutchinson	2B Maverick*	3A Rusk*	3A Wichita
3B Irion	3B McCulloch	3A Sabine*	3B Wilbarger
3A Jack	2A McLennan*	3A San Augustine*	2A Willacy*
2A Jackson*	2A McMullen*	2A San Jacinto*	2A Williamson*
2A Jasper*	2B Medina*	2A San Patricio*	2A Wilson*
3B Jeff Davis	3B Menard	3A San Saba*	3B Winkler
2A Jefferson*	3B Midland	3B Schleicher	3A Wise
2A Jim Hogg*	2A Milam*	3B Scurry	3A Wood*
2A Jim Wells*	3A Mills*	3B Shackelford	4B Yoakum
3A Johnson*	3B Mitchell	3A Shelby*	3A Young

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
2B Zapata*	4C Clark	4A Clay	4A Wayne
2B Zavala*	5B Columbia	5A Doddridge	5A Webster
Utah	4C Cowlitz	5A Fayette	5A Wetzel
5B Beaver	5B Douglas	4A Gilmer	4A Wirt
6B Box Elder	6B Ferry	5A Grant	4A Wood
6B Cache	5B Franklin	5A Greenbrier	4A Wyoming
6B Carbon	5B Garfield	5A Hampshire	**Wisconsin**
6B Daggett	5B Grant	5A Hancock	6A Adams
5B Davis	4C Grays Harbor	5A Hardy	7 Ashland
6B Duchesne	4C Island	5A Harrison	6A Barron
5B Emery	4C Jefferson	4A Jackson	7 Bayfield
5B Garfield	4C King	4A Jefferson	6A Brown
5B Grand	4C Kitsap	4A Kanawha	6A Buffalo
5B Iron	5B Kittitas	5A Lewis	7 Burnett
5B Juab	5B Klickitat	4A Lincoln	6A Calumet
5B Kane	4C Lewis	4A Logan	6A Chippewa
5B Millard	5B Lincoln	5A Marion	6A Clark
6B Morgan	4C Mason	5A Marshall	6A Columbia
5B Piute	6B Okanogan	4A Mason	6A Crawford
6B Rich	4C Pacific	4A McDowell	6A Dane
5B Salt Lake	6B Pend Oreille	4A Mercer	6A Dodge
5B San Juan	4C Pierce	5A Mineral	6A Door
5B Sanpete	4C San Juan	4A Mingo	7 Douglas
5B Sevier	4C Skagit	5A Monongalia	6A Dunn
6B Summit	5B Skamania	4A Monroe	6A Eau Claire
5B Tooele	4C Snohomish	4A Morgan	7 Florence
6B Uintah	5B Spokane	5A Nicholas	6A Fond du Lac
5B Utah	6B Stevens	5A Ohio	7 Forest
6B Wasatch	4C Thurston	5A Pendleton	6A Grant
3B Washington	4C Wahkiakum	4A Pleasants	6A Green
5B Wayne	5B Walla Walla	5A Pocahontas	6A Green Lake
5B Weber	4C Whatcom	5A Preston	6A Iowa
Vermont	5B Whitman	4A Putnam	7 Iron
6A (all)	5B Yakima	5A Raleigh	6A Jackson
Virginia	**West Virginia**	5A Randolph	6A Jefferson
4A (all)	5A Barbour	4A Ritchie	6A Juneau
Washington	4A Berkeley	4A Roane	6A Kenosha
5B Adams	4A Boone	5A Summers	6A Kewaunee
5B Asotin	4A Braxton	5A Taylor	6A La Crosse
5B Benton	5A Brooke	5A Tucker	6A Lafayette
5B Chelan	4A Cabell	4A Tyler	7 Langlade
4C Clallam	4A Calhoun	5A Upshur	7 Lincoln

TABLE B1-1 U.S. Climate Zones *(Continued)*
Key: A—Moist, B—Dry, C—Marine
(Absence of moisture designation indicates moisture regime is irrelevant.
Asterisk '*' indicates a warm-humid location.)

U.S. States	U.S. States	U.S. States	U.S. States
6A Manitowoc	6B Converse		
6A Marathon	6B Crook		
6A Marinette	6B Fremont		
6A Marquette	5B Goshen		
6A Menominee	6B Hot Springs		
6A Milwaukee	6B Johnson		
6A Monroe	6B Laramie		
6A Oconto	7 Lincoln		
7 Oneida	6B Natrona		
6A Outagamie	6B Niobrara		
6A Ozaukee	6B Park		
6A Pepin	5B Platte		
6A Pierce	6B Sheridan		
6A Polk	7 Sublette		
6A Portage	6B Sweetwater		
7 Price	7 Teton		
6A Racine	6B Uinta		
6A Richland	6B Washakie		
6A Rock	6B Weston		
6A Rusk			
6A Sauk	**U.S. Territories**		
7 Sawyer	**American Samoa**		
6A Shawano	1A (all)*		
6A Sheboygan	**Guam**		
6A St. Croix	1A (all)*		
7 Taylor	**Northern Mariana Islands**		
6A Trempealeau	1A (all)*		
6A Vernon	**Puerto Rico**		
7 Vilas	1A (all)*		
6A Walworth	**Virgin Islands**		
7 Washburn	1A (all)*		
6A Washington			
6A Waukesha			
6A Waupaca			
6A Waushara			
6A Winnebago			
6A Wood			
Wyoming			
6B Albany			
6B Big Horn			
6B Campbell			
6B Carbon			

TABLE B1-2 Canadian Climatic Zones

Province / City	Zone
Alberta (AB)	
Calgary International A	7
Edmonton International A	7
Grande Prairie A	7
Jasper	7
Lethbridge A	6
Medicine Hat A	6
Red Deer A	7
British Columbia (BC)	
Dawson Creek A	7
Fort Nelson A	8
Kamloops	5
Nanaimo A	5
New Westminster BC Pen	5
Penticton A	5
Prince George	7
Prince Rupert A	6
Vancouver International A	5
Victoria Gonzales Hts	5
Manitoba (MB)	
Brandon CDA	7
Churchill A	8
Dauphin A	7
Flin Flon	7
Portage La Prairie A	7
The Pas A	7
(Manitoba cont.)	
Winnipeg International A	7
New Brunswick (NB)	
Chatham A	7
Fredericton A	6
Moncton A	6
Saint John A	6
Newfoundland (NF)	
Corner Brook	6
Gander International A	7
Goose A	7
St John's A	6
Stephenville A	6
Northwest Territories (NW)	
Fort Smith A	8
Inuvik A	8
Yellowknife A	8
Nova Scotia (NS)	
Halifax International A	6
Kentville CDA	6
Sydney A	6
Truro	6
Yarmouth A	6
Nunavut	
Resolute A	8
Ontario (ON)	
Belleville	6
Cornwall	6
Hamilton RBG	5
Kapuskasing A	7
Kenora A	7
Kingston A	6
London A	6
North Bay A	7
Oshawa WPCP	6
Ottawa International A	6
Owen Sound MOE	6
Peterborough	6
St Catharines	5
Sudbury A	7
Thunder Bay A	7
Timmins A	7
Toronto Downsview A	6
Windsor A	5
Prince Edward Island (PE)	
Charlottetown A	6
Summerside A	6
Québec (PQ)	
Bagotville A	7
Drummondville	6
(Québec cont.)	
Granby	6
Montreal Dorval International A	6
Québec City A	7
Rimouski	7
Septles A	7
Shawinigan	7
Sherbrooke A	7
St Jean de Cherbourg	7
St Jerome	7
Thetford Mines	7
Trois Rivieres	7
Val d'Or A	7
Valleyfield	6
Saskatchewan (SK)	
Estevan A	7
Moose Jaw A	7
North Battleford A	7
Prince Albert A	7
Regina A	7
Saskatoon A	7
Swift Current A	7
Yorkton A	7
Yukon Territory (YT)	
Whitehorse A	8

TABLE B1-3 International Climate Zones

Country / City (Province or Region)	Zone
Argentina	
Buenos Aires/Ezeiza	3
Cordoba	3
Tucuman/Pozo	2
Australia	
Adelaide (SA)	4
Alice Springs (NT)	2
Brisbane (AL)	2
Darwin Airport (NT)	1
Perth/Guildford (WA)	3
Sydney/KSmith (NSW)	3
Azores (Terceira)	
Lajes	3
Bahamas	
Nassau	1
Belgium	
Brussels Airport	5
Bermuda	
St. Georges/Kindley	2
Bolivia	
La Paz/El Alto	5
Brazil	
Belem	1
Brasilia	2
Fortaleza	1
Porto Alegre	2
Recife/Curado	1
Rio de Janeiro	1
Salvador/Ondina	1
Sao Paulo	2
Bulgaria	
Sofia	5
Chile	
Concepcion	4
Punta Arenas/Chabunco	6
Santiago/Pedahuel	4
China	
Shanghai/Hongqiao	3
Cuba	
Guantanamo Bay NAS (Ote.)	1
Cyprus	
Akrotiri	3
Larnaca	3
Paphos	3
Czech Republic	
Prague/Libus	5
Dominican Republic	
Santo Domingo	1
Egypt	
Cairo	2
Luxor	1
Finland	
Helsinki/Seutula	7
France	
Lyon/Satolas	4
Marseille	4
Nantes	4
Nice	4
Paris/Le Bourget	4
Strasbourg	5
Germany	
Berlin/Schoenfeld	5
Hamburg	5
Hannover	5
Mannheim	5
Greece	
Souda (Crete)	3
Thessalonika/Mikra	4
Greenland	
Narssarssuaq	7
Hungary	
Budapest/Lorinc	5
Iceland	
Reykjavik	7
India	
Ahmedabad	1
Bangalore	1
Bombay/Santa Cruz	1
Calcutta/Dum Dum	1
Madras	1
Nagpur Sonegaon	1
New Delhi/Safdarjung	1
Indonesia	
Djakarta/Halimperda (Java)	1
Kupang Penfui (Sunda Island)	1
Makassar (Celebes)	1
Medan (Sumatra)	1
Palembang (Sumatra)	1
Surabaja Perak (Java)	1
Ireland	
Dublin Airport	5
Shannon Airport	4
Israel	
Jerusalem	3
Tel Aviv Port	2
Italy	
Milano/Linate	4
Napoli/Capodichino	4
Roma/Fiumicion	4
Jamaica	
Kingston/Manley	1
Montego Bay/Sangster	1
Japan	
Fukaura	5
Sapporo	5
Tokyo	3
Jordan	
Amman	3
Kenya	
Nairobi Airport	3
Korea	
Pyonggang	5
Seoul	4
Malaysia	
Kuala Lumpur	1
Penang/Bayan Lepas	1
Mexico	
Mexico City (Distrito Federal)	3
Guadalajara (Jalisco)	1
Monterrey (Nuevo Laredo)	3
Tampico (Tamaulipas)	1
Veracruz (Veracruz)	4
Merida (Yucatan)	1
Netherlands	
Amsterdam/Schiphol	5
New Zealand	
Auckland Airport	4
Christchurch	4
Wellington	4
Norway	
Bergen/Florida	5
Oslo/Fornebu	6
Pakistan	
Karachi Airport	1
Papua New Guinea	
Port Moresby	1
Paraguay	
Asuncion/Stroessner	1
Peru	
LimaCallao/Chavez	2
San Juan de Marcona	2
Talara	2
Philippines	
Manila Airport (Luzon)	1
Poland	
Krakow/Balice	5
Romania	
Bucuresti/Bancasa	5
Russia	
Kaliningrad (East Prussia)	5
Krasnoiarsk	7
Moscow Observatory	6
Petropavlovsk	7
(Russia cont.)	
RostovNaDonu	5
Vladivostok	6
Volgograd	6
Saudi Arabia	
Dhahran	1
Riyadh	1
Senegal	
Dakar/Yoff	1
Singapore	
Singapore/Changi	1
South Africa	
Cape Town/D F Malan	4
Johannesburg	4
Pretoria	3
Spain	
Barcelona	4
Madrid	4
Valencia/Manises	3
Sweden	
Stockholm/Arlanda	6
Switzerland	
Zurich	5
Syria	
Damascus Airport	3
Taiwan	
Tainan	1
Taipei	2
Tanzania	
Dar es Salaam	1
Thailand	
Bangkok	1
Tunisia	
Tunis/El Aouina	3
Turkey	
Adana	3
Ankara/Etimesgut	4
Istanbul/Yesilkoy	4
United Kingdom	
Birmingham (England)	5
Edinburgh (Scotland)	5
Glasgow Apt (Scotland)	5
London/Heathrow (England)	4
Uruguay	
Montevideo/Carrasco	3
Venezuela	
Caracas/Maiquetia	1
Vietnam	
Hanoi/Gialam	1
Saigon (Ho Chi Minh)	1

TABLE B1-4 International Climate Zone Definitions

Zone Number	Name	Thermal Criteria
1	Very Hot–Humid (1A), Dry (1B)	5000 < CDD10°C
2	Hot–Humid (2A), Dry (2B)	3500 < CDD10°C ≤ 5000
3A and 3B	Warm–Humid (3A), Dry (3B)	2500 < CDD10°C ≤ 3500
3C	Warm–Marine	CDD10°C ≤ 2500 and HDD18°C ≤ 2000
4A and 4B	Mixed–Humid (4A), Dry (4B)	CDD10°C ≤ 2500 and 2000 < HDD18°C ≤ 3000
4C	Mixed–Marine	2000 < HDD18°C ≤ 3000
5A, 5B and 5C	Cool–Humid (5A), Dry (5B), Marine (5C)	3000 < HDD18°C ≤ 4000
6A and 6B	Cold–Humid (6A), Dry (6B)	4000 < HDD18°C ≤ 5000
7	Very Cold	5000 < HDD18°C ≤ 7000
8	Subarctic	7000 < HDD18°C

(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 Semi-Exterior Surface Level. The building envelope assembly type, gross area, orientation, tilt, and associated space-conditioning category and building area type shall be specified. The surface shall be designated as exterior or semi-exterior. A semi-exterior surface separating a conditioned space from a semi-exterior space shall be specified with two associated space-conditioning categories. A semi-exterior surface separating a conditioned space from an unconditioned space shall be specified with an associated space-conditioning category and with an adjacency to an unconditioned space. Exterior surfaces with the same building envelope assembly type and associated space-conditioning category and building area type whose orientations differ by no more than 22.5 degrees and whose tilts differ by no more than 22.5 degrees are allowed to be described as a single surface.

C1.2.1 For Roofs. The class of construction, opaque area, U-factor, HC, and insulation position shall be specified. Where three-year-aged test data for the solar reflectance and three-year-aged thermal emittance of the exterior roof surface are available, the three-year-aged solar reflectance and three-year-aged thermal emittance shall be specified.

C1.2.2 For Above-Grade Walls. The class of construction, opaque area, U-factor, HC, and insulation position shall be specified.

C1.2.3 For Below-Grade Walls. The opaque area, average depth to the bottom of the wall, C-factor, HC, and insulation position shall be specified.

C1.2.4 For Floors. The class of construction, opaque area, U-factor, HC, and insulation position shall be specified.

C1.2.5 For Slab-on-Grade Floors. The class of construction, perimeter length, F-factor, and HC shall be specified.

C1.2.6 For Uninsulated Assemblies. All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor stabs, concrete floor beams over parking garages, roof parapet) shall be separately modeled.

C1.3 For Opaque Doors. The class of construction, area, and U-factor shall be specified. Each opaque door shall be associated with a surface as defined in Section C1.2 and shall have the orientation of that surface.

C1.4 For Fenestration. The class of construction, area, U-factor, SHGC, VT, and PF shall be specified for fenestration. For skylight wells, the width, depth, and height shall be defined as shown in Figure C1.4. Each fenestration element shall be associated with a surface as defined in Section C1.2 and shall have the orientation of that surface.

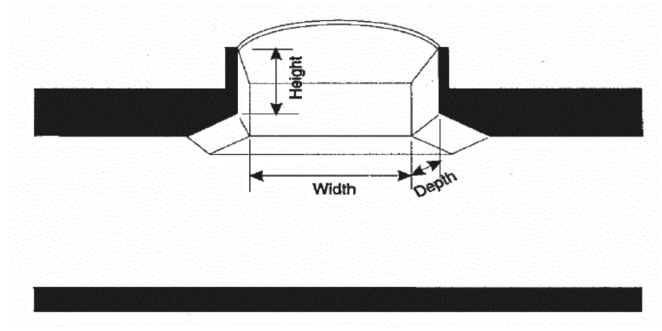

Figure C1.4 Skylight well dimensions.

C2. OUTPUT REQUIREMENTS

Output reports shall contain the following information.

C2.1 Name and contact information of the entity executing the simulation, and date of report.

C2.2 Location of the building, including street address and climate zone.

C2.3 Location corresponding to the weather data used to perform the simulation.

C2.4 Simulation program used to perform the simulation.

C2.5 Tables summarizing the minimum information described in Section C1.

C2.6 All differences between the proposed envelope performance factor and the base envelope performance factor.

C2.7 Total conductive heat gain and conductive heat loss through all opaque classes of construction.

C2.8 Total conductive heat gain, conductive heat loss, and solar heat gain through all fenestration classes of construction.

C3. SIMULATION GENERAL REQUIREMENTS

C3.1 Simulation Program. The simulation program shall be a computer-based program for the analysis of energy consumption in buildings. The simulation program shall include calculation methodologies for the building components being modeled.

Informative Note: Simulation programs include, but are not limited to, EnergyPlus and DOE-2.

C3.1.1 The simulation program shall be approved by the adopting authority and shall, at minimum, have the ability to explicitly model all of the following:

a. The base envelope performance factor, using only the input for the proposed envelope performance factor. The calculation procedure shall not allow the user to directly modify the building component characteristics of the base design.
b. 8760 hours per year.
c. Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays.

d. Thermal mass effects.
e. The number of thermal zones in the proposed building or nine thermal zones, whichever is greater.
f. Air-side economizers with integrated control.
g. Continuous daylight dimming controls and photosensors.

C3.1.2 The simulation program shall have the ability to determine the proposed envelope performance factor and base envelope performance factor by calculating annual energy costs.

C3.1.3 The simulation program shall be capable of performing design load calculations to determine required HVAC equipment capacities and airflow rates in accordance with Section 6.4.2 for both the proposed envelope design and the budget envelope design.

C3.1.4 The simulation program shall be tested according to ASHRAE Standard 140, and the results shall be published by the software provider.

C3.2 Climatic Data. The simulation program shall perform the simulation using hourly values of climatic data, including temperature, humidity, solar radiation, and wind speed and direction from representative climatic data, for the proposed envelope design location. For cities or urban regions for which several climatic data sources are available and for locations for which weather data are not available, the designer shall select available weather data that represent the climate at the construction site. Selected weather data shall be approved by the authority having jurisdiction.

C3.2.1 Surface Exposure. Semi-exterior surfaces separating conditioned spaces from unconditioned spaces shall be simulated as exterior surfaces with no exposure to wind or solar radiation.

C3.3 Purchased Energy Rates. The following rates for purchased energy shall be used to determine the proposed envelope performance factor and the base envelope performance factor:

a. Electricity: 0.1032/kWh
b. Heating: 0.99/therm

Exception: Where approved by the authority having jurisdiction, actual annual rates for purchased energy or state average energy prices published by the Department of Energy's Energy Information Administration shall be permitted. The same rates shall be used for both the proposed envelope performance factor and the base envelope performance factor.

C3.4 Compliance Calculations. The proposed envelope performance factor and base envelope performance factor shall be calculated using the same

a. simulation program,
b. climatic data, and
c. purchased energy rates.

C3.5 Calculation of Proposed Envelope Performance Factor. The simulation model for calculating the proposed envelope performance factor shall be developed in accordance with Sections C3.5.1 through C3.5.7.

C3.5.1 Space Conditioning. All conditioned spaces in the proposed building design shall be simulated as being both heated and cooled, even if no cooling or heating system is being installed. Temperature control setpoints and schedules shall be consistent with those in the building envelope trade-off schedules and loads for the applicable building area type. All semiheated spaces shall be simulated as being heated and not cooled. The heating temperature control setpoint shall be 10°C 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 4.6 m.
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 3 m. 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 0.91 m.
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 1.5 m.

C3.5.4 Schedules. The schedule types listed in Section C3.1.1(c) shall be required input. The schedules shall be consistent with those in the building envelope trade-off schedules and loads[1] for the applicable building area type.

C3.5.5 Building Envelope. The building envelope shall reflect the information specified in Section C1.

Exception: Where three-year-aged test data for the solar reflectance and three-year-aged thermal emittance of the exterior roof surface are unavailable, the exterior roof surface shall be modeled with a solar reflectance of 0.30 and a thermal emittance of 0.90.

C3.5.5.1 Shading. Manually operated interior shades shall be modeled on all vertical fenestration. Shades shall be modeled to be lowered when the transmitted luminous intensity is greater than 2000 cd/m^2 or the direct solar transmitted energy exceeds 95 W/m^2 and then remain lowered for rest of the day. Shades shall be modeled with visible light transmittance of 0.10, visible light reflectance of 0.40, solar transmittance of 0.21, and solar reflectance of 0.23. Permanent shading devices such as fins and overhangs shall be modeled.

C3.5.5.2 Dynamic Glazing. Automatically controlled dynamic glazing is allowed to be modeled. Manually controlled dynamic glazing shall use the average of the minimum and maximum values for both SHGC and VT.

C3.5.5.3 Infiltration. The peak infiltration rate of the building envelope (I_{75Pa}) at a fixed building pressure differential of 75 Pa shall be 2.03 L/s·m^2 exterior building enclosure area. The peak infiltration rate of the building envelope shall be converted to the appropriate units to describe the peak infiltration as a function of exterior wall area as follows:

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

where

I_{75Pa}	=	air leakage rate of the building envelope expressed in L/s·m^2 at a fixed building pressure differential of 75 Pa.
S	=	the total area of the envelope air pressure boundary, including the lowest floor, any below-grade walls, above-grade walls, and roof (or ceiling) (including windows and skylights), separating the interior conditioned space from the unconditioned environment measured in square feet (square meters),
I_{EW}	=	adjusted air leakage rate of the building envelope at a reference wind speed of 4.47 m/s and the above-ground exterior wall area.
A_{EW}	=	the total above-grade exterior wall area, m^2

Exception: If the simulation program cannot simulate infiltration as a function of exterior wall area, the peak infiltration of the building envelope shall be converted to the appropriate units to describe the peak infiltration as a function of floor area as follows:

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

where

I_{FLR}	=	adjusted air leakage rate of the building envelope at a reference wind speed of 4.47m/s and the above-ground exterior wall area.
A_{FLR}	=	the total gross floor area, m^2

C3.5.5.3.1 Infiltration Schedule. Infiltration shall be adjusted in accordance with the infiltration schedule in the building envelope trade-off schedules and loads for the applicable building area type.

C3.5.6 Interior Surfaces. Interior surfaces shall be modeled with visible light reflectances of 0.80 for ceilings, 0.50 for walls, and 0.20 for floors. Interior surfaces shall be modeled with a thermal emittance of 0.90.

C3.5.7 Lighting. Lighting power shall be determined using the lighting power density in Table 9.5.1 for the applicable building area type. Lighting power shall be adjusted in accordance with the lighting schedule in the building envelope trade-off schedules and loads for the applicable building area type. Fifty percent (50%) of lighting in daylight areas shall be

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

modeled with continuous daylight dimming controls such that when sufficient daylight is available at the corresponding photosensor, lighting power is reduced to maintain a minimum 50 fc for conditioned spaces and 30 fc for semiheated spaces. The minimum light output for the continuous daylight dimming shall be 6% of peak light output. Power input shall be modeled as 20% of lighting power density at the minimum light output and scaled linearly to 100% of lighting power density at peak light output.

C3.5.8 HVAC Systems. One HVAC system shall be provided for each thermal zone and shall have the following characteristics:

a. Constant-volume fan control
b. Electrically-provided cooling with constant COP equal to the minimum IEER allowed for air-cooled air conditioners of “All Other” heating section type with ≥18kW and <40 kW capacity, in accordance with Table 6.8.1-1, divided by 3.412.
c. Gas furnace with constant thermal efficiency equal to the minimum AFUE allowed for gas-fired warm-air furnaces with maximum capacity <66 kW, in accordance with Table 6.8.1-5.
d. The ventilation rate for each building area type shall be consistent with the ventilation rate in the building envelope trade-off schedules and loads for the applicable building area type.
e. Outdoor air economizers, except in Climate Zone 1. The high-limit shutoff shall be “Fixed Dry Bulb” type as described in Table 6.5.1.1.3.
f. System design supply air rates shall be based on a supply-air-to-room-air temperature difference of 11.0°C.
g. System capacities used in the annual simulation shall be 1.5 times the capacities determined by the sizing simulations.
h. Fans shall cycle on whenever the space calls for heating or cooling. The fan energy shall be included in the energy efficiency rating of the equipment, and the fan energy shall not be modeled explicitly.

C3.5.9 Miscellaneous Loads. Miscellaneous loads shall be modeled as included in the building envelope trade-off schedules and loads for the applicable building area type.

C3.5.10 Occupant Density. The occupant density shall be modeled according to the peak occupant density and the occupancy rate schedule in the building envelope trade-off schedules and loads for the applicable building area type.

C3.5.11 Heat Gain from Occupants. The sensible and latent heat gain due to occupants shall be modeled as included in the building envelope trade-off schedules and loads for the applicable building area type.

C3.6 Calculation of Base Envelope Performance Factor. The simulation model for calculating the base envelope performance factor shall modify the simulation model for calculating the proposed envelope performance factor as follows:

a. All opaque assemblies shall be modeled with the maximum U-factor required in Section 5.5.3 for the appropriate class of construction, space-conditioning category, and climate zone. Mass walls and mass floors shall be modeled with HC equal to 147 $kJ/m^2 \cdot K$. All other opaque assemblies shall be modeled with the same HC as the proposed building design. Mass walls shall be modeled with equal mass on each side of the insulation. All other opaque assemblies shall be modeled with insulation on the exterior.
b. The exterior roof surfaces shall be modeled with a solar reflectance and thermal emittance as required in Section 5.5.3.1.1(a). All other roofs, including roofs exempted from the requirements in Section 5.5.3.1.1, shall be modeled the same as in the proposed design.
c. Fenestration shall be assumed to be flush with the exterior wall or roof. If the fenestration area for new buildings or additions exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. If the fenestration area facing west or east of the proposed building exceeds the area limit set in Section 5.5.4.5, the baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, and 270 degrees, then averaging the results of the four simulations. Fenestration U-factor and SHGC shall be the maximum allowed for the appropriate class of construction, space-conditioning category, and climate zone in accordance with Section 5.5.4. Where there is no SHGC requirement, the SHGC shall be equal to 0.40 for all vertical fenestration, and 0.55 for skylights. The VT for fenestration in the base envelope design shall be equal to 1.10 times the SHGC.
d. Manually operated interior shades shall be modeled on all vertical fenestration as described in Section C3.5.5.1. Permanent shading devices, such as fins and overhangs, shall not be modeled.
e. Daylight areas and photosensor locations shall be modeled as described in Section C3.5.3 after reducing the fenestration area as described in Section C3.6(c).

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX D
CLIMATIC DATA

This normative appendix contains the climatic data necessary to determine building envelope and mechanical requirements for various U.S., Canadian, and international locations. (See Section 5.1.4 for additional information regarding the selection of climatic data.) The following definition applies: NA = not available.

TABLE D-1 U.S. and U.S. Territory Climatic Data

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
Alabama (AL)									
Alexander City	32.95 N	85.93 W	195	1617	2834	NA	NA	NA	NA
Anniston FAA AP	33.58 N	85.85 W	186	1586	2898	–7	34	24	NA
Auburn Agronomy Farm	32.60 N	85.50 W	198	1451	3016	NA	NA	NA	NA
Birmingham FAA AP	33.57 N	86.75 W	190	1621	2892	–8	33	24	760
Dothan	31.32 N	85.45 W	122	946	3699	–2	34	24	NA
Gadsden Steam Plant	34.03 N	86.00 W	172	1843	2669	NA	NA	NA	NA
Huntsville WSO AP	34.65 N	86.77 W	190	1846	2697	–9	33	23	NA
Mobile WSO AP	30.68 N	88.25 W	64	946	3756	–3	33	24	774
Montgomery WSO AP	32.30 N	86.40 W	67	1236	3328	–4	34	24	734
Selma	32.42 N	87.00 W	44	1249	3378	NA	NA	NA	NA
Talladega	33.43 N	86.08 W	169	1550	2832	NA	NA	NA	NA
Tuscaloosa FAA AP	33.23 N	87.62 W	51	1478	3124	–7	34	25	NA
Alaska (AK)									
Anchorage WSCMO AP	61.17 N	150.02 W	34	5872	382	–26	20	14	521
Barrow WSO AP	71.30 N	156.78 W	9	11,237	0	–41	11	9	NA
Fairbanks WSFO AP	64.82 N	147.87 W	132	7744	578	–44	25	15	682
Juneau AP	58.37 N	134.58 W	3	4943	311	–16	21	14	540
Kodiak WSO AP	57.75 N	152.50 W	33	4898	251	–14	18	13	384
Nome WSO AP	64.50 N	165.43 W	3	7849	152	–35	18	13	210
Arizona (AZ)									
Douglas FAA AP	31.47 N	109.60 W	1537	2659	N.A.	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Arizona cont.)									
Flagstaff WSO AP	35.13 N	111.67 W	2135	3962	923	–17	28	13	NA
Kingman	35.20 N	114.02 W	1078	1784	2800	–6	36	17	NA
Nogales	31.42 N	110.95 W	1085	1627	2530	NA	NA	NA	NA
Phoenix WSFO AP	33.43 N	112.02 W	338	750	4681	1	42	21	746
Prescott	34.57 N	112.43 W	1586	2775	1597	–9	33	16	725
Tucson WSO AP	32.13 N	110.93 W	787	932	3845	–1	39	18	716
Winslow WSO AP	35.02 N	110.73 W	1490	2653	2045	–12	34	16	634
Yuma WSO AP	32.67 N	114.60 W	62	515	4943	4	43	22	697
Arkansas (AR)									
Blytheville AFB	35.97 N	89.95 W	78	2031	2852	–11	35	25	NA
Camden	33.60 N	92.82 W	35	1641	2949	NA	NA	NA	NA
Fayetteville	36.00 N	94.17 W	381	2244	2473	–14	34	24	NA
Ft. Smith WSO AP	35.33 N	94.37 W	136	1932	2821	–11	36	24	547
Hot Springs	34.52 N	93.05 W	207	1767	2913	NA	NA	NA	NA
Jonesboro	35.88 N	90.70 W	118	1947	2843	NA	NA	NA	NA
Little Rock FAA AP	34.73 N	92.23 W	78	1753	2944	–9	35	25	626
Pine Bluff	34.22 N	92.02 W	65	1676	3037	NA	NA	NA	NA
Texarkana FAA AP	33.45 N	94.00 W	110	1275	3418	–7	35	25	NA
California (CA)									
Bakersfield WSO AP	35.42 N	119.05 W	150	1212	3361	0	38	21	848
Blythe FAA Airport	33.62 N	114.72 W	118	636	4883	NA	NA	NA	NA
Burbank Hollywood	34.20 N	118.37 W	236	669	3250	4	35	21	NA
Chico University Farm	39.70 N	121.82 W	56	1641	2474	NA	NA	NA	NA
Crescent City	41.77 N	124.20 W	12	2443	904	NA	NA	NA	NA
El Centro	32.77 N	115.57 W	–9	642	4518	NA	NA	NA	NA
Eureka WSO City	40.80 N	124.17 W	18	2498	849	NA	NA	NA	NA
Fairfield/Travis AFB	38.27 N	121.93 W	19	1420	2346	–1	34	19	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	Number of Hours 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(California cont.)									
Fresno WSO AP	36.77 N	119.72 W	99	1420	2972	–1	38	21	785
Laguna Beach	33.55 N	117.78 W	10	1198	2156	NA	NA	NA	NA
Livermore	37.67 N	121.77 W	146	1616	2117	NA	NA	NA	NA
Lompoc	34.65 N	120.45 W	28	1473	1800	NA	NA	NA	NA
Long Beach WSO AP	33.82 N	118.15 W	10	794	2934	4	31	19	1502
Los Angeles WSO AP	33.93 N	118.38 W	30	810	2654	6	27	18	1849
Merced/Castle AFB	37.37 N	120.57 W	57	1493	2608	–1	36	21	NA
Monterey	36.60 N	121.90 W	117	1736	1430	NA	NA	NA	NA
Napa State Hospital	38.28 N	122.27 W	18	1580	1924	NA	NA	NA	NA
Needles FAA Airport	34.77 N	114.62 W	278	727	4803	NA	NA	NA	NA
Oakland/Intl	37.73 N	122.20 W	2	1469	1737	NA	NA	NA	1905
Oceanside Marina	33.22 N	117.40 W	3	1117	2261	NA	NA	NA	NA
Ontario/Intl	34.05 N	117.62 W	293	827	3235	2	37	21	NA
Oxnard	34.20 N	119.18 W	14	1107	2211	4	26	18	NA
Palm Springs	33.83 N	116.50 W	129	547	4753	NA	NA	NA	NA
Palmdale	34.58 N	118.10 W	791	1638	2702	NA	NA	NA	NA
Pasadena	34.15 N	118.15 W	263	807	3042	NA	NA	NA	NA
Petaluma Fire Stn 3	38.23 N	122.63 W	8	1694	1771	NA	NA	NA	NA
Pomona Cal Poly	34.07 N	117.82 W	225	952	2858	NA	NA	NA	NA
Redding WSO	40.50 N	122.30 W	153	1586	2758	NA	NA	NA	NA
Redlands	34.05 N	117.18 W	401	1042	3019	NA	NA	NA	NA
Richmond	37.93 N	122.35 W	16	1420	1825	NA	NA	NA	NA
Riverside/March AFB	33.90 N	117.25 W	468	1034	2942	1	37	20	NA
Sacramento FAA AP	38.52 N	121.50 W	5	1527	2486	–1	36	20	990
Salinas FAA AP	36.67 N	121.60 W	21	1647	1639	1	26	17	NA
San Bernardino/Norton	34.10 N	117.23 W	352	1012	3028	1	38	21	NA
San Diego WSO AP	32.73 N	117.17 W	3	698	2902	7	27	19	1911

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(California cont.)									
San Francisco WSO AP	37.62 N	122.38 W	2	1676	1602	3	26	17	1796
San Jose	37.35 N	121.90 W	20	1326	2186	2	32	19	NA
San Luis Obispo Poly	35.30 N	120.67 W	96	1388	1940	NA	NA	NA	NA
Santa Ana Fire Station	33.75 N	117.87 W	41	688	3017	NA	NA	NA	NA
Santa Barbara FAA AP	34.43 N	119.83 W	2	1354	1916	1	27	18	NA
Santa Cruz	36.98 N	122.02 W	39	1649	1618	NA	NA	NA	NA
Santa Maria WSO AP	34.90 N	120.45 W	77	1658	1621	0	28	17	2016
Santa Monica Pier	34.00 N	118.50 W	4	1011	2303	NA	NA	NA	NA
Santa Paula	34.32 N	119.15 W	72	1133	2286	NA	NA	NA	NA
Santa Rosa	38.45 N	122.70 W	50	1602	1907	NA	NA	NA	NA
Stockton WSO AP	37.90 N	121.25 W	6	1504	2642	–1	36	20	NA
Ukiah	39.15 N	123.20 W	189	1641	2149	NA	NA	NA	NA
Visalia	36.33 N	119.30 W	99	1395	2881	NA	NA	NA	NA
Yreka	41.72 N	122.63 W	800	2992	1451	NA	NA	NA	NA
Colorado (CO)									
Alamosa WSO AP	37.45 N	105.87 W	2296	4861	763	–27	28	13	NA
Boulder	40.03 N	105.28 W	1652	3086	1567	NA	NA	NA	NA
Colorado Sprgs WSO AP	38.82 N	104.72 W	1856	3564	1284	–19	31	14	725
Denver WSFO AP	39.77 N	104.87 W	1611	3344	1518	–19	32	15	739
Durango	37.28 N	107.88 W	2011	3839	1079	NA	NA	NA	NA
Ft. Collins	40.58 N	105.08 W	1525	3538	1339	NA	NA	NA	NA
Grand Junction WSO AP	39.10 N	108.55 W	1477	3082	2018	–17	34	16	518
Greeley UNC	40.42 N	104.70 W	1437	3503	1499	NA	NA	NA	NA
La Junta FAA AP	38.05 N	103.52 W	1277	2925	2108	NA	NA	NA	NA
Pueblo WSO AP	38.28 N	104.52 W	1414	3007	1866	–18	34	17	720
Sterling	40.62 N	103.22 W	1200	3634	1561	NA	NA	NA	NA
Trinidad FAA AP	37.25 N	104.33 W	1751	3046	1653	–19	32	16	NA
Connecticut (CT)									
Bridgeport WSO AP	41.17 N	73.13 W	3	3076	1665	–13	29	22	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Connecticut cont.)									
Hartford-Brainard Fld	41.73 N	72.65 W	4	3419	1538	–17	31	22	598
Norwalk Gas Plant	41.12 N	73.42 W	11	3258	1538	NA	NA	NA	NA
Norwich Pub Util Plt	41.53 N	72.07 W	6	3261	1493	NA	NA	NA	NA
Delaware (DE)									
Dover	39.15 N	75.52 W	9	2409	2163	–10	32	24	NA
Wilmington WSO AP	39.67 N	75.60 W	724	2743	1976	–12	32	23	617
Florida (FL)									
Belle Glade Exp Stn	26.67 N	80.63 W	4	251	4603	NA	NA	NA	NA
Daytona Beach WSO AP	29.18 N	81.05 W	8	505	4204	1	32	25	641
Ft. Lauderdale	26.07 N	80.15 W	3	95	5408	8	32	26	NA
Ft. Myers FAA AP	26.58 N	81.87 W	4	232	4958	6	34	25	NA
Ft. Pierce	27.47 N	80.35 W	7	272	4693	NA	NA	NA	NA
Gainesville Mun AP	29.68 N	82.27 W	42	704	3894	–1	33	25	NA
Jacksonville WSO AP	30.50 N	81.70 W	7	797	3804	–2	34	25	674
Key West WSO AP	24.55 N	81.75 W	1	56	5652	13	32	26	NA
Lakeland	28.02 N	81.92 W	44	327	4707	NA	NA	NA	NA
Miami WSCMO AP	25.80 N	80.30 W	3	111	5263	8	32	25	259
Ocala	29.20 N	82.08 W	22	517	4276	NA	NA	NA	NA
Orlando WSO Mc Coy	28.43 N	81.33 W	27	381	4571	3	34	24	571
Panama City/Tyndall	30.07 N	85.58 W	5	675	3902	1	32	26	NA
Pensacola FAA AP	30.47 N	87.20 W	34	898	3787	–2	33	26	NA
St Augustine WFOY	29.90 N	81.32 W	2	578	4034	NA	NA	NA	NA
St Petersburg	27.77 N	82.63 W	2	335	4743	6	34	26	NA
Tallahassee WSO AP	30.38 N	84.37 W	16	947	3688	–4	34	24	747
Tampa WSCMO AP	27.97 N	82.53 W	5	403	4577	2	33	25	592
West Palm Beach WSO AP	26.68 N	80.12 W	5	179	5027	6	32	26	308
Georgia (GA)									
Albany	31.53 N	84.13 W	54	1225	3344	–3	35	24	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Georgia cont.)									
Americus	32.05 N	84.25 W	149	1350	3130	NA	NA	NA	NA
Athens WSO AP	33.95 N	83.32 W	244	1607	2822	–7	33	24	NA
Atlanta WSO AP	33.65 N	84.43 W	307	1662	2799	–8	33	23	749
Augusta WSO AP	33.37 N	81.97 W	45	1425	3066	–6	34	24	774
Brunswick	31.17 N	81.50 W	3	877	3738	–1	33	26	NA
Columbus WSO AP	32.52 N	84.95 W	136	1256	3362	–5	34	24	NA
Dalton	34.75 N	84.95 W	213	1973	2526	NA	NA	NA	NA
Dublin	32.50 N	82.90 W	65	1376	3147	NA	NA	NA	NA
Gainesville	34.30 N	83.85 W	356	1944	2394	NA	NA	NA	NA
La Grange	33.05 N	85.02 W	217	1482	2898	NA	NA	NA	NA
Macon WSO AP	32.70 N	83.65 W	107	1297	3237	–5	34	24	787
Savannah WSO AP	32.13 N	81.20 W	14	1026	3549	–3	34	24	NA
Valdosta/Moody AFB	30.97 N	83.20 W	71	862	4009	–1	34	25	NA
Waycross	31.25 N	82.32 W	44	1125	3429	–2	34	24	NA
Hawaii (HI)									
Hilo (Hawaii)	19.72 N	155.07 W	10	0	4866	16	29	23	153
Honolulu WSFO AP (Oahu)	21.33 N	157.92 W	2	0	5527	16	31	23	69
Kaneohe Mauka (Oahu)	21.42 N	157.82 W	0	57	4975	19	29	23	NA
Idaho (ID)									
Boise WSFO AP	43.57 N	116.22 W	865	3256	1559	–17	34	17	647
Burley FAA AP	42.53 N	113.77 W	1267	3747	1208	–21	32	17	NA
Coeur D'Alene R S	47.68 N	116.75 W	657	3466	1231	NA	NA	NA	NA
Idaho Falls FAA AP	43.52 N	112.07 W	1441	4479	1029	–24	32	16	NA
Lewiston WSO AP	46.38 N	117.02 W	437	2928	1647	–14	34	18	748
Moscow-Univ of Idaho	46.73 N	116.97 W	810	3768	994	NA	NA	NA	NA
Mountain Home	43.13 N	115.70 W	972	3431	1514	–18	36	17	NA
Pocatello WSO AP	42.92 N	112.60 W	1357	3989	1190	–22	32	16	546
Twin Falls WSO	42.55 N	114.35 W	1207	3761	1108	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
Illinois (IL)									
Aurora	41.75 N	88.35 W	196	3722	1600	NA	NA	NA	NA
Belleville/Scott AFB	38.55 N	89.85 W	138	2710	2304	–16	34	25	NA
Carbondale Sewage Plt	37.73 N	89.17 W	118	2703	2186	NA	NA	NA	NA
Champaign	40.03 N	88.28 W	230	3160	2054	NA	NA	NA	NA
Chicago Midway AP	41.73 N	87.77 W	188	3431	1806	NA	NA	NA	NA
Chicago O'Hare WSO AP	41.98 N	87.90 W	205	3631	1634	–21	31	23	613
Chicago University	41.78 N	87.60 W	181	3196	1884	NA	NA	NA	NA
Danville	40.13 N	87.65 W	170	3117	1928	–20	32	25	NA
Decatur	39.83 N	89.02 W	188	3068	2029	–19	33	24	NA
Dixon	41.83 N	89.52 W	213	3818	1647	NA	NA	NA	NA
Freeport Waste Wtr Plt	42.30 N	89.60 W	228	3983	1522	NA	NA	NA	NA
Galesburg	40.95 N	90.38 W	235	3508	1805	NA	NA	NA	NA
Joliet Brandon Rd Dam	41.50 N	88.10 W	165	3591	1681	NA	NA	NA	NA
Moline WSO AP	41.45 N	90.50 W	177	3597	1782	–22	32	23	640
Mt. Vernon	38.35 N	88.87 W	149	2883	2121	NA	NA	NA	NA
Peoria WSO AP	40.67 N	89.68 W	198	3416	1855	–21	32	23	NA
Quincy FAA AP	39.93 N	91.20 W	232	3202	1986	–20	33	24	NA
Rantoul	40.32 N	88.17 W	225	3435	1827	NA	NA	NA	NA
Rockford WSO AP	42.20 N	89.10 W	220	3872	1584	–23	31	23	NA
Springfield WSO AP	39.85 N	89.68 W	181	3160	2019	–20	33	24	600
Waukegan	42.35 N	87.88 W	213	3964	1397	NA	NA	NA	NA
Indiana (IN)									
Anderson Sewage Plant	40.10 N	85.72 W	258	3287	1717	NA	NA	NA	NA
Bloomington Indiana U	39.17 N	86.52 W	251	2949	1992	NA	NA	NA	NA
Columbus	39.20 N	85.92 W	189	3076	1863	NA	NA	NA	NA
Evansville WSO AP	38.05 N	87.53 W	115	2616	2263	–16	33	24	611
Ft. Wayne WSO AP	41.00 N	85.20 W	242	3485	1709	–20	31	23	601

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Indiana cont.)									
Goshen College	41.57 N	85.83 W	245	3490	1634	NA	NA	NA	NA
Hobart	41.53 N	87.25 W	182	3357	1760	NA	NA	NA	NA
Indianapolis WSFO	39.73 N	86.27 W	241	3119	1918	–19	31	23	NA
Kokomo	40.42 N	86.05 W	260	3572	1654	NA	NA	NA	NA
Lafayette	40.35 N	86.87 W	182	3460	1705	–21	32	24	NA
Marion	40.57 N	85.67 W	240	3478	1664	NA	NA	NA	NA
Muncie Ball State Univ	40.22 N	85.42 W	286	3348	1776	NA	NA	NA	NA
Peru/Grissom AFB	40.65 N	86.15 W	248	3282	1910	–19	32	24	NA
Richmond Wtr Wks	39.88 N	84.88 W	309	3213	1669	NA	NA	NA	NA
Shelbyville Sewage Plt	39.52 N	85.78 W	228	3213	1828	NA	NA	NA	NA
South Bend WSO AP	41.70 N	86.32 W	235	3517	1622	–19	31	22	635
Terre Haute	39.35 N	87.42 W	169	3101	1939	–19	32	24	NA
Valparaiso Waterworks	41.52 N	87.03 W	243	3482	1634	NA	NA	NA	NA
Iowa (IA)									
Ames	42.03 N	93.80 W	334	3764	1711	NA	NA	NA	NA
Burlington	40.78 N	91.12 W	182	3302	2000	–20	33	24	649
Cedar Rapids FAA AP	41.88 N	91.70 W	263	3847	1668	–24	32	23	NA
Clinton	41.80 N	90.27 W	178	3513	1828	NA	NA	NA	NA
Des Moines WSFO AP	41.53 N	93.65 W	285	3609	1873	–23	32	23	667
Dubuque WSO AP	42.40 N	90.70 W	1065	4071	1484	NA	NA	NA	NA
Ft. Dodge	42.50 N	94.20 W	339	4034	1612	–25	31	23	NA
Iowa City	41.65 N	91.53 W	195	3459	1908	NA	NA	NA	NA
Keokuk Lock and Dam	40.40 N	91.37 W	160	3316	1926	NA	NA	NA	NA
Marshalltown	42.07 N	92.93 W	265	3983	1563	NA	NA	NA	NA
Mason City FAA AP	43.17 N	93.33 W	363	4354	1474	–26	31	23	610
Newton	41.70 N	93.05 W	285	3768	1739	NA	NA	NA	NA
Ottumwa Airport	41.10 N	92.45 W	256	3483	1897	–21	33	24	NA
Sioux City WSO AP	42.40 N	96.38 W	336	3829	1749	–24	32	23	602
Waterloo WSO AP	42.55 N	92.40 W	264	4114	1563	–26	31	23	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
Kansas (KS)									
Atchison	39.57 N	95.12 W	288	2880	2189	NA	NA	NA	NA
Chanute FAA Airport	37.67 N	95.48 W	298	2583	2348	NA	NA	NA	NA
Dodge City WSO AP	37.77 N	99.97 W	786	2778	2272	–18	36	21	637
El Dorado	37.82 N	96.83 W	408	2548	2398	NA	NA	NA	NA
Garden City FAA AP	37.93 N	100.72 W	878	2898	2187	–19	36	21	NA
Goodland WSO AP	39.37 N	101.70 W	1112	3319	1677	–19	34	19	625
Great Bend	38.35 N	98.77 W	563	2599	2458	NA	NA	NA	NA
Hutchinson	37.93 N	98.03 W	478	2835	2281	NA	NA	NA	NA
Liberal	37.05 N	100.92 W	863	2614	2325	NA	NA	NA	NA
Manhattan	39.20 N	96.58 W	324	2802	2308	NA	NA	NA	NA
Parsons	37.37 N	95.28 W	277	2559	2411	NA	NA	NA	NA
Russell FAA AP	38.87 N	98.82 W	568	2966	2188	–20	36	22	NA
Salina FAA AP	38.80 N	97.63 W	383	2834	2315	–19	36	23	NA
Topeka WSFO AP	39.07 N	95.63 W	267	2925	2156	–19	34	24	608
Wichita WSO AP	37.65 N	97.43 W	402	2662	2417	–17	36	23	NA
Kentucky (KY)									
Ashland	38.45 N	82.62 W	169	2903	1822	NA	NA	NA	NA
Bowling Green FAA AP	36.97 N	86.42 W	166	2404	2296	–14	33	24	NA
Covington WSO AP	39.07 N	84.67 W	264	2916	1938	–17	32	23	661
Hopkinsville/Campbell	36.67 N	87.50 W	174	2182	2585	NA	NA	NA	NA
Lexington WSO AP	38.03 N	84.60 W	294	2657	2086	–16	32	23	618
Louisville WSFO AP	38.18 N	85.73 W	145	2508	2222	–14	32	24	636
Madisonville	37.35 N	87.52 W	134	2315	2383	NA	NA	NA	NA
Owensboro	37.77 N	87.15 W	123	2408	2346	NA	NA	NA	NA
Paducah WSO	37.07 N	88.77 W	124	2377	2398	–14	34	24	NA
Louisiana (LA)									
Alexandria	31.32 N	92.47 W	26	1113	3559	–3	34	26	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Louisiana cont.)									
Baton Rouge WSO AP	30.53 N	91.13 W	19	927	3803	–3	33	25	677
Bogalusa	30.78 N	89.87 W	30	1062	3587	NA	NA	NA	NA
Houma	29.58 N	90.73 W	4	794	3874	NA	NA	NA	NA
Lafayette FAA AP	30.20 N	91.98 W	11	882	3821	–2	34	26	NA
Lake Charles WSO AP	30.12 N	93.22 W	2	898	3785	–2	33	26	668
Minden	32.58 N	93.28 W	56	1407	3235	NA	NA	NA	NA
Monroe FAA AP	32.52 N	92.05 W	23	1337	3355	–6	34	26	NA
Natchitoches	31.77 N	93.08 W	39	1196	3485	NA	NA	NA	NA
New Orleans WSCMO AP	29.98 N	90.25 W	1	841	3839	–1	33	26	789
Shreveport WSO AP	32.47 N	93.82 W	77	1258	3426	–6	35	25	697
Maine (ME)									
Augusta FAA AP	44.32 N	69.80 W	106	4194	1163	–19	29	21	NA
Bangor FAA AP	44.80 N	68.82 W	49	4406	1064	–22	29	21	669
Caribou WSO AP	46.87 N	68.02 W	190	5362	817	–26	28	19	692
Lewiston	44.10 N	70.22 W	54	4024	1256	NA	NA	NA	NA
Millinocket	45.65 N	68.70 W	109	4946	949	NA	NA	NA	NA
Portland WSMO AP	43.65 N	70.32 W	17	4099	1079	–19	28	21	665
Waterville Pmp Stn	44.55 N	69.65 W	27	4101	1211	NA	NA	NA	NA
Maryland (MD)									
Baltimore WSO AP	39.18 N	76.67 W	59	2615	2061	–12	33	23	NA
Cumberland	39.63 N	78.75 W	222	2798	1907	NA	NA	NA	NA
Hagerstown	39.65 N	77.73 W	201	2941	1856	NA	NA	NA	NA
Salisbury	38.37 N	75.58 W	3	2237	2223	–11	32	24	NA
Massachusetts (MA)									
Boston WSO AP	42.37 N	71.03 W	6	3134	1609	–14	31	22	713
Clinton	42.40 N	71.68 W	121	3721	1365	NA	NA	NA	NA
Framingham	42.28 N	71.42 W	51	3479	1497	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Massachusetts cont.)									
Lawrence	42.70 N	71.17 W	17	3512	1471	NA	NA	NA	NA
Lowell	42.65 N	71.37 W	33	3522	1508	NA	NA	NA	NA
New Bedford	41.63 N	70.93 W	36	3014	1652	NA	NA	NA	NA
Springfield	42.10 N	72.58 W	57	3197	1687	NA	NA	NA	NA
Taunton	41.90 N	71.07 W	6	3526	1367	NA	NA	NA	NA
Worcester WSO AP	42.27 N	71.87 W	300	3877	1224	–18	28	21	NA
Michigan (MI)									
Adrian	41.92 N	84.02 W	231	3743	1437	NA	NA	NA	NA
Alpena WSO AP	45.07 N	83.57 W	210	4602	988	–22	29	21	695
Battle Creek/Kellogg	42.30 N	85.23 W	287	3564	1888	NA	NA	NA	NA
Benton Harbor AP	42.13 N	86.43 W	197	3502	1572	NA	NA	NA	NA
Detroit City Airport	42.42 N	83.02 W	190	3426	1692	–18	31	22	NA
Escanaba	45.75 N	87.03 W	182	4774	924	NA	NA	NA	NA
Flint WSO AP	42.97 N	83.75 W	233	3877	1362	–19	30	22	634
Grand Rapids WSO AP	42.88 N	85.52 W	215	3874	1409	–18	30	22	622
Holland	42.80 N	86.12 W	185	3748	1409	NA	NA	NA	NA
Jackson FAA AP	42.27 N	84.45 W	306	3773	1504	–19	30	23	NA
Kalamazoo State Hosp	42.28 N	85.60 W	288	3461	1675	NA	NA	NA	NA
Lansing WSO AP	42.77 N	84.60 W	256	3945	1361	–19	30	22	NA
Marquette	46.55 N	87.38 W	202	4642	961	–25	28	19	NA
Mt. Pleasant University	43.58 N	84.77 W	242	4131	1288	NA	NA	NA	NA
Muskegon WSO AP	43.17 N	86.23 W	191	3847	1312	–16	28	21	NA
Pontiac State Hospital	42.65 N	83.30 W	299	3696	1539	NA	NA	NA	NA
Port Huron	42.98 N	82.42 W	179	3832	1412	NA	NA	NA	NA
Saginaw FAA AP	43.53 N	84.08 W	201	3966	1376	–18	31	22	NA
Sault Ste Marie WSO	46.47 N	84.37 W	220	5176	789	–24	27	20	733
Traverse City FAA AP	44.73 N	85.58 W	189	4305	1182	–19	30	21	679
Ypsilanti East Mich U	42.25 N	83.62 W	237	3592	1599	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
Minnesota (MN)									
Albert Lea	43.62 N	93.42 W	374	4526	1449	NA	NA	NA	NA
Alexandria FAA AP	45.87 N	95.38 W	431	4999	1287	–29	30	21	NA
Bemidji Airport	47.50 N	94.93 W	419	5667	989	NA	NA	NA	NA
Brainerd	46.37 N	94.20 W	359	5243	1088	–31	29	20	NA
Duluth WSO AP	46.83 N	92.18 W	435	5454	853	–29	27	19	650
Faribault	44.30 N	93.27 W	286	4599	1388	NA	NA	NA	NA
International Falls WSO AP	48.57 N	93.38 W	359	5826	906	–34	28	19	656
Mankato	44.15 N	94.02 W	254	4447	1495	NA	NA	NA	NA
Minneapolis-St Paul WSO AP	44.88 N	93.22 W	254	4434	1489	–27	31	22	566
Rochester WSO AP	43.92 N	92.50 W	395	4583	1320	–27	29	22	652
St Cloud WSO AP	45.55 N	94.07 W	316	4960	1194	–29	31	22	NA
Virginia	47.50 N	92.55 W	437	5569	879	NA	NA	NA	NA
Willmar State Hospital	45.13 N	95.02 W	343	4798	1369	NA	NA	NA	NA
Winona	44.05 N	91.63 W	198	4274	1497	NA	NA	NA	NA
Mississippi (MS)									
Biloxi/Keesler AFB	30.42 N	88.92 W	8	826	3859	–1	33	26	NA
Clarksdale	34.20 N	90.57 W	52	1771	2976	NA	NA	NA	NA
Columbus AFB	33.65 N	88.45 W	67	1538	3092	–7	34	26	NA
Greenville	33.38 N	91.02 W	40	1543	3145	NA	NA	NA	NA
Greenwood FAA AP	33.50 N	90.08 W	47	1499	3200	–7	34	26	NA
Hattiesburg	31.32 N	89.30 W	49	1211	3381	NA	NA	NA	NA
Jackson WSFO AP	32.32 N	90.08 W	100	1371	3278	–6	34	24	640
Laurel	31.68 N	89.12 W	68	1293	3274	NA	NA	NA	NA
McComb FAA AP	31.23 N	90.47 W	125	1175	3347	–5	33	24	NA
Meridian WSO AP	32.33 N	88.75 W	89	1358	3224	–6	34	24	719
Natchez	31.55 N	91.38 W	59	1057	3543	NA	NA	NA	NA
Tupelo WSO AP	34.27 N	88.73 W	110	1711	2902	–8	34	24	NA
Vicksburg Military Pk	32.35 N	90.85 W	77	1220	3366	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	Number of Hours 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
Missouri (MO)									
Cape Girardeau FAA AP	37.23 N	89.57 W	102	2437	2422	–14	34	25	NA
Columbia WSO AP	38.82 N	92.22 W	270	2896	2084	–18	33	24	633
Farmington	37.70 N	90.38 W	284	2801	2029	NA	NA	NA	NA
Hannibal	39.72 N	91.37 W	217	3127	2047	NA	NA	NA	NA
Jefferson City Wtr Plt	38.58 N	92.15 W	204	2946	2058	NA	NA	NA	NA
Joplin FAA AP	37.17 N	94.50 W	298	2391	2454	–16	34	24	NA
Kansas City WSO AP	39.32 N	94.72 W	296	2996	2140	–18	34	24	NA
Kirksville Radio KIRX	40.22 N	92.58 W	295	3259	1941	NA	NA	NA	NA
Mexico	39.18 N	91.88 W	236	3106	2036	NA	NA	NA	NA
Moberly Radio KWIX	39.40 N	92.43 W	256	2891	2193	NA	NA	NA	NA
Poplar Bluff R S	36.77 N	90.42 W	115	2404	2427	–13	33	24	NA
Rolla	38.13 N	91.77 W	350	2638	2325	NA	NA	NA	NA
Rolla Univ of MO	37.95 N	91.77 W	359	2755	2214	NA	NA	NA	NA
St Joseph	39.77 N	94.92 W	247	3106	2102	NA	NA	NA	NA
St Louis WSCMO AP	38.75 N	90.37 W	163	2643	2379	–17	34	24	NA
Montana (MT)									
Billings WSO AP	45.80 N	108.53 W	1087	3980	1370	–25	32	17	617
Bozeman	45.82 N	110.88 W	1813	5504	373	–29	31	16	NA
Butte FAA AP	45.95 N	112.50 W	1688	5287	640	–30	29	29	NA
Cut Bank FAA AP	48.60 N	112.37 W	1169	4947	819	–29	29	15	672
Glasgow WSO AP	48.22 N	106.62 W	696	4858	1247	–30	32	17	570
Glendive	47.10 N	104.72 W	632	4543	1455	NA	NA	NA	NA
Great Falls WSCMO AP	47.48 N	111.37 W	1116	4301	1107	–28	31	16	641
Havre WSO AP	48.55 N	109.77 W	787	4693	1184	–32	32	17	NA
Helena WSO AP	46.60 N	112.00 W	1186	4462	1068	–28	31	15	651
Kalispell WSO AP	48.30 N	114.27 W	903	4654	747	–24	30	16	NA
Lewistown FAA AP	47.07 N	109.45 W	1259	4711	878	–28	30	16	673

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Montana cont.)									
Livingston FAA AP	45.70 N	110.45 W	1418	4011	1056	NA	NA	NA	NA
Miles City FAA AP	46.43 N	105.87 W	801	4331	1489	–28	34	18	565
Missoula WSO AP	46.92 N	114.08 W	972	4329	933	–23	31	16	658
Nebraska (NE)									
Chadron FAA AP	42.83 N	03.08 W	1009	3900	1496	NA	NA	NA	NA
Columbus	41.47 N	97.33 W	441	3635	1858	NA	NA	NA	NA
Fremont	41.43 N	96.48 W	359	3411	1901	NA	NA	NA	NA
Grand Island WSO AP	40.97 N	98.32 W	561	3567	1802	–22	34	22	611
Hastings	40.58 N	98.35 W	586	3614	1787	NA	NA	NA	NA
Kearney	40.73 N	99.02 W	649	3638	1717	NA	NA	NA	NA
Lincoln WSO AP	40.85 N	96.75 W	362	3488	1919	–22	34	23	NA
Mc Cook	40.22 N	100.58 W	786	3397	1798	NA	NA	NA	NA
Norfolk WSO AP	41.98 N	97.43 W	472	3818	1707	–24	33	22	NA
North Platte WSO AP	41.13 N	100.68 W	845	3811	1521	–23	33	21	592
Omaha (Eppley Field)	41.30 N	95.90 W	298	3500	1888	–22	33	24	NA
Scottsbluff WSO AP	41.87 N	103.60 W	1202	3738	1489	–24	33	18	620
Sidney	41.23 N	103.00 W	1316	3870	1338	–22	33	17	NA
Nevada (NV)									
Carson City	39.15 N	119.77 W	1417	3162	1284	NA	NA	NA	NA
Elko FAA AP	40.83 N	115.78 W	1546	3932	1191	–21	33	15	569
Ely WSO AP	39.28 N	114.85 W	1908	4234	954	–21	31	13	683
Las Vegas WSO AP	36.08 N	115.17 W	658	1337	3747	–3	41	19	719
Lovelock FAA AP	40.07 N	118.55 W	1188	3261	1603	NA	NA	NA	606
Reno WSFO AP	39.50 N	119.78 W	1342	3152	1391	–13	33	16	752
Tonopah AP	38.07 N	117.08 W	1653	3185	1578	–14	33	14	660
Winnemucca WSO AP	40.90 N	117.80 W	1309	3508	1322	–17	34	16	608
New Hampshire (NH)									
Berlin	44.45 N	71.18 W	283	4803	954	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(New Hampshire cont.)									
Concord WSO AP	43.20 N	71.50 W	105	4197	1159	–22	31	21	683
Keene	42.92 N	72.27 W	146	3860	1332	NA	NA	NA	NA
Portsmouth/Pease AFB	43.08 N	70.82 W	31	3651	1343	–16	29	21	NA
New Jersey (NJ)									
Atlantic City WSO AP	39.45 N	74.57 W	42	2872	1777	–13	31	23	NA
Long Branch Oakhurst	40.27 N	74.00 W	9	2918	1698	NA	NA	NA	NA
Newark WSO AP	40.70 N	74.17 W	9	2716	2082	–12	32	23	644
New Mexico (NM)									
Alamogordo/Holloman	32.85 N	106.10 W	1248	1796	2626	–7	36	17	NA
Albuquerque WSFO AP	35.05 N	106.62 W	1623	2458	2171	–11	34	16	703
Artesia	32.77 N	104.38 W	1011	1959	2546	NA	NA	NA	NA
Carlsbad FAA AP	32.33 N	104.27 W	985	1562	3062	–7	37	19	NA
Clovis/Cannon AFB	34.38 N	103.32 W	1309	2213	2321	–12	34	18	NA
Farmington	36.73 N	108.23 W	1677	3035	1837	–13	33	16	NA
Gallup FAA AP	35.52 N	108.78 W	1971	3469	1308	–18	31	13	NA
Grants Airport	35.17 N	107.90 W	1987	3282	1378	NA	NA	NA	NA
Hobbs	32.70 N	103.13 W	1101	1584	2867	NA	NA	NA	NA
Raton Filter Plant	36.92 N	104.43 W	2112	3391	1215	NA	NA	NA	NA
Roswell FAA AP	33.30 N	104.53 W	1118	1815	2757	–10	36	18	677
Socorro	34.08 N	106.88 W	1397	2263	2136	NA	NA	NA	NA
Tucumcari	35.20 N	103.68 W	1245	2173	2331	–13	35	18	710
New York (NY)									
Albany WSFO AP	42.75 N	73.80 W	83	3830	1403	–22	30	21	605
Auburn	42.92 N	76.53 W	234	3768	1406	NA	NA	NA	NA
Batavia	42.98 N	78.18 W	271	3698	1409	NA	NA	NA	NA
Binghamton WSO AP	42.22 N	75.98 W	487	4041	1218	–19	28	21	662
Buffalo WSCMO AP	42.93 N	78.73 W	214	3748	1371	–17	29	21	697

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(New York cont.)									
Cortland	42.60 N	76.18 W	344	3982	1236	NA	NA	NA	NA
Elmira/Chemung Co	42.17 N	76.90 W	290	3803	1345	–19	31	22	NA
Geneva Research Farm	42.88 N	77.03 W	218	3855	1313	NA	NA	NA	NA
Glens Falls FAA AP	43.35 N	73.62 W	97	4242	1212	–23	29	22	NA
Gloversville	43.05 N	74.35 W	247	4258	1177	NA	NA	NA	NA
Ithaca Cornell Univ	42.45 N	76.45 W	292	4004	1176	NA	NA	NA	NA
Lockport	43.18 N	78.65 W	158	3724	1379	NA	NA	NA	NA
Massena FAA AP	44.93 N	74.85 W	65	4586	1137	–26	29	22	627
NY Central Pk WSO City	40.78 N	73.97 W	40	2669	2019	NA	NA	NA	790
NY Kennedy WSO AP	40.65 N	73.78 W	4	2793	1857	–12	31	22	NA
NY La Guardia WSO AP	40.77 N	73.90 W	3	2728	1971	–11	32	23	790
Oswego East	43.47 N	76.50 W	106	3741	1351	NA	NA	NA	NA
Plattsburgh AFB	44.65 N	73.47 W	50	4354	1208	–23	28	21	NA
Poughkeepsie FAA AP	41.63 N	73.88 W	47	3551	1479	–17	31	22	NA
Rochester WSO AP	43.12 N	77.67 W	166	3741	1337	–17	30	22	608
Rome/Griffiss AFB	43.23 N	75.40 W	154	4025	1302	–21	30	21	NA
Schenectady	42.83 N	73.92 W	67	3823	1389	NA	NA	NA	NA
Syracuse WSO AP	43.12 N	76.12 W	128	3797	1333	–19	29	22	730
Utica	43.10 N	75.28 W	152	3926	1308	NA	NA	NA	NA
Watertown	43.97 N	75.87 W	151	4189	1274	–24	18	21	NA
North Carolina (NC)									
Asheville WSO AP	35.43 N	82.55 W	652	2393	1869	–12	29	22	915
Charlotte WSO AP	35.22 N	80.93 W	213	1856	2613	–8	33	23	777
Durham	36.03 N	78.97 W	123	2148	2311	NA	NA	NA	NA
Elizabeth City FAA AP	36.27 N	76.18 W	3	1744	2647	NA	NA	NA	NA
Fayetteville/Pope AFB	35.17 N	79.02 W	66	1620	2949	–6	34	24	NA
Goldsboro	35.33 N	77.97 W	33	1689	2788	–6	34	24	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(North Carolina cont.)									
Greensboro WSO AP	36.08 N	79.95 W	270	2147	2302	–9	32	23	718
Greenville	35.62 N	77.38 W	9	1738	2680	NA	NA	NA	NA
Henderson	36.37 N	78.42 W	146	2243	2223	NA	NA	NA	NA
Hickory FAA AP	35.73 N	81.38 W	348	2071	2333	–8	33	22	NA
Jacksonville/New River	34.70 N	77.43 W	8	1365	3154	–5	33	26	NA
Lumberton	34.70 N	79.07 W	39	1784	2624	NA	NA	NA	NA
New Bern FAA AP	35.07 N	77.05 W	5	1523	2923	–6	33	26	NA
Raleigh-Durham WSFO AP	35.87 N	78.78 W	114	1921	2499	–9	32	24	740
Rocky Mount	35.90 N	77.72 W	33	1845	2548	NA	NA	NA	NA
Wilmington WSO AP	34.27 N	77.90 W	21	1372	3087	–5	33	26	NA
North Dakota (ND)									
Bismarck WSFO AP	46.77 N	100.77 W	502	4982	1191	–29	32	19	556
Devils Lake KDLR	48.12 N	98.87 W	446	5528	1096	–31	31	19	NA
Dickinson FAA AP	46.78 N	102.80 W	786	4809	1196	NA	NA	NA	NA
Fargo WSO AP	46.90 N	96.80 W	274	5141	1272	–30	31	21	546
Grand Forks FAA AP	47.95 N	97.17 W	258	5407	1158	–29	31	21	NA
Jamestown FAA AP	46.92 N	98.68 W	454	5093	1257	NA	NA	NA	NA
Minot FAA AP	48.27 N	101.28 W	522	5107	1186	–29	31	19	581
Ohio (OH)									
Akron-Canton WSO AP	40.92 N	81.43 W	368	3422	1544	–18	29	22	680
Ashtabula	41.85 N	80.80 W	210	3572	1447	NA	NA	NA	NA
Bowling Green	41.38 N	83.62 W	205	3601	1598	NA	NA	NA	NA
Cambridge	40.02 N	81.58 W	243	3049	1732	NA	NA	NA	NA
Cincinnati-Abbe WSO	39.15 N	84.52 W	231	2771	2074	–15	32	24	NA
Cleveland WSFO AP	41.42 N	81.87 W	234	3445	1531	–17	30	22	NA
Columbus WSO AP	40.00 N	82.88 W	247	3171	1733	–17	31	23	708
Dayton WSCMO AP	39.90 N	84.20 W	303	3171	1805	–18	31	23	611

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Ohio cont.)									
Defiance	41.28 N	84.38 W	213	3682	1561	NA	NA	NA	NA
Findlay FAA AP	41.02 N	83.67 W	242	3501	1615	–19	31	22	NA
Fremont	41.33 N	83.12 W	182	3577	1568	NA	NA	NA	NA
Lancaster	39.73 N	82.63 W	262	3327	1631	NA	NA	NA	NA
Lima Sewage Plant	40.72 N	84.13 W	259	3474	1694	NA	NA	NA	NA
Mansfield WSO AP	40.82 N	82.52 W	394	3477	1566	–18	29	22	NA
Marion	40.62 N	83.13 W	294	3559	1576	NA	NA	NA	NA
Newark Water Works	40.08 N	82.42 W	254	3143	1726	NA	NA	NA	NA
Norwalk	41.27 N	82.62 W	204	3574	1508	NA	NA	NA	NA
Portsmouth	38.75 N	82.88 W	164	2729	1989	NA	NA	NA	NA
Sandusky	41.45 N	82.72 W	178	3406	1659	NA	NA	NA	NA
Springfield New Wtr Wk	39.97 N	83.82 W	283	3474	1550	NA	NA	NA	NA
Steubenville	40.38 N	80.63 W	302	3167	1697	NA	NA	NA	NA
Toledo Express WSO AP	41.58 N	83.80 W	203	3655	1511	–19	31	22	652
Warren	41.20 N	80.82 W	274	3557	1414	NA	NA	NA	NA
Wooster Exp Station	40.78 N	81.92 W	310	3544	1428	NA	NA	NA	NA
Youngstown WSO AP	41.25 N	80.67 W	359	3636	1409	–18	29	21	679
Zanesville FAA AP	39.95 N	81.90 W	268	3174	1674	–17	31	23	NA
Oklahoma (OK)									
Ada	34.78 N	96.68 W	309	1768	2954	NA	NA	NA	NA
Altus AFB	34.65 N	99.27 W	420	1750	3171	–11	38	23	NA
Ardmore	34.20 N	97.15 W	262	1501	3321	NA	NA	NA	NA
Bartlesville	36.75 N	96.00 W	217	2098	2764	NA	NA	NA	NA
Chickasha Exp Station	35.05 N	97.92 W	330	1870	2943	NA	NA	NA	NA
Enid	36.42 N	97.87 W	379	2104	2844	–15	37	23	NA
Lawton	34.62 N	98.45 W	350	1921	2927	–11	36	23	NA
McAlester FAA AP	34.88 N	95.78 W	231	1863	2907	–12	36	24	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Oklahoma cont.)									
Muskogee	35.77 N	95.33 W	177	1896	2881	NA	NA	NA	NA
Norman	35.18 N	97.45 W	338	1831	2929	NA	NA	NA	NA
Oklahoma City WSFO AP	35.40 N	97.60 W	390	2033	2762	–13	36	23	733
Ponca City FAA AP	36.73 N	97.10 W	304	2348	2662	NA	NA	NA	NA
Seminole	35.23 N	96.67 W	263	1721	3084	NA	NA	NA	NA
Stillwater	36.12 N	97.10 W	272	2238	2621	NA	NA	NA	NA
Tulsa WSO AP	36.18 N	95.90 W	203	2051	2861	–13	36	24	591
Woodward	36.45 N	99.38 W	579	2167	2713	NA	NA	NA	NA
Oregon (OR)									
Astoria WSO AP	46.15 N	123.88 W	2	2866	798	–4	22	17	1236
Baker FAA AP	44.83 N	117.82 W	1026	3975	967	NA	NA	NA	NA
Bend	44.07 N	121.28 W	1115	3848	781	NA	NA	NA	NA
Corvallis State Univ	44.63 N	123.20 W	68	2735	1139	NA	NA	NA	NA
Eugene WSO AP	44.12 N	123.22 W	110	2526	1308	–6	31	18	NA
Grants Pass	42.42 N	123.33 W	292	2344	1659	NA	NA	NA	NA
Klamath Falls	42.20 N	121.78 W	1249	3686	1086	–16	31	17	NA
Medford WSO AP	42.38 N	122.88 W	396	2562	1661	–6	35	19	749
Pendleton WSO AP	45.68 N	118.85 W	454	2941	1548	–16	34	17	NA
Portland WSFO AP	45.60 N	122.60 W	6	2512	1398	–6	30	19	1060
Roseburg KQEN	43.20 N	123.35 W	141	2396	1448	NA	NA	NA	NA
Salem WSO AP	44.92 N	123.02 W	59	2737	1167	–7	31	19	916
Pennsylvania (PA)									
Allentown WSO AP	40.65 N	75.43 W	118	3214	1682	–15	31	22	710
Altoona FAA AP	40.30 N	78.32 W	449	3411	1511	–15	30	21	NA
Chambersburg	39.93 N	77.63 W	195	3097	1700	NA	NA	NA	NA
Erie WSO AP	42.08 N	80.18 W	223	3488	1473	–17	28	21	716
Harrisburg FAA AP	40.22 N	76.85 W	103	2971	1866	–13	32	23	648

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Pennsylvania cont.)									
Johnstown	40.33 N	78.92 W	370	3138	1682	NA	NA	NA	NA
Lancaster	40.05 N	76.28 W	82	3102	1711	NA	NA	NA	NA
Meadville	41.63 N	80.17 W	324	3852	1227	NA	NA	NA	NA
New Castle	41.02 N	80.37 W	251	3634	1390	NA	NA	NA	NA
Philadelphia WSCMO AP	39.88 N	75.23 W	3	2752	2013	–12	32	23	646
Pittsburgh WSCMO2 AP	40.50 N	80.22 W	350	3316	1576	–17	30	21	700
Reading	40.37 N	75.93 W	82	3220	1678	NA	NA	NA	NA
State College	40.80 N	77.87 W	356	3536	1461	NA	NA	NA	NA
Uniontown	39.92 N	79.72 W	291	3158	1618	NA	NA	NA	NA
Warren	41.85 N	79.15 W	368	3828	1297	NA	NA	NA	NA
West Chester	39.97 N	75.63 W	137	2935	1827	NA	NA	NA	NA
Williamsport WSO AP	41.25 N	76.92 W	159	3382	1553	–17	31	22	NA
York Pump Station 22	39.92 N	76.75 W	118	2920	1819	NA	NA	NA	NA
Rhode Island (RI)									
Newport	41.52 N	71.32 W	6	3144	1416	NA	NA	NA	NA
Providence WSO AP	41.73 N	71.43 W	15	3269	1524	–15	30	22	684
South Carolina (SC)									
Anderson	34.53 N	82.67 W	243	1647	2722	NA	NA	NA	NA
Charleston WSO AP	32.90 N	80.03 W	12	1118	3438	NA	NA	NA	NA
Charleston WSO City	32.78 N	79.93 W	3	1037	3502	–4	33	25	NA
Columbia WSFO AP	33.95 N	81.12 W	64	1472	3060	–6	34	24	705
Florence FAA AP	34.18 N	79.72 W	44	1436	3109	–5	34	24	NA
Georgetown	33.35 N	79.25 W	3	1156	3304	NA	NA	NA	NA
Greenville-Spartanburg WSO AP	34.90 N	82.22 W	296	1818	2569	–7	33	23	851
Greenwood	34.17 N	82.20 W	187	1827	2596	NA	NA	NA	NA
Orangeburg	33.50 N	80.87 W	48	1408	3043	NA	NA	NA	NA
Spartanburg	34.98 N	81.88 W	256	1604	2803	NA	NA	NA	NA
Sumter/Shaw AFB	33.97 N	80.48 W	73	1392	3029	–4	34	24	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data (*Continued*)

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
South Dakota (SD)									
Aberdeen WSO AP	45.45 N	98.43 W	395	4692	1387	NA	NA	NA	NA
Brookings	44.32 N	96.77 W	500	4807	1238	NA	NA	NA	NA
Huron WSO AP	44.38 N	98.22 W	390	4402	1505	–27	33	22	545
Mitchell	43.72 N	98.00 W	388	4199	1625	NA	NA	NA	NA
Pierre FAA AP	44.38 N	100.28 W	526	4117	1632	–26	35	21	557
Rapid City WSO AP	44.05 N	103.07 W	963	4056	1340	–24	33	18	572
Sioux Falls WSFO AP	43.57 N	96.73 W	432	4338	1519	–27	32	22	599
Watertown FAA AP	44.92 N	97.15 W	532	4653	1388	NA	NA	NA	NA
Yankton	42.88 N	97.35 W	359	4058	1631	NA	NA	NA	NA
Tennessee (TN)									
Athens	35.43 N	84.58 W	286	2252	2244	NA	NA	NA	NA
Bristol WSO AP	36.48 N	82.40 W	464	2448	2012	–13	31	22	NA
Chattanooga WSO AP	35.03 N	85.20 W	210	1993	2561	–9	33	24	684
Clarksville Sew Plt	36.55 N	87.37 W	116	2311	2356	NA	NA	NA	NA
Columbia	35.63 N	87.08 W	198	2337	2248	NA	NA	NA	NA
Dyersburg FAA AP	36.02 N	89.40 W	102	1964	2783	NA	NA	NA	NA
Greeneville Exp Stn	36.10 N	82.85 W	402	2440	2061	NA	NA	NA	NA
Jackson FAA AP	35.60 N	88.92 W	131	1967	2731	–11	34	24	NA
Knoxville WSO AP	35.80 N	84.00 W	289	2187	2313	–11	32	23	703
Memphis FAA-AP	35.05 N	90.00 W	80	1712	3037	–9	34	25	851
Murfreesboro	35.92 N	86.37 W	167	2218	2372	NA	NA	NA	NA
Nashville WSO AP	36.12 N	86.68 W	176	2072	2605	–12	33	24	749
Tullahoma	35.35 N	86.20 W	319	2017	2457	NA	NA	NA	NA
Texas (TX)									
Abilene WSO AP	32.42 N	99.68 W	543	1436	3361	–9	36	22	648
Alice	27.73 N	98.07 W	61	590	4512	NA	NA	NA	NA
Amarillo WSO AP	35.23 N	101.70 W	1094	2366	2293	–14	34	19	680

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Texas cont.)									
Austin WSO AP	30.30 N	97.70 W	181	938	3984	–4	36	23	664
Bay City Waterworks	28.98 N	95.98 W	15	761	4006	NA	NA	NA	NA
Beaumont Research Ctr	30.07 N	94.28 W	8	932	3724	–2	33	26	NA
Beeville	28.45 N	97.70 W	77	762	4107	–2	37	25	NA
Big Spring	32.25 N	101.45 W	761	1540	3123	NA	NA	NA	NA
Brownsville WSO AP	25.90 N	97.43 W	5	353	4876	2	34	25	422
Brownwood	31.72 N	99.00 W	422	1222	3599	NA	NA	NA	NA
Corpus Christi WSO AP	27.77 N	97.50 W	13	564	4457	0	34	26	543
Corsicana	32.08 N	96.47 W	129	1331	3407	NA	NA	NA	NA
Dallas FAA AP	32.85 N	96.85 W	134	1255	3659	–8	37	23	NA
Del Rio/Laughlin AFB	29.37 N	100.78 W	329	870	4004	–2	37	23	732
Denton	33.20 N	97.10 W	192	1481	3231	NA	NA	NA	NA
Eagle Pass	28.70 N	100.48 W	245	801	4268	NA	NA	NA	NA
El Paso WSO AP	31.80 N	106.40 W	1194	1504	3049	–6	37	18	735
Ft. Worth/Meacham	32.82 N	97.35 W	211	1280	3643	–7	37	23	NA
Galveston WSO City	29.30 N	94.80 W	2	702	4099	NA	NA	NA	NA
Greenville	33.20 N	96.22 W	185	1641	3071	NA	NA	NA	NA
Harlingen	26.20 N	97.67 W	11	452	4669	NA	NA	NA	NA
Houston /Hobby	29.65 N	95.28 W	15	762	4087	–2	34	25	NA
Houston-Bush Intercontinental Airport	29.97 N	95.35 W	29	888	3820	–3	34	25	NA
Huntsville	30.72 N	95.55 W	150	1034	3721	NA	NA	NA	NA
Killeen/Robert-Gray	31.07 N	97.83 W	309	1182	3598	–7	36	23	NA
Lamesa	32.70 N	101.93 W	903	1755	2837	NA	NA	NA	NA
Laredo	27.57 N	99.50 W	131	569	4719	0	38	23	598
Longview	32.47 N	94.73 W	100	1352	3289	NA	NA	NA	NA
Lubbock WSFO AP	33.65 N	101.82 W	991	1906	2685	–12	35	19	743
Lufkin FAA AP	31.23 N	94.75 W	85	1084	3626	–5	35	25	681

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Texas cont.)									
McAllen	26.20 N	98.22 W	37	432	4776	1	37	24	NA
Midland/Odessa WSO AP	31.95 N	102.18 W	870	1528	3104	–8	36	19	729
Mineral Wells FAA AP	32.78 N	98.07 W	284	1458	3342	NA	NA	NA	NA
Palestine	31.78 N	95.60 W	141	1114	3586	NA	NA	NA	NA
Pampa No 2	35.53 N	100.98 W	990	2421	2295	NA	NA	NA	NA
Pecos	31.42 N	103.50 W	795	1392	3329	NA	NA	NA	NA
Plainview	34.18 N	101.70 W	1027	2065	2479	NA	NA	NA	NA
Port Arthur WSO AP	29.95 N	94.02 W	4	833	3886	NA	NA	NA	697
San Angelo WSO AP	31.37 N	100.50 W	580	1341	3372	–7	36	21	619
San Antonio WSFO	29.53 N	98.47 W	242	913	3968	–3	36	23	NA
Sherman	33.63 N	96.62 W	219	1606	3157	NA	NA	NA	721
Snyder	32.72 N	100.92 W	711	1769	2877	NA	NA	NA	NA
Temple	31.08 N	97.37 W	213	1196	3604	NA	NA	NA	NA
Tyler	32.35 N	95.40 W	166	1219	3645	NA	NA	NA	NA
Vernon	34.08 N	99.30 W	366	1770	3114	NA	NA	NA	NA
Victoria WSO AP	28.85 N	96.92 W	31	720	4171	–2	34	24	NA
Waco WSO AP	31.62 N	97.22 W	152	1211	3704	–6	37	24	622
Wichita Falls WSO AP	33.97 N	98.48 W	302	1690	3176	NA	NA	NA	723
Utah (UT)									
Cedar City FAA AP	37.70 N	113.10 W	1709	3312	1539	–17	33	15	629
Logan Utah State Univ	41.75 N	111.80 W	1459	3808	1412	NA	NA	NA	NA
Moab	38.60 N	109.60 W	1208	2497	2420	NA	NA	NA	NA
Ogden Sugar Factory	41.23 N	112.03 W	1304	3306	1696	NA	NA	NA	NA
Richfield Radio KSVC	38.77 N	112.08 W	1606	3537	1278	NA	NA	NA	NA
Saint George	37.10 N	113.57 W	841	1786	3013	NA	NA	NA	NA
Salt Lake City NWSFO	40.78 N	111.95 W	1286	3203	1820	–14	34	17	586
Vernal Airport	40.45 N	109.52 W	1603	4201	1297	NA	NA	NA	NA

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
Vermont (VT)									
Burlington WSO AP	44.47 N	73.15 W	101	4317	1238	–24	29	21	637
Rutland	43.60 N	72.97 W	188	3926	1303	NA	NA	NA	NA
Virginia (VA)									
Charlottesville	38.03 N	78.52 W	265	2347	2168	NA	NA	NA	NA
Danville-Bridge St	36.58 N	79.38 W	124	2191	2353	NA	NA	NA	NA
Fredericksburg Natl Pk	38.32 N	77.45 W	27	2530	2086	NA	NA	NA	NA
Lynchburg WSO AP	37.33 N	79.20 W	279	2411	2071	–11	32	23	NA
Norfolk WSO AP	36.90 N	76.20 W	6	1942	2488	–7	33	24	685
Richmond WSO AP	37.50 N	77.33 W	49	2202	2346	–10	33	24	716
Roanoke WSO AP	37.32 N	79.97 W	350	2422	2064	–11	32	22	713
Staunton Sewage Plant	38.15 N	79.03 W	422	2929	1669	NA	NA	NA	NA
Winchester	39.18 N	78.12 W	207	2927	1786	NA	NA	NA	NA
Washington (WA)									
Aberdeen	46.97 N	123.82 W	3	2936	827	NA	NA	NA	NA
Bellingham FAA AP	48.80 N	122.53 W	45	3116	838	–9	24	18	NA
Bremerton	47.57 N	122.67 W	49	2844	1022	NA	NA	NA	NA
Ellensburg	46.97 N	120.55 W	451	3761	1111	NA	NA	NA	NA
Everett	47.98 N	122.18 W	18	2951	922	NA	NA	NA	NA
Kennewick	46.22 N	119.10 W	118	2719	1775	NA	NA	NA	NA
Longview	46.15 N	122.92 W	3	2830	1032	NA	NA	NA	NA
Olympia WSO AP	46.97 N	122.90 W	58	3142	866	–8	28	18	985
Port Angeles	48.12 N	123.40 W	12	3164	698	NA	NA	NA	NA
Seattle EMSU WSO	47.65 N	122.30 W	6	2562	1178	NA	NA	NA	NA
Seattle-Tacoma WSCMO AP	47.45 N	122.30 W	137	2727	1123	–5	27	18	982
Spokane WSO AP	47.63 N	117.53 W	718	3801	1129	NA	NA	NA	640
Tacoma/McChord AFB	47.15 N	122.48 W	98	2864	1011	–8	28	17	NA
Walla Walla FAA AP	46.10 N	118.28 W	355	2754	1756	–16	35	18	NA
Wenatchee	47.42 N	120.32 W	195	3099	1642	–16	33	18	NA
Yakima WSO AP	46.57 N	120.53 W	324	3315	1304	–16	33	18	703

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
West Virginia (WV)									
Beckley WSO AP	37.78 N	81.12 W	763	3088	1494	NA	NA	NA	NA
Bluefield FAA AP	37.30 N	81.22 W	874	2906	1615	–15	28	21	NA
Charleston WSFO AP	38.37 N	81.60 W	309	2581	2031	–14	31	23	704
Clarksburg	39.27 N	80.35 W	288	3062	1674	NA	NA	NA	NA
Elkins WSO AP	38.88 N	79.85 W	607	3400	1311	–19	28	21	NA
Huntington WSO AP	38.37 N	82.55 W	252	2592	2008	–14	32	23	NA
Martinsburg FAA AP	39.40 N	77.98 W	161	2884	1871	–13	33	23	NA
Morgantown FAA AP	39.65 N	79.92 W	377	2979	1753	–16	31	22	NA
Parkersburg	39.27 N	81.57 W	187	2830	1948	–16	31	22	NA
Wisconsin (WI)									
Appleton	44.25 N	88.37 W	228	4274	1396	NA	NA	NA	NA
Ashland Exp Farm	46.57 N	90.97 W	198	4978	1006	NA	NA	NA	NA
Beloit	42.50 N	89.03 W	237	3978	1521	NA	NA	NA	NA
Eau Claire FAA AP	44.87 N	91.48 W	270	4628	1337	–28	31	22	661
Fond du Lac	43.80 N	88.45 W	231	4189	1429	NA	NA	NA	NA
Green Bay WSO AP	44.48 N	88.13 W	207	4494	1209	–25	29	22	651
La Crosse FAA AP	43.87 N	91.25 W	198	4162	1550	–26	31	23	644
Madison WSO AP	43.13 N	89.33 W	261	4263	1327	–24	31	22	658
Manitowoc	44.10 N	87.68 W	201	4221	1218	NA	NA	NA	NA
Marinette	45.10 N	87.63 W	184	4477	1262	NA	NA	NA	NA
Milwaukee WSO AP	42.95 N	87.90 W	204	4069	1327	–22	30	22	618
Racine	42.70 N	87.77 W	181	3982	1366	NA	NA	NA	NA
Sheboygan	43.75 N	87.72 W	197	3937	1328	NA	NA	NA	NA
Stevens Point	44.50 N	89.57 W	328	4449	1292	NA	NA	NA	NA
Waukesha	43.02 N	88.23 W	262	3954	1477	NA	NA	NA	NA
Wausau FAA AP	44.92 N	89.62 W	364	4682	1212	–26	29	21	NA
Wyoming (WY)									
Casper WSO AP	42.92 N	106.47 W	1627	4268	1157	–25	32	14	535
Cheyenne WSFO AP	41.15 N	104.82 W	1865	4070	1048	–22	29	14	608

TABLE D-1 U.S. and U.S. Territory Climatic Data *(Continued)*

State/City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		Number of Hours 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	$13 < T_{db} < 21$
(Wyoming cont.)									
Cody	44.52 N	109.07 W	1539	4128	1143	–26	31	14	NA
Evanston	41.27 N	110.95 W	2075	4914	714	NA	NA	NA	NA
Lander WSO AP	42.82 N	108.73 W	1636	4383	1213	–26	31	14	NA
Laramie FAA AP	41.32 N	105.68 W	2214	5004	687	NA	NA	NA	NA
Newcastle	43.85 N	104.22 W	1344	4037	1399	NA	NA	NA	NA
Rawlins FAA AP	41.80 N	107.20 W	2053	4708	892	NA	NA	NA	NA
Rock Springs FAA AP	41.60 N	109.07 W	2054	4647	963	–23	29	12	552
Sheridan WSO AP	44.77 N	106.97 W	1208	4336	1124	–26	32	16	574
Torrington Exp Farm	42.08 N	104.22 W	1249	3822	1349	NA	NA	NA	NA
District of Columbia (DC)									
R. Reagan Nat'l. Airport	38.85 N	77.03 W	20	2248	2439	–9	34	24	657
Puerto Rico (PR)									
San Juan/Isla Verde WSFO	18.43 N	66.00 W	3	0	6337	21	32	26	NA
Pacific Islands (PI)									
Guam (GU)—Andersen AFB	13.58 N	144.93 E	185	0	5939	23	31	26	NA
Marshall Island (MH)—Kwajalein Atoll	8.73 N	167.73 E	8	0	6483	24	31	26	NA
Midway Island (MH) —Midway Island NAF	28.22 N	177.37 W	4	74	4624	15	30	24	NA
Samoa (WS)—Pago Pago WSO Airport	14.33 S	170.72 W	3	0	6121	22	31	27	NA
Wake Island—Wake Island WSO Airport	19.28 N	166.65 E	4	0	6165	22	31	26	NA
Philippines									
Philippines (PH)—Angeles, Clark AFB	15.18 N	120.55 E	145	0	6267	21	35	25	NA

TABLE D-2 Canadian Climatic Data

Province/City	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
									Dry-Bulb	Wet-Bulb
								99.6%	1.0%	1.0%
Alberta (AB)										
Calgary International A	51.12	N	114.02	W	1076	5492	648	–30	27	15
Edmonton International A	53.30	N	113.58	W	714	6124	594	–33	26	17
Grande Prairie A	55.18	N	118.88	W	665	6244	573	–36	26	16
Jasper	52.88	N	118.07	W	1060	5691	471	NA	NA	NA
Lethbridge A	49.63	N	112.80	W	928	4879	961	–30	29	16
Medicine Hat A	50.02	N	110.72	W	716	4993	1101	–31	31	17
Red Deer A	52.18	N	113.90	W	904	5981	608	–33	26	16
British Columbia (BC)										
Dawson Creek A	55.73	N	120.18	W	654	6353	494	NA	NA	NA
Ft. Nelson A	58.83	N	122.58	W	381	7189	563	–36	26	16
Kamloops	50.67	N	120.33	W	378	3776	1297	–22	31	17
Nanaimo A	49.05	N	123.87	W	29	3363	816	NA	NA	NA
New Westminster BC Pen	49.22	N	122.90	W	17	3067	939	NA	NA	NA
Penticton A	49.47	N	119.60	W	343	3611	1112	–15	31	18
Prince George	53.88	N	122.67	W	691	5275	503	–32	26	15
Prince Rupert A	54.30	N	130.43	W	33	4250	318	–14	17	14
Vancouver International A	49.18	N	123.17	W	2	3157	853	–8	23	18
Victoria Gonzales Hts	48.42	N	123.32	W	69	3052	714	–5	24	17
Manitoba (MB)										
Brandon CDA	49.87	N	99.98	W	362	6094	923	–34	29	19
Churchill A	58.73	N	94.07	W	27	9288	153	–38	22	16
Dauphin A	51.10	N	100.05	W	304	6246	844	–33	29	19
Flin Flon	54.77	N	101.85	W	334	6837	751	NA	NA	NA
Portage La Prairie A	49.90	N	98.27	W	269	5886	1004	–32	29	19
The Pas A	53.97	N	101.10	W	270	6939	684	–36	26	18
Winnipeg International A	49.90	N	97.23	W	238	6032	991	–33	29	19

TABLE D-2 Canadian Climatic Data *(Continued)*

Province/City	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
									Dry-Bulb	Wet-Bulb
								99.6%	1.0%	1.0%
New Brunswick (NB)										
Chatham A	47.02	N	65.45	W	33	5016	851	–24	28	19
Fredericton A	45.87	N	66.53	W	16	4814	906	–24	28	20
Moncton A	46.12	N	64.68	W	70	4851	793	–23	27	19
Saint John A	45.33	N	65.88	W	102	4876	655	–23	24	18
Newfoundland (NF)										
Corner Brook	48.95	N	57.95	W	4	4864	597	NA	NA	NA
Gander International A	48.95	N	54.57	W	150	5197	531	–20	24	17
Goose A	53.32	N	60.42	W	145	6676	421	–31	25	16
St John's A	47.62	N	52.73	W	133	4938	471	–16	23	18
Stephenville A	48.53	N	58.55	W	7	4927	529	–19	22	18
Northwest Territories (NW)										
Ft. Smith A	60.02	N	111.95	W	202	7884	518	–37	26	16
Inuvik A	68.30	N	133.48	W	58	10,227	272	–42	24	15
Yellowknife A	62.47	N	114.45	W	204	8642	473	–39	23	15
Nova Scotia (NS)										
Halifax International A	44.88	N	63.52	W	126	4518	813	–19	26	19
Kentville CDA	45.07	N	64.48	W	48	4268	925	NA	NA	NA
Sydney A	46.17	N	60.05	W	55	4647	715	–18	26	19
Truro	45.37	N	63.27	W	39	4776	719	–23	25	19
Yarmouth A	43.83	N	66.08	W	42	4175	656	–14	22	18
Nunavut										
Resolute A	74.72	N	94.98	W	66	12,702	0	–41	9	6
Ontario (ON)										
Belleville	44.15	N	77.40	W	75	4198	1251	NA	NA	NA
Cornwall	45.02	N	74.75	W	63	4479	1215	NA	NA	NA
Hamilton RBG	43.28	N	79.88	W	101	3818	1361	NA	NA	NA

TABLE D-2 Canadian Climatic Data *(Continued)*

Province/City	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
									Dry-Bulb	Wet-Bulb
								99.6%	1.0%	1.0%
(Ontario cont.)										
Kapuskasing A	49.42	N	82.47	W	226	6523	616	–34	27	18
Kenora A	49.78	N	94.37	W	406	6047	903	–33	27	18
Kingston A	44.22	N	76.60	W	92	4348	1089	NA	NA	NA
London A	43.03	N	81.15	W	277	4203	1181	–19	28	21
North Bay A	46.35	N	79.43	W	357	5441	838	–28	26	19
Oshawa WPCP	43.87	N	78.83	W	83	4029	1170	NA	NA	NA
Ottawa International A	45.32	N	75.67	W	115	4762	1136	–25	28	21
Owen Sound MOE	44.58	N	80.93	W	178	4294	1053	NA	NA	NA
Peterborough	44.28	N	78.32	W	193	4465	1097	NA	NA	NA
St Catharines	43.20	N	79.25	W	90	3722	1424	NA	NA	NA
Sudbury A	46.62	N	80.80	W	347	5550	865	–28	27	19
Thunder Bay A	48.37	N	89.32	W	198	5868	666	–30	27	19
Timmins A	48.57	N	81.37	W	294	6319	681	–33	27	18
Toronto Downsview A	43.75	N	79.48	W	197	4059	1317	–20	29	21
Windsor A	42.27	N	82.97	W	189	3677	1488	–17	30	22
Prince Edward Island (PE)										
Charlottetown A	46.28	N	63.13	W	47	4777	778	–21	25	19
Summerside A	46.43	N	63.83	W	23	4673	853	–21	25	19
Québec (PQ)										
Bagotville A	48.33	N	71.00	W	158	5891	722	–31	27	18
Drummondville	45.88	N	72.48	W	81	4778	1124	NA	NA	NA
Granby	45.38	N	72.70	W	167	4648	1102	NA	NA	NA
Montreal Dorval International A	45.47	N	73.75	W	30	4603	1192	–24	28	21
Québec City A	46.80	N	71.38	W	69	5249	873	–27	27	20
Rimouski	48.45	N	68.52	W	35	5369	675	NA	NA	NA
Sept-Iles A	50.22	N	66.27	W	54	6271	383	–29	21	15
Shawinigan	46.57	N	72.75	W	121	5137	956	NA	NA	NA

TABLE D-2 Canadian Climatic Data *(Continued)*

Province/City	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
									Dry-Bulb	Wet-Bulb
								99.6%	1.0%	1.0%
Sherbrooke A	45.43	N	71.68	W	237	5258	762	–29	27	20
St Jean de Cherbourg	48.88	N	67.12	W	350	6265	445	NA	NA	NA
St Jerome	45.80	N	74.05	W	169	5095	984	NA	NA	NA
Thetford Mines	46.10	N	71.35	W	380	5382	792	NA	NA	NA
Trois Rivieres	46.37	N	72.60	W	52	5069	981	NA	NA	NA
Val d'Or A	48.07	N	77.78	W	336	6253	663	–33	27	18
Valleyfield	45.28	N	74.10	W	45	4491	1260	NA	NA	NA
Saskatchewan (SK)										
Estevan A	49.22	N	102.97	W	571	5607	996	–32	30	18
Moose Jaw A	50.33	N	105.55	W	576	5549	1007	–33	31	18
North Battleford A	52.77	N	108.25	W	547	6182	818	–35	28	17
Prince Albert A	53.22	N	105.68	W	427	6672	696	–37	27	18
Regina A	50.43	N	104.67	W	576	5985	900	–34	29	18
Saskatoon A	52.17	N	106.68	W	500	6177	854	–35	29	17
Swift Current A	50.28	N	107.68	W	817	5627	856	–32	29	17
Yorkton A	51.27	N	102.47	W	497	6351	820	–34	28	18
Yukon Territory (YT)										
Whitehorse A	60.72	N	135.07	W	702	7109	339	–37	23	13

TABLE D-3 International Climatic Data

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
Argentina											
Buenos Aires/Ezeiza		34.82	S	58.53	W	20	1228	2607	–1	32	22
Cordoba		31.32	S	64.22	W	474	1009	2879	–1	33	22
Tucuman/Pozo		26.85	S	65.10	W	440	637	3679	NA	NA	NA
Australia											
Adelaide	SA	34.95	S	138.53	E	6	1157	2434	4	33	18
Alice Springs	NT	23.80	S	133.90	E	543	634	4321	1	39	18
Brisbane	QL	27.43	S	153.08	E	2	303	3894	7	30	22
Darwin Airport	NT	12.43	S	130.87	E	29	0	6520	18	33	24
Perth/Guildford	WA	31.92	S	115.97	E	17	837	2974	5	35	19
Sydney/K Smith	NSW	33.95	S	151.18	E	6	751	2922	6	29	19
Azores											
Lajes	Terceira	38.75	N	27.08	W	55	711	2718	8	26	22
Bahamas											
Nassau		25.05	N	77.47	W	3	16	5431	14	32	26
Belgium											
Brussels Airport		50.90	N	4.47	E	39	3033	1034	–9	26	19
Bermuda											
St Georges/Kindley		32.37	N	64.68	W	6	94	4647	NA	NA	NA
Bolivia											
La Paz/El Alto		16.50	S	68.18	W	4050	3994	132	–4	17	7
Brazil											
Belem		1.43	S	48.48	W	24	0	6418	22	32	26
Brasilia		15.77	S	47.93	W	1161	32	4413	9	31	18
Fortaleza		3.72	S	38.55	W	19	1	6527	22	32	26
Porto Alegre		30.08	S	51.18	W	7	501	3931	4	33	24
Recife/Curado		8.13	S	34.92	W	11	1	6084	21	33	26
Rio de Janeiro		22.90	S	43.17	W	5	8	5382	15	37	25
Salvador/Ondina		13.00	S	38.52	W	51	0	5992	20	31	26
Sao Paulo		23.50	S	46.62	W	795	248	4011	9	31	21

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
Bulgaria											
Sofia		42.82	N	23.38	E	595	3127	1393	–12	29	18
Chile											
Concepcion		36.77	S	73.05	W	12	1977	1268	2	23	17
Punta Arenas/Chabunco		53.03	S	70.85	W	33	4337	219	–5	16	12
Santiago/Pedahuel		33.38	S	70.88	W	480	1567	1928	–2	31	18
China											
Beijing/Peking	Municipalities	39.93	N	116.28	E	55	2918	2286	–11	33	22
Hong Kong Intl Arpt	Special Admin. Region	22.33	N	114.18	E	24	302	4386	9	33	26
Shanghai	Municipalities	31.40	N	121.47	E	4	1768	2847	–2	33	27
Shanghai/Hongqiao	Municipalities	31.17	N	121.43	E	7	1769	2848	–3	33	28
Tianjin/Tientsin	Municipalities	39.10	N	117.17	E	5	2749	2472	–10	33	23
Anqing	Anhui	30.53	N	117.05	E	20	1718	3042	–2	34	27
Bengbu	Anhui	32.95	N	117.37	E	22	2025	2807	–5	34	26
Fuyang	Anhui	32.93	N	115.83	E	39	2022	2780	–5	34	26
Hefei/Luogang	Anhui	31.87	N	117.23	E	36	1926	2839	–4	34	27
Huang Shan (Mtns)	Anhui	30.13	N	118.15	E	1836	3735	915	–13	21	18
Huoshan	Anhui	31.40	N	116.33	E	68	1953	2726	–5	34	27
Changting	Fujian	25.85	N	116.37	E	311	1057	3494	–1	33	25
Fuding	Fujian	27.33	N	120.20	E	38	1038	3487	1	33	27
Fuzhou	Fujian	26.08	N	119.28	E	85	775	3915	4	34	27
Jiuxian Shan	Fujian	25.72	N	118.10	E	1651	2180	1535	–5	23	20
Longyan	Fujian	25.10	N	117.02	E	341	622	4027	3	34	24
Nanping	Fujian	26.65	N	118.17	E	128	861	3881	1	35	26
Pingtan	Fujian	25.52	N	119.78	E	31	821	3639	6	31	26
Pucheng	Fujian	27.92	N	118.53	E	275	1292	3300	–2	34	25
Shaowu	Fujian	27.33	N	117.43	E	192	1153	3462	–1	34	26
Xiamen	Fujian	24.48	N	118.08	E	139	563	4070	6	33	26
Yong'An	Fujian	25.97	N	117.35	E	204	872	3843	1	35	25

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Dunhuang	Gansu	40.15	N	94.68	E	1140	3629	1818	–17	34	18
Hezuo	Gansu	35.00	N	102.90	E	2910	5422	273	–20	21	12
Huajialing	Gansu	35.38	N	105.00	E	2450	5153	484	–16	21	13
Jiuquan/Suzhou	Gansu	39.77	N	98.48	E	1478	4065	1374	–19	30	17
Lanzhou	Gansu	36.05	N	103.88	E	1518	3250	1641	–12	31	17
Mazong Shan (Mount)	Gansu	41.80	N	97.03	E	1770	5104	971	–23	29	13
Minqin	Gansu	38.63	N	103.08	E	1367	3914	1572	–18	32	16
Pingliang	Gansu	35.55	N	106.67	E	1348	3471	1337	–13	29	18
Ruo'ergai	Gansu	33.58	N	102.97	E	3441	6014	129	–22	18	11
Tianshui	Gansu	34.58	N	105.75	E	1143	2885	1707	–9	30	19
Wudu	Gansu	33.40	N	104.92	E	1079	1899	2361	–2	32	20
Wushaoling (Pass)	Gansu	37.20	N	102.87	E	3044	6499	146	–20	18	10
Xifengzhen	Gansu	35.73	N	107.63	E	1423	3595	1327	–12	28	17
Yumenzhen	Gansu	40.27	N	97.03	E	1527	4230	1315	–19	30	15
Zhangye	Gansu	38.93	N	100.43	E	1483	4049	1355	–19	31	17
Fogang	Guangdong	23.87	N	113.53	E	68	590	4283	4	34	26
Gaoyao	Guangdong	23.05	N	112.47	E	12	400	4718	6	34	27
Guangzhou/Baiyun	Guangdong	23.13	N	113.32	E	8	409	4640	6	34	26
Heyuan	Guangdong	23.73	N	114.68	E	41	501	4488	4	34	26
Lian Xian	Guangdong	24.78	N	112.38	E	98	922	3899	2	35	26
Lianping	Guangdong	24.37	N	114.48	E	214	723	3994	2	34	25
Meixian	Guangdong	24.30	N	116.12	E	84	520	4454	4	34	26
Shangchuan Island	Guangdong	21.73	N	112.77	E	18	285	4789	8	32	27
Shantou	Guangdong	23.40	N	116.68	E	3	433	4302	7	32	27
Shanwei	Guangdong	22.78	N	115.37	E	5	293	4595	8	32	26
Shaoguan	Guangdong	24.80	N	113.58	E	68	761	4203	3	35	26
Shenzhen	Guangdong	22.55	N	114.10	E	18	295	4776	7	33	26
Xinyi	Guangdong	22.35	N	110.93	E	84	316	4868	6	34	26

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Yangjiang	Guangdong	21.87	N	111.97	E	22	304	4705	7	32	26
Zhangjiang	Guangdong	21.22	N	110.40	E	28	235	5001	8	33	27
Beihai	Guangxi	21.48	N	109.10	E	16	345	4903	6	33	27
Bose	Guangxi	23.90	N	106.60	E	242	398	4716	6	35	26
Guilin	Guangxi	25.33	N	110.30	E	166	1095	3638	1	34	26
Guiping	Guangxi	23.40	N	110.08	E	44	531	4491	5	34	27
Hechi/Jnchengjiang	Guangxi	24.70	N	108.05	E	214	683	4161	4	34	26
Lingling	Guangxi	26.23	N	111.62	E	174	1449	3330	0	34	26
Liuzhou	Guangxi	24.35	N	109.40	E	97	761	4225	3	34	26
Longzhou	Guangxi	22.37	N	106.75	E	129	378	4776	6	35	27
Mengshan	Guangxi	24.20	N	110.52	E	145	825	3958	2	33	26
Nanning/Wuxu	Guangxi	22.82	N	108.35	E	73	476	4619	5	34	26
Napo	Guangxi	23.30	N	105.95	E	794	713	3594	3	31	23
Qinzhou	Guangxi	21.95	N	108.62	E	6	427	4675	6	33	27
Wuzhou	Guangxi	23.48	N	111.30	E	120	597	4408	4	34	26
Bijie	Guizhou	27.30	N	105.23	E	1511	2132	1942	–3	28	20
Dushan	Guizhou	25.83	N	107.55	E	1018	1679	2516	–3	28	22
Guiyang	Guizhou	26.58	N	106.72	E	1074	1599	2605	–2	29	21
Luodian	Guizhou	25.43	N	106.77	E	441	751	3926	3	34	25
Rongjiang/Guzhou	Guizhou	25.97	N	108.53	E	287	1093	3534	1	34	25
Sansui	Guizhou	26.97	N	108.67	E	611	1846	2588	–2	31	24
Sinan	Guizhou	27.95	N	108.25	E	418	1385	3177	1	34	24
Weining	Guizhou	26.87	N	104.28	E	2236	2573	1301	–6	24	16
Xingren	Guizhou	25.43	N	105.18	E	1379	1441	2515	–1	28	20
Zunyi	Guizhou	27.70	N	106.88	E	845	1717	2596	–1	31	23
Danxian/Nada	Hainan	19.52	N	109.58	E	169	136	5337	9	34	26
Dongfang/Basuo	Hainan	19.10	N	108.62	E	8	59	5649	12	33	27
Haikou	Hainan	20.03	N	110.35	E	15	117	5366	11	34	27

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Qionghai/Jiaji	Hainan	19.23	N	110.47	E	25	74	5490	11	34	27
Sanhu Island	Hainan	16.53	N	111.62	E	5	0	6268	20	32	28
Xisha Island	Hainan	16.83	N	112.33	E	5	0	6234	20	32	28
Yaxian/Sanya	Hainan	18.23	N	109.52	E	7	4	5964	16	32	27
Baoding	Hebei	38.85	N	115.57	E	19	2750	2450	–10	34	23
Cangzhou	Hebei	38.33	N	116.83	E	11	2716	2502	–10	33	23
Chengde	Hebei	40.97	N	117.93	E	374	3766	1864	–18	32	21
Fengning/Dagezhen	Hebei	41.22	N	116.63	E	661	4384	1430	–20	30	19
Huailai/Shacheng	Hebei	40.40	N	115.50	E	538	3605	1891	–15	32	20
Leting	Hebei	39.43	N	118.90	E	12	3288	1979	–14	31	24
Qinglong	Hebei	40.40	N	118.95	E	228	3673	1812	–18	31	22
Shijiazhuang	Hebei	38.03	N	114.42	E	81	2608	2483	–9	34	23
Tangshan	Hebei	39.67	N	118.15	E	29	3153	2149	–13	32	23
Weichang/Zhuizishan	Hebei	41.93	N	117.75	E	844	4778	1223	–21	29	18
Xingtai	Hebei	37.07	N	114.50	E	78	2503	2570	–8	34	23
Yu Xian	Hebei	39.83	N	114.57	E	910	4416	1414	–23	30	18
Zhangjiakou	Hebei	40.78	N	114.88	E	726	3790	1779	–17	31	19
Aihui	Heilongjiang	50.25	N	127.45	E	166	6578	1022	–33	28	20
Anda	Heilongjiang	46.38	N	125.32	E	150	5592	1379	–29	30	20
Baoqing	Heilongjiang	46.32	N	132.18	E	83	5406	1322	–27	29	21
Fujin	Heilongjiang	47.23	N	131.98	E	65	5703	1309	–28	29	21
Hailun	Heilongjiang	47.43	N	126.97	E	240	6121	1187	–31	29	20
Harbin	Heilongjiang	45.75	N	126.77	E	143	5461	1379	–29	30	21
Hulin	Heilongjiang	45.77	N	132.97	E	103	5543	1238	–27	28	21
Huma	Heilongjiang	51.72	N	126.65	E	179	7032	978	–38	29	20
Jixi	Heilongjiang	45.28	N	130.95	E	234	5288	1288	–26	29	21
Keshan	Heilongjiang	48.05	N	125.88	E	237	6171	1180	–32	29	20
Mudanjiang	Heilongjiang	44.57	N	129.60	E	242	5258	1361	–27	30	21

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Qiqihar	Heilongjiang	47.38	N	123.92	E	148	5513	1397	–28	30	20
Shangzhi	Heilongjiang	45.22	N	127.97	E	191	5744	1216	–32	29	21
Suifenhe	Heilongjiang	44.38	N	131.15	E	498	5677	952	–27	27	20
Sunwu	Heilongjiang	49.43	N	127.35	E	235	6852	880	–36	28	20
Tailai	Heilongjiang	46.40	N	123.42	E	150	5239	1480	–26	31	20
Tonghe	Heilongjiang	45.97	N	128.73	E	110	5899	1228	–31	29	22
Yichun	Heilongjiang	47.72	N	128.90	E	232	6244	1091	–33	28	20
Anyang/Zhangde	Henan	36.12	N	114.37	E	76	2399	2582	–8	34	24
Boxian	Henan	33.88	N	115.77	E	42	2226	2642	–7	34	25
Gushi	Henan	32.17	N	115.67	E	58	1982	2758	–4	34	27
Lushi	Henan	34.05	N	111.03	E	570	2540	2147	–8	32	23
Nanyang	Henan	33.03	N	112.58	E	131	2099	2639	–5	33	25
Xihua	Henan	33.78	N	114.52	E	53	2240	2569	–6	34	26
Xinyang	Henan	32.13	N	114.05	E	115	1987	2734	–5	33	26
Zhengzhou	Henan	34.72	N	113.65	E	111	2303	2563	–7	34	24
Zhumadian	Henan	33.00	N	114.02	E	83	2159	2621	–6	34	25
Fangxian	Hubei	32.03	N	110.77	E	435	2049	2491	–5	33	24
Guanghua	Hubei	32.38	N	111.67	E	91	1914	2771	–3	34	26
Jiangling/Jingzhou	Hubei	30.33	N	112.18	E	33	1702	2959	–2	34	27
Macheng	Hubei	31.18	N	114.97	E	59	1759	2979	–3	35	27
Wuhan/Nanhu	Hubei	30.62	N	114.13	E	23	1744	3018	–2	34	27
Yichang	Hubei	30.70	N	111.30	E	134	1562	3042	–1	34	26
Zaoyang	Hubei	32.15	N	112.67	E	127	1924	2797	–4	34	26
Zhongxiang	Hubei	31.17	N	112.57	E	66	1773	2911	–2	33	27
Changde	Hunan	29.05	N	111.68	E	35	1609	3067	–1	35	27
Chenzhou	Hunan	25.80	N	113.03	E	185	1387	3475	–1	35	25
Nanyue	Hunan	27.30	N	112.70	E	1279	2703	1717	–8	25	22
Sangzhi	Hunan	29.40	N	110.17	E	322	1609	2905	–1	34	25

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Shaoyang	Hunan	27.23	N	111.47	E	248	1552	3140	–1	34	25
Tongdao/Shuangjiang	Hunan	26.17	N	109.78	E	397	1503	3022	–1	32	25
Wugang	Hunan	26.73	N	110.63	E	340	1585	3013	–1	33	25
Yuanling	Hunan	28.47	N	110.40	E	143	1565	3023	–1	34	26
Yueyang	Hunan	29.38	N	113.08	E	52	1594	3156	–1	34	27
Zhijiang	Hunan	27.45	N	109.68	E	273	1587	2992	–1	33	26
Abag Qi/Xin Hot	Inner Mongolia	44.02	N	114.95	E	1128	6252	1029	–32	29	16
Arxan	Inner Mongolia	47.17	N	119.95	E	1028	7668	536	–37	25	16
Bailing-Miao	Inner Mongolia	41.70	N	110.43	E	1377	5222	1114	–26	29	15
Bayan Mod	Inner Mongolia	40.75	N	104.50	E	1329	4312	1617	–21	32	15
Bugt	Inner Mongolia	48.77	N	121.92	E	739	6801	659	–30	26	17
Bugt	Inner Mongolia	42.33	N	120.70	E	401	4363	1586	–20	31	20
Chifeng/Ulanhad	Inner Mongolia	42.27	N	118.97	E	572	4206	1675	–20	31	19
Dongsheng	Inner Mongolia	39.83	N	109.98	E	1459	4527	1223	–20	28	15
Duolun/Dolonnur	Inner Mongolia	42.18	N	116.47	E	1247	5779	859	–28	27	16
Ejin Qi	Inner Mongolia	41.95	N	101.07	E	941	4063	1995	–21	35	16
Erenhot	Inner Mongolia	43.65	N	112.00	E	966	5483	1356	–29	32	16
Guaizihu	Inner Mongolia	41.37	N	102.37	E	960	3994	2094	–20	36	16
Hailar	Inner Mongolia	49.22	N	119.75	E	611	7072	891	–35	28	18
Hails	Inner Mongolia	41.45	N	106.38	E	1510	4946	1287	–24	30	14
Haliut	Inner Mongolia	41.57	N	108.52	E	1290	4959	1280	–23	30	16
Hohhot	Inner Mongolia	40.82	N	111.68	E	1065	4457	1394	–20	30	17
Huade	Inner Mongolia	41.90	N	114.00	E	1484	5627	889	–25	27	15
Jartai	Inner Mongolia	39.78	N	105.75	E	1033	3867	1920	–19	34	17
Jarud Qi/Lubei	Inner Mongolia	44.57	N	120.90	E	266	4581	1587	–22	32	20
Jining	Inner Mongolia	41.03	N	113.07	E	1416	5154	950	–23	27	15
Jurh	Inner Mongolia	42.40	N	112.90	E	1152	5037	1334	–25	31	15
Lindong/Bairin Zuoq	Inner Mongolia	43.98	N	119.40	E	485	4974	1307	–24	30	19

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Linhe	Inner Mongolia	40.77	N	107.40	E	1041	4057	1664	–18	32	18
Linxi	Inner Mongolia	43.60	N	118.07	E	800	5086	1206	–23	29	18
Mandal	Inner Mongolia	42.53	N	110.13	E	1223	4981	1340	–23	31	15
Naran Bulag	Inner Mongolia	44.62	N	114.15	E	1183	6497	920	–31	29	15
Nenjiang	Inner Mongolia	49.17	N	125.23	E	243	6656	1044	–35	29	19
Otog Qi/Ulan	Inner Mongolia	39.10	N	107.98	E	1381	4290	1392	–20	30	15
Tongliao	Inner Mongolia	43.60	N	122.27	E	180	4621	1639	–23	31	21
Tulihe	Inner Mongolia	50.45	N	121.70	E	733	8217	501	–41	26	17
Uliastai	Inner Mongolia	45.52	N	116.97	E	840	6301	1051	–31	30	17
Xi Ujimqin Qi	Inner Mongolia	44.58	N	117.60	E	997	6187	920	–30	28	16
Xilin Hot/Abagnar	Inner Mongolia	43.95	N	116.07	E	991	5822	1139	–29	30	16
Xin Barag Youqi	Inner Mongolia	48.67	N	116.82	E	556	6423	1080	–31	30	17
Dongtai	Jiangsu	32.87	N	120.32	E	5	2118	2562	–5	33	27
Ganyu/Dayishan	Jiangsu	34.83	N	119.13	E	10	2451	2364	–7	32	26
Liyang	Jiangsu	31.43	N	119.48	E	8	1954	2727	–4	34	27
Lusi	Jiangsu	32.07	N	121.60	E	10	2007	2540	–3	32	27
Qingjiang	Jiangsu	33.60	N	119.03	E	19	2232	2534	–6	32	27
Shenyang/Hede	Jiangsu	33.77	N	120.25	E	7	2277	2428	–6	32	27
Xuzhou	Jiangsu	34.28	N	117.15	E	42	2267	2609	–7	33	25
Ganzhou	Jiangxi	25.85	N	114.95	E	125	1069	3844	1	35	26
Guangchang	Jiangxi	26.85	N	116.33	E	142	1272	3540	–1	35	26
Ji'An	Jiangxi	27.12	N	114.97	E	78	1321	3543	0	35	26
Jingdezhen	Jiangxi	29.30	N	117.20	E	60	1456	3272	–2	35	26
Lu Shan (Mountain)	Jiangxi	29.58	N	115.98	E	1165	2652	1800	–9	26	22
Nanchang	Jiangxi	28.60	N	115.92	E	50	1492	3320	–1	35	27
Nancheng	Jiangxi	27.58	N	116.65	E	82	1394	3400	–1	34	26
Xiushui	Jiangxi	29.03	N	114.58	E	147	1585	3101	–3	35	26
Xunwu	Jiangxi	24.95	N	115.65	E	299	921	3714	1	33	25

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Yichun	Jiangxi	27.80	N	114.38	E	129	1509	3181	–1	34	26
Changbai	Jilin	41.35	N	128.17	E	1018	5807	834	–27	26	19
Changchun	Jilin	43.90	N	125.22	E	238	4914	1504	–25	29	21
Changling	Jilin	44.25	N	123.97	E	190	4966	1514	–25	30	21
Dunhua	Jilin	43.37	N	128.20	E	526	5513	1050	–27	27	20
Huadian	Jilin	42.98	N	126.75	E	264	5181	1380	–32	29	22
Ji'An	Jilin	41.10	N	126.15	E	179	4229	1635	–23	30	22
Linjiang	Jilin	41.72	N	126.92	E	333	4803	1429	–26	29	21
Qian Gorlos	Jilin	45.12	N	124.83	E	138	5034	1539	–26	30	22
Yanji	Jilin	42.88	N	129.47	E	178	4822	1331	–23	29	21
Chaoyang	Liaoning	41.55	N	120.45	E	176	3929	1887	–20	32	21
Dalian/Dairen/Luda	Liaoning	38.90	N	121.63	E	97	3138	1912	–12	30	23
Dandong	Liaoning	40.05	N	124.33	E	14	3690	1674	–17	29	23
Haiyang Island	Liaoning	39.05	N	123.22	E	10	3041	1856	–10	28	25
Jinzhou	Liaoning	41.13	N	121.12	E	70	3665	1887	–17	30	22
Kuandian	Liaoning	40.72	N	124.78	E	261	4302	1482	–24	29	22
Qingyuan	Liaoning	42.10	N	124.95	E	235	4652	1527	–27	30	22
Shenyang/Dongta	Liaoning	41.77	N	123.43	E	43	4010	1847	–22	31	23
Siping	Liaoning	43.18	N	124.33	E	165	4578	1610	–24	30	22
Yingkou	Liaoning	40.67	N	122.20	E	4	3758	1891	–18	30	24
Zhangwu	Liaoning	42.42	N	122.53	E	84	4308	1700	–22	30	22
Yanchi	Ningxia	37.78	N	107.40	E	1349	3841	1541	–19	31	16
Yinchuan	Ningxia	38.48	N	106.22	E	1112	3676	1655	–17	31	19
Zhongning	Ningxia	37.48	N	105.67	E	1185	3454	1705	–16	31	19
Daqaidam	Qinghai	37.85	N	95.37	E	3174	5986	408	–24	24	9
Darlag	Qinghai	33.75	N	99.65	E	3968	6742	56	–25	16	9
Delingha	Qinghai	37.37	N	97.37	E	2982	5103	650	–20	25	11
Dulan/Qagan Us	Qinghai	36.30	N	98.10	E	3192	5371	428	–18	24	10

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Gangca/Shaliuhe	Qinghai	37.33	N	100.13	E	3301	6551	97	–22	18	10
Golmud	Qinghai	36.42	N	94.90	E	2809	4674	801	–17	26	11
Henan	Qinghai	34.73	N	101.60	E	3500	6448	86	–27	18	10
Lenghu	Qinghai	38.83	N	93.38	E	2734	5589	634	–22	26	10
Madoi/Huangheyan	Qinghai	34.92	N	98.22	E	4273	7853	17	–28	15	6
Qumarleb	Qinghai	34.13	N	95.78	E	4176	7320	37	–27	17	8
Tongde	Qinghai	35.27	N	100.65	E	3290	6233	160	–26	20	10
Tuotuohe/Tanggulash	Qinghai	34.22	N	92.43	E	4535	8058	12	–29	16	6
Wudaoliang	Qinghai	35.22	N	93.08	E	4613	8397	5	–27	13	4
Xining	Qinghai	36.62	N	101.77	E	2262	4121	900	–16	26	14
Yushu	Qinghai	33.02	N	97.02	E	3682	5197	306	–19	21	11
Zadoi	Qinghai	32.90	N	95.30	E	4068	6254	121	–23	18	9
Ankang/Xing'an	Shaanxi	32.72	N	109.03	E	291	1801	2733	–2	34	25
Baoji	Shaanxi	34.35	N	107.13	E	610	2414	2214	–6	33	21
Hanzhong	Shaanxi	33.07	N	107.03	E	509	2042	2363	–3	32	24
Hua Shan (Mount)	Shaanxi	34.48	N	110.08	E	2063	4358	842	–15	22	15
Tongchuan	Shaanxi	35.17	N	109.05	E	914	3039	1732	–10	30	19
Xi'An	Shaanxi	34.30	N	108.93	E	398	2407	2376	–6	34	23
Yan An	Shaanxi	36.60	N	109.50	E	959	3262	1740	–15	31	19
Yulin	Shaanxi	38.23	N	109.70	E	1058	3911	1574	–20	31	18
Chengshantou (Cape)	Shandong	37.40	N	122.68	E	47	2847	1751	–6	26	23
Dezhou	Shandong	37.43	N	116.32	E	22	2579	2551	–9	33	24
Haiyang	Shandong	36.77	N	121.17	E	64	2746	2079	–9	29	24
Heze/Caozhou	Shandong	35.25	N	115.43	E	51	2378	2571	–8	33	25
Huimin	Shandong	37.50	N	117.53	E	12	2783	2372	–11	33	24
Jinan/Sinan	Shandong	36.68	N	116.98	E	58	2312	2798	–8	34	24
Linyi	Shandong	35.05	N	118.35	E	86	2438	2442	–8	32	24
Longkou	Shandong	37.62	N	120.32	E	5	2871	2124	–9	31	24

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Quingdao/Singtao	Shandong	36.07	N	120.33	E	77	2584	2151	–8	30	23
Rizhao	Shandong	35.38	N	119.53	E	15	2553	2181	–7	29	25
Tai Shan (Mtns)	Shandong	36.25	N	117.10	E	1536	4605	854	–17	21	17
Weifang	Shandong	36.70	N	119.08	E	51	2676	2397	–11	33	24
Xinxian	Shandong	36.03	N	115.58	E	47	2566	2459	–9	33	25
Yanzhou	Shandong	35.57	N	116.85	E	53	2515	2451	–10	33	24
Yiyuan/Nanma	Shandong	36.18	N	118.15	E	302	2830	2194	–11	32	22
Datong	Shanxi	40.10	N	113.33	E	1069	4376	1396	–21	30	17
Hequ	Shanxi	39.38	N	111.15	E	861	4075	1600	–21	32	19
Jiexiu	Shanxi	37.05	N	111.93	E	750	3166	1825	–13	32	20
Lishi	Shanxi	37.50	N	111.10	E	951	3634	1644	–17	31	19
Taiyuan/Wusu/Wusu	Shanxi	37.78	N	112.55	E	779	3370	1740	–15	31	20
Wutai Shan (Mtn)	Shanxi	39.03	N	113.53	E	2898	7897	56	–29	17	11
Yangcheng	Shanxi	35.48	N	112.40	E	659	2809	2063	–10	31	21
Yuanping	Shanxi	38.75	N	112.70	E	838	3725	1635	–17	31	19
Yuncheng	Shanxi	35.03	N	111.02	E	376	2463	2529	–8	35	22
Yushe	Shanxi	37.07	N	112.98	E	1042	3601	1543	–16	30	18
Barkam	Sichuan	31.90	N	102.23	E	2666	3011	1046	–10	26	15
Batang	Sichuan	30.00	N	99.10	E	2589	2000	1815	–5	29	15
Chengdu	Sichuan	30.67	N	104.02	E	508	1505	2691	0	31	25
Da Xian	Sichuan	31.20	N	107.50	E	311	1388	3030	1	34	25
Daocheng/Dabba	Sichuan	29.05	N	100.30	E	3729	4785	347	–15	20	9
Dawu	Sichuan	30.98	N	101.12	E	2959	3394	911	–12	25	14
Emei Shan	Sichuan	29.52	N	103.33	E	3049	5254	212	–13	16	12
Fengjie	Sichuan	31.05	N	109.50	E	607	1605	2802	0	33	24
Garze	Sichuan	31.62	N	100.00	E	3394	4253	551	–15	22	12
Jiulong/Gyaisi	Sichuan	29.00	N	101.50	E	2994	3058	871	–8	24	13
Kangding/Dardo	Sichuan	30.05	N	101.97	E	2617	3817	680	–9	22	14

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Langzhong	Sichuan	31.58	N	105.97	E	385	1418	2884	1	33	25
Liangping	Sichuan	30.68	N	107.80	E	455	1518	2840	1	33	25
Litang	Sichuan	30.00	N	100.27	E	3950	5204	205	–17	18	9
Luzhou	Sichuan	28.88	N	105.43	E	336	1194	3161	3	34	25
Mianyang	Sichuan	31.47	N	104.68	E	472	1540	2746	–1	32	24
Nanchong	Sichuan	30.80	N	106.08	E	310	1359	3012	1	34	25
Neijiang	Sichuan	29.58	N	105.05	E	357	1242	3106	2	34	25
Pingwu	Sichuan	32.42	N	104.52	E	877	1730	2404	–1	31	22
Songpan/Sungqu	Sichuan	32.65	N	103.57	E	2852	4072	608	–13	23	13
Wanyuan	Sichuan	32.07	N	108.03	E	674	1864	2391	–2	32	23
Xichang	Sichuan	27.90	N	102.27	E	1599	965	2895	1	31	19
Ya'An	Sichuan	29.98	N	103.00	E	629	1435	2456	1	31	25
Yibin	Sichuan	28.80	N	104.60	E	342	1135	3175	3	33	26
Youyang	Sichuan	28.83	N	108.77	E	665	1839	2492	–2	31	23
Baingoin	Tibet	31.37	N	90.02	E	4701	6937	39	–22	16	6
Dengqen	Tibet	31.42	N	95.60	E	3874	5182	282	–15	20	10
Lhasa	Tibet	29.67	N	91.13	E	3650	3645	796	–10	24	11
Lhunze	Tibet	28.42	N	92.47	E	3861	4416	480	–13	20	9
Nagqu	Tibet	31.48	N	92.07	E	4508	6966	35	–24	16	6
Nyingchi	Tibet	29.57	N	94.47	E	3001	3124	894	–7	23	14
Pagri	Tibet	27.73	N	89.08	E	4301	6431	6	–20	13	7
Qamdo	Tibet	31.15	N	97.17	E	3307	3639	852	–12	25	13
Shiquanhe	Tibet	32.50	N	80.08	E	4279	6718	287	–26	21	7
Sog Xian	Tibet	31.88	N	93.78	E	4024	5859	175	–21	19	9
Tingri/Xegar	Tibet	28.63	N	87.08	E	4302	5552	254	–18	19	8
Xainza	Tibet	30.95	N	88.63	E	4671	6583	55	–20	17	6
Xigaze	Tibet	29.25	N	88.88	E	3837	4242	591	–14	22	10
Akqi	Xinjiang	40.93	N	78.45	E	1986	4251	1142	–18	27	14

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Alar	Xinjiang	40.50	N	81.05	E	1013	3290	2157	–16	33	19
Altay	Xinjiang	47.73	N	88.08	E	737	5236	1328	–29	30	17
Andir	Xinjiang	37.93	N	83.65	E	1264	3438	2113	–18	36	17
Bachu	Xinjiang	39.80	N	78.57	E	1117	3017	2380	–14	34	18
Balguntay	Xinjiang	42.67	N	86.33	E	1753	4227	1091	–17	27	14
Bayanbulak	Xinjiang	43.03	N	84.15	E	2459	8339	113	–38	19	10
Baytik Shan (Mtns)	Xinjiang	45.37	N	90.53	E	1651	5707	754	–24	26	12
Fuyun	Xinjiang	46.98	N	89.52	E	827	5639	1326	–33	32	16
Hami	Xinjiang	42.82	N	93.52	E	739	3621	2181	–18	35	19
Hoboksar	Xinjiang	46.78	N	85.72	E	1294	5247	966	–23	27	14
Hotan	Xinjiang	37.13	N	79.93	E	1375	2816	2341	–11	33	18
Jinghe	Xinjiang	44.62	N	82.90	E	321	4358	2006	–26	34	20
Kaba He	Xinjiang	48.05	N	86.35	E	534	5086	1384	–29	31	18
Karamay	Xinjiang	45.60	N	84.85	E	428	4370	2347	–26	35	17
Kashi	Xinjiang	39.47	N	75.98	E	1291	3011	2102	–13	32	18
Korla	Xinjiang	41.75	N	86.13	E	933	3156	2340	–14	34	19
Kuqa	Xinjiang	41.72	N	82.95	E	1100	3169	2192	–15	33	18
Mangnai	Xinjiang	38.25	N	90.85	E	2945	5803	404	–20	24	9
Pishan	Xinjiang	37.62	N	78.28	E	1376	2965	2262	–13	34	18
Qijiaojing	Xinjiang	43.48	N	91.63	E	874	3954	2051	–19	35	16
Qitai	Xinjiang	44.02	N	89.57	E	794	4923	1552	–29	32	17
Ruoqiang	Xinjiang	39.03	N	88.17	E	889	3195	2378	–15	37	19
Shache	Xinjiang	38.43	N	77.27	E	1232	3004	2150	–13	33	19
Tacheng	Xinjiang	46.73	N	83.00	E	535	4318	1575	–24	32	18
Tikanlik	Xinjiang	40.63	N	87.70	E	847	3385	2296	–17	36	19
Turpan	Xinjiang	42.93	N	89.20	E	37	2920	3355	–14	40	21
Urumqi	Xinjiang	43.78	N	87.62	E	919	4563	1675	–22	32	16
Yining	Xinjiang	43.95	N	81.33	E	663	3676	1714	–22	32	19

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Yiwu/Araturuk	Xinjiang	43.27	N	94.70	E	1729	5201	854	–22	26	13
Baoshan	Yunnan	25.13	N	99.22	E	1655	1195	2402	1	27	19
Chuxiong	Yunnan	25.02	N	101.53	E	1773	1168	2452	0	28	17
Dali	Yunnan	25.70	N	100.18	E	1992	1332	2119	1	26	18
Deqen	Yunnan	28.50	N	98.90	E	3488	4380	371	–8	19	12
Guangnan	Yunnan	24.07	N	105.07	E	1251	1020	2990	0	30	20
Huili	Yunnan	26.65	N	102.25	E	1788	1373	2264	–1	28	18
Huize	Yunnan	26.42	N	103.28	E	2110	1957	1676	–4	25	17
Jiangcheng	Yunnan	22.62	N	101.82	E	1121	421	3577	6	29	20
Jinghong	Yunnan	22.02	N	100.80	E	553	51	5059	10	34	22
Kunming/Wujiaba	Yunnan	25.02	N	102.68	E	1892	1367	2092	0	26	17
Lancang/Menglangba	Yunnan	22.57	N	99.93	E	1054	273	3977	5	31	19
Lijing	Yunnan	26.83	N	100.47	E	2394	1883	1565	–1	25	16
Lincang	Yunnan	23.95	N	100.22	E	1503	628	3105	4	28	18
Luxi	Yunnan	24.53	N	103.77	E	1708	1252	2412	–1	27	17
Mengding	Yunnan	23.57	N	99.08	E	512	93	4879	8	34	22
Mengla	Yunnan	21.50	N	101.58	E	633	74	4825	9	33	22
Mengzi	Yunnan	23.38	N	103.38	E	1302	526	3554	4	30	19
Ruili	Yunnan	24.02	N	97.83	E	776	265	4191	6	31	21
Simao	Yunnan	22.77	N	100.98	E	1303	442	3473	6	29	18
Tengchong	Yunnan	25.12	N	98.48	E	1649	1200	2227	1	26	18
Yuanjiang	Yunnan	23.60	N	101.98	E	398	92	5476	9	36	24
Yuanmou	Yunnan	25.73	N	101.87	E	1120	279	4536	5	34	19
Zhanyi	Yunnan	25.58	N	103.83	E	1900	1403	2142	–1	27	16
Zhaotong	Yunnan	27.33	N	103.75	E	1950	2257	1654	–5	27	17
Dachen Island	Zhejiang	28.45	N	121.88	E	84	1505	2759	1	29	27
Dinghai	Zhejiang	30.03	N	122.12	E	37	1555	2866	–1	31	27
Hangzhou/Jianqiao	Zhejiang	30.23	N	120.17	E	43	1705	2974	–2	35	27

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Kuocang Shan	Zhejiang	28.82	N	120.92	E	1371	3017	1436	–10	25	21
Lishui	Zhejiang	28.45	N	119.92	E	62	1284	3447	–1	36	26
Qixian Shan	Zhejiang	27.95	N	117.83	E	1409	2401	1753	–7	25	21
Qu Xian	Zhejiang	28.97	N	118.87	E	71	1514	3189	–1	35	26
Shengsi/Caiyuanzhen	Zhejiang	30.73	N	122.45	E	81	1642	2725	–1	30	26
Shengxian	Zhejiang	29.60	N	120.82	E	108	1666	3017	–3	35	26
Shipu	Zhejiang	29.20	N	121.95	E	127	1547	2870	–1	31	27
Taishan	Zhejiang	27.00	N	120.70	E	106	1262	3014	3	29	26
Tianmu Shan (Mtns)	Zhejiang	30.35	N	119.42	E	1494	3397	1236	–12	24	21
Wenzhou	Zhejiang	28.02	N	120.67	E	7	1169	3323	1	33	27
Cuba											
Guantanamo Bay NAS	Ote.	19.90	N	75.15	W	23	0	6511	19	34	26
Cyprus											
Akrotiri		34.58	N	32.98	E	23	715	3415	4	32	22
Larnaca		34.88	N	33.63	E	2	807	3349	3	33	22
Paphos		34.75	N	32.40	E	9	711	3291	4	30	24
Czech Republic (Former Czechoslovakia)											
Prague/Libus		50.00	N	14.45	E	305	3542	1029	–16	27	18
Dominican Republic											
Santo Domingo		18.47	N	69.88	W	13	0	6034	NA	NA	NA
Egypt											
Cairo		30.13	N	31.40	E	74	463	4441	7	36	21
Luxor		25.67	N	32.70	E	88	323	5472	4	42	22
Finland											
Helsinki/Seutula		60.32	N	24.97	E	51	5028	632	–24	24	16
France											
Lyon/Satolas		45.73	N	5.08	E	248	2739	1449	–8	30	21
Marseille		43.45	N	5.22	E	8	1774	2185	–4	31	21

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(France cont.)											
Nantes		47.17	N	1.60	W	27	2381	1378	–5	28	20
Nice		43.65	N	7.20	E	10	1467	2213	2	28	23
Paris/Le Bourget		48.97	N	2.45	E	66	2803	1228	–8	28	20
Strasbourg		48.55	N	7.63	E	153	3074	1218	–11	29	20
Germany											
Berlin/Schoenfeld		52.38	N	13.52	E	47	3517	1011	–12	28	18
Hamburg		53.63	N	9.98	E	16	3511	872	–12	26	18
Hannover		52.47	N	9.70	E	55	3385	961	–13	27	18
Mannheim		49.53	N	8.50	E	97	3016	1257	NA	NA	NA
Greece											
Souda	Crete	35.55	N	24.12	E	127	982	3040	4	32	19
Thessalonika/Mikra		40.52	N	22.97	E	8	1883	2286	–4	32	21
Greenland											
Narssarssuaq		61.18	N	45.42	W	24	6401	162	–28	17	9
Hungary											
Budapest/Lorinc		47.43	N	19.18	E	140	3074	1471	–13	30	20
Iceland											
Reykjavik		64.13	N	21.93	W	61	5159	163	–10	14	11
India											
Ahmedabad		23.07	N	72.63	E	55	17	6471	11	41	23
Bangalore		12.97	N	77.58	E	920	1	5227	15	33	19
Bombay/Santa Cruz		19.12	N	72.85	E	8	1	6318	17	34	23
Calcutta/Dum Dum		22.65	N	88.45	E	5	14	6147	12	36	26
Madras		13.00	N	80.18	E	16	0	6891	20	37	25
Nagpur Sonegaon		21.10	N	79.05	E	309	10	6263	12	42	22
New Delhi/Safdarjung		28.58	N	77.20	E	214	267	5589	7	41	22
Indonesia											
Djakarta/Halimperda	Java	6.25	S	106.90	E	30	0	6376	NA	NA	NA
Kupang Penfui	Sunda Island	10.17	S	123.67	E	108	1	6492	NA	NA	NA

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(Indonesia cont.)											
Makassar	Celebes	5.07	S	119.55	E	17	2	6378	NA	NA	NA
Medan	Sumatra	3.57	N	98.68	E	26	0	6384	NA	NA	NA
Palembang	Sumatra	2.90	S	104.70	E	10	0	6425	NA	NA	NA
Surabaja Perak	Java	7.22	S	112.72	E	3	0	6716	NA	NA	NA
Ireland											
Dublin Airport		53.43	N	6.25	W	85	3059	709	–2	21	16
Shannon Airport		52.68	N	8.92	W	20	2837	808	–2	22	17
Israel											
Jerusalem		31.78	N	35.22	E	809	1346	2561	1	30	18
Tel Aviv Port		32.10	N	34.78	E	10	531	3806	7	30	23
Italy											
Milano/Linate		45.43	N	9.28	E	107	2504	1853	–6	31	22
Napoli/Capodichino		40.88	N	14.30	E	72	1477	2389	0	32	23
Roma/Fiumicino		41.80	N	12.23	E	2	1491	2318	–1	30	23
Jamaica											
Kingston/Manley		17.93	N	76.78	W	14	0	6589	22	37	26
Montego Bay/Sangster		18.50	N	77.92	W	1	1	6064	21	32	26
Japan											
Fukaura		40.65	N	139.93	E	68	3068	1629	–1	33	26
Sapporo		43.05	N	141.33	E	17	3752	1399	–11	27	22
Tokyo		35.68	N	139.77	E	36	1659	2638	–1	31	25
Jordan											
Amman		31.98	N	35.98	E	767	1298	3015	1	33	18
Kenya											
Nairobi Airport		1.32	S	36.93	E	1624	152	3432	9	28	16
Korea											
Pyonggang		38.40	N	127.30	E	371	3742	1578	–16	29	23
Seoul		37.57	N	126.97	E	86	2782	2198	NA	NA	NA

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
									99.6%	1.0%	1.0%
Malaysia											
Kuala Lumpur		3.13	N	101.55	E	17	0	6406	22	34	26
Penang/Bayan Lepas		5.30	N	100.27	E	3	0	6373	NA	NA	NA
Mexico											
Mexico City	Distrito Federal	19.40	N	99.20	W	2308	668	2646	4	28	14
Guadalajara	Jalisco	20.67	N	103.38	W	1589	389	3401	NA	NA	NA
Monterrey	Nuevo Laredo	25.87	N	100.20	W	450	469	4626	NA	NA	NA
Tampico	Tamaulipas	22.22	N	97.85	W	12	120	5483	10	32	27
Veracruz	Veracruz	19.15	N	96.12	W	16	9	5559	14	33	27
Merida	Yucatan	20.98	N	89.65	W	9	6	6179	14	37	24
Netherlands											
Amsterdam/Schiphol		52.30	N	4.77	E	–4	3162	899	–8	25	18
New Zealand											
Auckland Airport		37.02	S	174.80	E	7	1246	2028	2	24	19
Christchurch		43.48	S	172.55	E	36	2422	1175	–2	26	16
Wellington		41.28	S	174.77	E	128	1998	1254	2	22	17
Norway											
Bergen/Florida		60.38	N	5.33	E	39	3823	563	–9	20	14
Oslo/Fornebu		59.90	N	10.62	E	16	4456	739	–18	25	17
Pakistan											
Karachi Airport		24.90	N	67.13	E	23	642	6138	NA	NA	NA
Papua New Guinea											
Port Moresby		9.43	S	147.22	E	28	1	6262	NA	NA	NA
Paraguay											
Asuncion/Stroessner		25.27	S	57.63	W	101	261	5003	5	35	24
Peru											
Lima-Callao/Chavez		12.00	S	77.12	W	13	144	3747	14	29	23
San Juan de Marcona		15.35	S	75.15	W	60	170	3758	NA	NA	NA
Talara		4.57	S	81.25	W	86	2	4985	16	31	24

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
Philippines											
Manila Airport	Luzon	14.52	N	121.00	E	23	0	6361	21	34	27
Poland											
Krakow/Balice		50.08	N	19.80	E	237	3847	1115	–18	27	19
Puerto Rico											
San Juan/Isla Verde WSFO		18.43	N	66.00	W	3	0	6337	21	32	26
Romania											
Bucuresti/Bancasa		44.50	N	26.13	E	94	3034	1638	–13	31	21
Russia (Former Soviet Union)											
Kaliningrad	East Prussia	54.70	N	20.62	E	27	3953	883	–19	25	18
Krasnoiarsk		56.00	N	92.88	E	194	6266	751	–34	27	17
Moscow Observatory		55.75	N	37.57	E	156	4776	949	–23	26	18
Petropavlovsk		53.02	N	158.72	E	7	5615	294	–15	19	14
Rostov-Na-Donu		47.25	N	39.82	E	79	3533	1675	–17	30	20
Vladivostok		43.12	N	131.90	E	138	4953	960	–22	24	19
Volgograd		48.68	N	44.35	E	145	4199	1578	–21	31	18
Saudi Arabia											
Dhahran		26.27	N	50.17	E	22	212	6076	NA	NA	NA
Riyadh		24.70	N	46.73	E	611	298	5958	5	43	18
Senegal											
Dakar/Yoff		14.73	N	17.50	W	27	3	5417	16	31	25
Singapore											
Singapore/Changi		1.37	N	103.98	E	15	0	6664	23	32	26
South Africa											
Cape Town/D F Malan		33.97	S	18.60	E	46	936	2474	3	28	19
Johannesburg		26.13	S	28.23	E	1694	1066	2362	1	28	16
Pretoria		25.73	S	28.18	E	1330	639	3238	4	31	17
Spain											
Barcelona		41.28	N	2.07	E	4	1466	2203	0	29	23

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
									99.6%	1.0%	1.0%
(Spain cont.)											
Madrid		40.47	N	3.57	W	582	2038	2057	–4	34	20
Valencia/Manises		39.50	N	0.47	W	203	1942	5045	1	30	23
Sweden											
Stockholm/Arlanda		59.65	N	17.95	E	61	4513	721	–19	25	16
Switzerland											
Zurich		47.38	N	8.57	E	569	3342	1108	–11	27	18
Syria											
Damascus Airport		33.42	N	36.52	E	610	1539	2941	–4	37	18
Taiwan											
Alisan Shan		23.52	N	120.80	E	2406	2448	1088	NA	NA	NA
Chiayi (TW-AFB)		23.50	N	120.42	E	28	177	4959	9	33	27
Chiayyi		23.47	N	120.38	E	25	153	5160	8	33	28
Chilung		25.13	N	121.75	E	3	262	4752	10	33	26
Chinmen		24.43	N	118.43	E	12	541	4122	NA	NA	NA
Dawu		22.35	N	120.90	E	9	13	5753	NA	NA	NA
Hengchun		22.00	N	120.75	E	24	13	5622	16	32	27
Hengchun/Wu Lu Tien		22.03	N	120.72	E	13	12	5782	NA	NA	NA
Hsinchu/Singjo		24.82	N	120.93	E	8	268	4759	9	33	28
Hua Lien		23.97	N	121.62	E	19	122	4929	NA	NA	NA
Hwalien		24.02	N	121.62	E	15	123	5024	NA	NA	NA
Joyutang		23.88	N	120.85	E	1015	324	3964	NA	NA	NA
Kao Hsiung Intl. Arpt.		22.57	N	120.35	E	8	62	5390	12	33	26
Kao Hsiung		22.62	N	120.27	E	29	39	5522	12	32	27
Kungkuan		24.27	N	120.62	E	203	300	4614	NA	NA	NA
Kungshan		22.78	N	120.25	E	10	88	5292	NA	NA	NA
Lan Yu		22.03	N	121.55	E	325	53	4870	14	29	27
Makung		23.57	N	119.62	E	31	157	4976	11	32	28
Matsu Island		26.17	N	119.93	E	92	1082	3277	NA	NA	NA

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
(Taiwan cont.)											
North Pingtung		22.70	N	120.47	E	29	49	5583	11	34	27
Peng Hu		23.52	N	119.57	E	21	159	5038	NA	NA	NA
Penkaiyu		25.63	N	122.07	E	102	295	4533	NA	NA	NA
Sing Jo		24.80	N	120.97	E	33	297	4711	NA	NA	NA
Sinkung		23.10	N	121.37	E	37	49	5334	NA	NA	NA
South Pingtung		22.67	N	120.45	E	24	39	5682	12	34	27
Taichung		24.15	N	120.68	E	78	173	4995	9	33	26
Taichung/Shui Nan		24.18	N	120.65	E	111	212	4953	8	34	28
Tainan (TW-AFB)		22.95	N	120.20	E	16	83	5405	10	33	28
Tainan		23.00	N	120.22	E	14	99	5320	11	33	27
Taipei		25.03	N	121.52	E	8	243	4942	9	34	27
Taipei/Chiang Kai Shek		25.08	N	121.23	E	23	330	4698	9	33	27
Taipei/Sungshan		25.07	N	121.53	E	6	281	4697	9	34	27
Taitung		22.75	N	121.15	E	10	41	5419	NA	NA	NA
Taitung/Fongyentsun		22.80	N	121.18	E	37	40	5426	NA	NA	NA
Taoyuan (AB)		25.07	N	121.23	E	50	348	4620	9	33	28
Tung Shih		23.27	N	119.67	E	45	106	5120	NA	NA	NA
Wu-Chi		24.25	N	120.52	E	5	225	4828	10	32	27
Yilan		24.77	N	121.75	E	7	229	4676	NA	NA	NA
Tanzania											
Dar es Salaam		6.88	S	39.20	E	55	2	5975	NA	NA	NA
Thailand											
Bangkok		13.73	N	100.57	E	16	0	6906	18	36	26
Tunisia											
Tunis/El Aouina		36.83	N	10.23	E	5	921	3205	5	34	23
Turkey											
Adana		37.00	N	35.42	E	66	1026	3388	0	34	22
Ankara/Etimesgut		39.95	N	32.68	E	806	2868	1709	–17	30	17
Istanbul/Yesilkoy		40.97	N	28.82	E	37	1963	2098	–3	29	21

TABLE D-3 International Climatic Data *(Continued)*

Country/City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature	
										Dry-Bulb	Wet-Bulb
									99.6%	1.0%	1.0%
United Kingdom											
Birmingham	England	52.45	N	1.73	W	99	3259	753	–6	24	17
Edinburgh	Scotland	55.95	N	3.35	W	41	3526	556	–6	21	16
Glasgow Apt	Scotland	55.87	N	4.43	W	7	3493	578	–6	22	16
London/Heathrow	England	51.48	N	0.45	W	24	2786	1052	–4	26	18
Uruguay											
Montevideo/Carrasco		34.83	S	56.03	W	33	1180	2557	2	30	22
Venezuela											
Caracas/Maiquetia		10.60	N	66.98	W	72	5	6389	21	33	28
Vietnam											
Hanoi/Gialam		21.02	N	105.80	E	8	183	5482	NA	NA	NA
Saigon (Ho Chi Minh)		10.82	N	106.67	E	19	0	6698	20	34	25

(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.

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BLAST
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www.bso.uiuc.edu/BLAST/index.html

DOE-2
Building Energy Simulation news
http://simulationresearch.lbl.gov/un.html

MICA
Midwest Insulation Contractors Association
16712 Elm Circle
Omaha, NE 68130
www.micainsulation.org

The Green Grid Administration
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IWEC Data
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1791 Tullie Circle, NE
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(F) 404-321-5478
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NEBB
National Environmental Balancing Bureau
8575 Grovemont Circle
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www.nebb.org

SMACNA
Sheet Metal & Air Conditioning Contractors' National Association
4201 Lafayette Center Drive
Chantilly, VA 20151
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www.smacna.org

TMY2 Data
National Renewable Energy Laboratory
NREL/RReDC
Attn: Pamela Gray-Hann
1617 Cole Blvd., MS-1612
Golden, Colorado, USA 80401
http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

WYEC2 Data
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(F) 404-321-5478
www.ashrae.org/bookstore

Subsection No.	Reference	Title/Source
3.2 Computer Room Energy	Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011	The Green Grid
3.2 IT Equipment Energy	Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011	The Green Grid
3.2 Power Usage Effectiveness	Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011	The Green Grid
6.4.2	*2013 ASHRAE Handbook—Fundamentals*	ASHRAE
6.4.4.1.1	MICA Insulation Standards—7th Edition	National Commercial and Industrial Insulation Standards
6.4.4.2.1	SMACNA Duct Construction Standards—2005	HVAC Duct Construction Standards, Metal and Flexible
6.4.4.2.2	SMACNA Duct Leakage Test Procedures—2012	HVAC Air Duct Leakage Test Manual Sections 3,5, and 6
6.8.2.3.1	NEBB Procedural Standards—2013	Procedural Standards for Building Systems Commissioning
6.8.2.3.1	AABC 2002	Associated Air Balance Council, National Standards for Total System Balance
6.8.2.3.1	ASHRAE Standard 111-2008	Measurement, Testing, Adjusting and Balancing of Building HVAC Systems
6.8.2.2	ASHRAE Guideline 4-2008 (RA2013)	Preparation of Operating and Maintenance Documentation for Building Systems
6.8.2.4	ASHRAE Guideline 1.1-2007	HVAC&R Technical Requirements for the Commissioning Process
7.4.1 and 7.5	*2011 ASHRAE Handbook—HVAC Applications*	Chapter 49, Service Water Heating/ASHRAE
11.2.1	DOE-2	Support provided by Lawrence Berkeley National Laboratory at the referenced Web site
11.2.1	BLAST	University of Illinois
11.2.2	IWEC	International Weather for Energy Calculations
11.2.2	TMY 2 Data	Typical Meteorological Year
Appendix B	U.S. Climate Zone Map	Briggs, R.S., R.G. Lucas, and Z.T. Taylor. 2003. Climate classification for building energy codes and standards: Part 1-Development process. ASHRAE Transactions 109(1):109-21.

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

INFORMATIVE APPENDIX F
ADDENDA DESCRIPTION INFORMATION

ANSI/ASHRAE/IES Standard 90.1-2013 incorporates all addenda to ANSI/ASHRAE/IES Standard 90.1-2010. The following table lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE, IES, and ANSI approval dates for each addendum.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
bb (formerly Addendum bb to 90.1-2007)	5. Building Envelope; Appendix A	This addenda modifies the building envelope requirements for opaque assemblies and fenestration in tables 5.5.1 through 5.5.8 and the associated text in section 5.5.4.5. It also updates the NFRC 301 reference and modifies two metal building roof assemblies in Table A2.3.	3/23/2012	4/4/2012	3/23/2012	5/11/2012
bz (formerly Addendum bz to 90.1-2007)	6. Heating, Ventilating, and Air Conditioning	This addendum adds a Section 8.4.2 which specifies requirements for installation of basic electrical metering of major end uses (total electrical energy, HVAC Systems, interior lighting, exterior lighting and receptacle circuits) to provide basic reporting of energy consumption data to building occupant.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
cg (formerly Addendum cg to 90.1-2007)	11. Energy Cost Budget; Appendix G	This addenda modifies the simulation requirements for modeling mandatory automatic daylighting controls as well as automatic lighting controls. It also modifies the simulation requirements for automatic lighting controls in the proposed design, beyond the minimum mandatory requirements. Table G3.2 which provided power adjustment percentages for automatic lighting controls has been deleted and savings through automatic control devices are now required to be modeled in building simulation through schedule adjustments for the proposed design.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
ci (formerly Addendum ci to 90.1-2007)	3. Definitions; 11. Energy Cost Budget; Appendix G	This addenda modifies requirements for the cooling tower in Chapter 11, from two-speed to variable speed. A formula has been specified to calculate the condenser water design supply temperature. Similar revisions have been made to Appendix G for the cooling tower requirements. Definitions for cooling design wet-bulb temperature and heating design wet-bulb temperature have been added to Chapter 3.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
cj (formerly Addendum cj to 90.1-2007)	Appendix G	Creates modeling rules for computer rooms in Appendix G	6/26/2012	6/26/2013	6/28/2013	7/24/2013

*These descriptions may not be complete and are provided for information only.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
cm (formerly Addendum cm to 90.1-2007)	5. Building Envelope	The proposed text clarifies how to interpret the use of dynamic glazing products given the requirements in Addendum bb (envelope requirements).	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dm (previously from 2007)	5. Building Envelope	This addenda modifies section 5.4.3.4. for vestibules. It adds a size limit for large buildings, exemptions for semi heated spaces and elevator lobbies in parking garages	1/26/2013	1/29/2013	2/11/2013	2/12/2013
ds (formerly Addendum ds to 90.1-2007)	5. Building Envelope	This addendum corrects the definitions of primary sidelighted area, secondary sidelighted area, and sidelighting effective area to use the term "vertical fenestration" instead of "window" to clarify that glazed doors and other fenestration products are included as well as windows. Additionally, the definition of daylight area under rooftop monitors is corrected to include the spread of light beyond the width of the rooftop monitor glazing.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
a	10. Other Equipment; 12. Normative References	This addendum specifies that nominal efficiencies for motors are required to be established in accordance with DOE 10 CFR 431 instead of NEMA Standards. It modifies the footnotes to Tables 10.8A, 10.8B, 10.8 C.The corresponding reference for 10 CFR 431 has also been added.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
b	10. Other Equipment 12. Normative References	This addendum requires escalators and moving walks to automatically slow when not conveying passengers. The corresponding reference to ASME A17.1/CSA B44 has also been added to the Normative References.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
c	Appendix G	This addendum adds requirements for laboratory exhaust fans to section G3.1.1, Baseline HVAC System Type and Definition. Lab exhaust fans are required to be modeled as constant horsepower, reflecting constant volume stack discharge with outside air bypass.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
e	Appendix G	This addendum updates language in Section G3.1, part 5 'Building Envelope', to require that existing buildings use the same envelope baseline as new buildings with the exception of fenestration area.	6/27/2012	6/27/2012	6/18/2012	7/26/2012
f	Appendix G	This addendum modifies Section G.3.1, Building Envelope. It specifies the vertical fenestration area for calculating baseline building performance for new buildings and additions.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
g	6. Heating, Ventilating, and Air Conditioning; 12. Normative References	This addendum adds efficiency requirements for commercial refrigerators, freezers and refrigeration equipment. Table 6.8.1L and Table 6.8.1M have been added which specify the energy use limits for refrigerators and freezers. The corresponding references have also been added in Chapter 12.	6/25/2011	6/29/2011	6/30/2011	6/30/2011

*These descriptions may not be complete and are provided for information only.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
h	6. Heating, Ventilating, and Air Conditioning	This addendum modifies the minimum efficiency standards for water to air heat pumps (water loop, ground water and ground loop). The proposed cooling EERs and heating COPs are more stringent than the present values. This addendum also removes the small duct high velocity product class from Table 6.8.1B.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
i	6. Heating, Ventilating, and Air Conditioning	This addendum increases the minimum efficiency standards for SPVAC and SPVHP. It also creates a new product class for SPVAC and SPVHP used in space constrained applications. This new product class only applies to non-weatherized products with cooling capacities <36,000 Btu/h and intended to replace an existing AC.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
j	6. Heating, Ventilating, and Air Conditioning	This addendum modifies notes to Table 8.1 and specifies that nominal efficiencies would be established in accordance with the 10 CFR 431 test procedure for low voltage dry-type transformers. The corresponding references have also been added in Chapter 12.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
k	8. Power; 12. Normative References	This addendum modifies notes to Table 8.1 and specifies that nominal efficiencies would be established in accordance with the 10 CFR 431 test procedure for low voltage dry-type transformers. The corresponding references have also been added in Chapter 12.	6/25/2011	6/29/2011	6/30/2011	6/30/2011
l	6. Heating, Ventilating, and Air Conditioning	This addendum fixes the mistake with 90.1-2010 fan power limitations which required the user to perform calculations for fan bhp even if the simplified nameplate hp option was being used.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
m	9. Lighting	This addendum adds some control requirements for lighting alterations, for interior and exterior applications. It adds a section for submittals and includes loading docks as a tradable surface. It modifies the provisions for additional interior lighting power, which would now be calculated on the basis of controlled wattage.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
n	10. Other Equipment	This addendum clarifies that the total lumens/watt for the entire elevator cab is required to meet the efficiency requirement and it is not required for each individual light source.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
o	5. Building Envelope; 3. Definitions	This addendum adds the definition for sectional garage doors. It also modifies Section 5.4.3.2 (d), fenestration air leakage provisions for doors, to include requirements for glazed sectional garage doors.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
p	5. Building Envelope; 12. Normative References	This addendum modifies Section 5.5.3.1 and requires roof solar reflectance and thermal emittance testing to be in accordance with CRRC-1 Standard. It also modifies Section 12 by adding the reference for CRRC.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
q	5. Building Envelope; 3. Definitions; 12. Normative References	This addendum modifies Section 5.8.2.2, by clarifying the requirements for labeling of fenestration and door products. The corresponding references to NFRC in Chapter 12 have also been updated.	6/27/2012	6/27/2012	6/18/2012	6/28/2012

*These descriptions may not be complete and are provided for information only.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
r	12. Normative References; Appendix G	This addendum clarifies the requirements related to temperature and humidity control in Appendix G and relocates all related wording to the Schedules section of Table3.1. Additionally, clarity is provided for modeling systems that provide occupant thermal comfort via means other than other than directly controlling the air dry bulb and wet-bulb temperature (i.e. radiant cooling/heating, elevated air speed, etc.). It permits the use of ASHRAE Standard 55 for calculation of PMV-PPD. This addendum also updates the Normative References by including a reference to ASHRAE Standard 55-2010.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
s	6. Heating, Ventilating, and Air Conditioning	This addendum modifies the requirement for the static pressure sensor location and the control requirements for set point reset for systems with DDC of individual zones. Insures that savings from previously required static pressure reset will be realized.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
u	6. Heating, Ventilating, and Air Conditioning	This addendum adds new definition as Fan Efficiency Grade (FEG) and requires each fan has a FEG of 67 or higher as defined by AMCA205-10 (Energy Efficiency Classification for Fans)	1/26/2013	1/29/2013	2/11/2013	2/12/2013
v	8. Power	This addendum clarifies the requirement for controlled receptacles in open offices. It also requires the automatically controlled receptacles to be appropriately identified for the users benefit.	1/26/2013	1/29/2013	2/11/2013	2/28/2013
w	3. Definitions; 11. Energy Cost Budget Method; Appendix G	This addendum adds definitions for on-site renewable energy and purchased energy. It clarifies the process for accounting for on-site renewable energy and purchased energy as well as calculating the annual energy costs in the ECB approach and Appendix G.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
y	3. Definitions 10. Other Equipment	This addendum revises the definitions of general purpose electric motors (subtype I &II) based on information from NEMA. It also updates the standard to include the new federal energy efficiency standards used in HVAC equipment, to be in effect from 2015. It adds Table 10.8D which specifies minimum average full-load efficiency for Polyphase Small Electric Motors; and Table 10.8E which specifies minimum average full-load efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run Small Electric Motors.	1/21/2012	1/23/2012	1/18/2012	1/26/2012
z	6. Heating, Ventilating, and Air Conditioning	This addendum relocates the requirements for water economizers into the main economizer section, Section 6.5.1.5.	1/21/2012	1/23/2012	1/18/2012	1/26/2012

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
aa	6. Heating, Ventilating, and Air Conditioning	Prior to this addendum certain controls requirements were only required when the controls were provided by a DDC system. This addendum eliminates that contingency for set point overlap restrictions, humidification and dehumidification controls, VAV fan control set point reset, multiple-zone VAV system ventilation optimization control, hydronic system design and control, and instead specifies how the system must perform. This will in effect require DDC for systems where these controls are needed.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
ad	12. Normative References	Adds reference to specific addenda to AHRI standards 340/360 and 130 being referenced	6/27/2012	6/27/2012	6/18/2012	6/28/2012
ae	12. Normative References	Adds reference to specific addenda to AHRI standards 210/240 and 550/590 being referenced	7/26/2013	7/30/2013	7/29/2013	8/28/2013
af	6. Heating, Ventilating, and Air Conditioning	Modifies heat rejection equipment (cooling tower) requirements to require VSDs on fans, operate all fans at the same speed instead of sequencing them, and require that systems with multiple condenser water pumps operate those pumps in parallel at reduced flow.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
ag	Appendix G	Establishes a method for gaining credit in Appendix G for buildings that undergo whole building air leakage testing to demonstrate that they have an air-tight building.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ah	Appendix G	Sets system sizing requirements in appendix G for humid climates based on humidity ratio instead of SA delta T. Sets baseline system dehumidification requirements.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
ai	Appendix G	Modifies Appendix G to account for 3 prescriptive addenda that were incorporated in to standard 90.1-2010, but did not make it into Appendix G in time for publication. Updates economizer requirements to match addendum cy, establishes baseline transformer efficiency requirements to match addendum o, and establishes path A for centrifugal chiller baselines from addendum m.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
aj	6. Heating, Ventilating, and Air Conditioning	Requires fractional horsepower motors >= 1/22 hp to EC motors or minimum 70% efficient in accordance with DOE 10 CFR 431. Also requires adjustable speed or other method to balance airflow.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
al	Appendix G	Establishes a consistent fuel source for space heating for baseline systems based on climate zone. Establishes a consistent fuel source for service water heating based on building type.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
am	6. Heating, Ventilating, and Air Conditioning	Establishes minimum turndown for boilers and boiler plants with of at least 1,000,000 Btu/h.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
an	Appendix C	Rewrites entire Appendix C to use a simulation based approach for envelope trade-offs.	7/26/2013	7/30/2013	7/29/2013	8/28/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
ap	6. Heating, Ventilating, and Air Conditioning	Adds Power Utilization Effectiveness (PUE) as an alternative compliance methodology for data centers.	1/26/2013	1/29/2013	2/11/2013	5/3/2013
aq	6. Heating, Ventilating, and Air Conditioning; 11. Energy Cost Budget	This addendum makes changes to the requirements for fan control for both constant volume and VAV units including extending the fan part load power requirements down to ¼ HP In addition it defines the requirements for integrated economizer control and defines DX unit capacity staging requirements	6/26/2013	6/26/2013	6/28/2013	7/1/2013
ar	6. Heating, Ventilating, and Air Conditioning	Adds mandatory and prescriptive requirements for walk-in coolers and freezers and refrigerated display cases.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
as	6. Heating, Ventilating, and Air Conditioning	Avoidance of simultaneous heating and cooling at AHU. Requires humidifiers mounted in the airstream to have an automatic control valve shutting off preheat when humidification is not required, and insulation on the humidification system dispersion tube surface.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
at	3. Definitions; 5. Building Envelope; 9. Lighting	Deletes the term clerestory and instead adds roof monitor and clarifies the definition. Changes the references in Chapters 5 and 9 from clerestory to roof monitor.	6/27/2012	6/27/2012	6/18/2012	6/28/2012
au	6. Heating, Ventilating, and Air Conditioning	This addendum modifies Table 6.5.3.1.1B which addresses fan power limitation pressure drop adjustment credits. Deductions are added for systems without any central heating or cooling as well as systems with electric resistance heating. Sound attenuation credit is modified to be available only when there are background noise criteria requirements.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
av	6. Heating, Ventilating, and Air Conditioning	This addendum modifies Section 6.5.1, exception k, applicable to Tier IV data centers, in an attempt to make economizer exceptions more strict and in agreement with ASHRAE TC 9.9	6/26/2013	6/26/2013	6/28/2013	7/24/2013
aw	11. Energy Cost Budget; Appendix G	This addendum updates the reference year for ASHRAE Standard 140 and exempts software used for ECB and Appendix G compliance from having to meet certain sections of ASHRAE Standard 140	1/26/2013	1/29/2013	2/11/2013	2/12/2013
ax	Appendix G	Table G3.1 Part 14 of Appendix G is modified to exclude the condition which permits a building surface, shaded by an adjacent structure, to be simulated as north facing if the simulation program is incapable of simulating shading by adjacent structures.	6/26/2013	6/26/2013	6/28/2013	7/1/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
ay	3. Definitions; 9. Lighting	This addenda modifies daylighting requirements. It modifies definitions for daylight area under skylights, daylight area under roof monitors, primary sidelight area, secondary sidelight area. It modifies the thresholds for applying automatic daylighting control for sidelighting and toplighting, to a wattage basis and provides characteristics for the required photo controls. It modifies Table 9.6.2 to include continuous dimming in secondary sidelighted areas, which is now based on a W level rather than area of the space. It eliminates the need for effective aperture calculation.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
az	6. Heating, Ventilating, and Air Conditioning	This addendum increases the minimum efficiency of open circuit axial fan cooling towers. An additional requirement has been added which states that the minimum efficiency requirements for all types of cooling towers also applies to accessories which affect the thermal performance of the unit. An additional footnote clarifies that the certification requirements do not apply to field erected cooling towers.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
ba	6. Heating, Ventilating, and Air Conditioning	Adds requirements for door switches to disable or reset mechanical heating or cooling when doors are left open.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
bc	9. Lighting	Modifies requirements for automatic lighting control for guestroom type spaces. Exception to this requirement are lighting and switched receptacles controlled by captive key systems.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
bd	9. Lighting	This addenda adds more specific requirements for the functional testing of lighting controls, specifically, occupancy sensors, automatic time switches and daylight controls.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
be	9. Lighting	Minor revisions to Section 9.7.2.2, which addresses the scope of the operating and maintenance manuals required for lighting equipment and controls.	1/26/2013	1/29/2013	2/11/2013	2/12/2013
bf	8. Power	This addenda addresses Section 8.4.2 on automatic receptacle control and increases the spaces where plug shutoff control is required. It also clarifies the application of this requirement for furniture systems, states a labeling requirement to distinguish controlled and uncontrolled receptacles and restricts the use of plug-in devices to comply with this requirement.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
bg	5. Building Envelope	Requirements for low E storm window retrofits.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bh	9. Lighting	Modifies Table 9.6.1 Space-By-Space Lighting Power Density allowance	7/26/2013	7/30/2013	8/12/2013	9/4/2013
bi	6. Heating, Ventilating, and Air Conditioning	Increase SEER and HSPF for air-cooled commercial air conditioners and heat pumps below 65,000 Btu/h. Effective 1/1/2015	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bj	6. Heating, Ventilating, and Air Conditioning	Re-establishes the product class for Small Duct High Velocity (SDHV) air conditioners and heart pumps. Adds efficiency requirements for systems at <65.000 Btuh	6/26/2013	6/26/2013	6/28/2013	7/1/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
bk	6. Heating, Ventilating, and Air Conditioning	Increases cooling efficiency for PTACs	1/26/2013	1/29/2013	2/11/2013	2/12/2013
bl	11. Energy Cost Budget; Appendix G	Provide rules for removing fan energy from efficiency metrics when modeling in ECB or Appendix G.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
bn	8. Power; 10. Other Equipment	Establishes electric and fuel metering requirements	7/26/2013	7/30/2013	7/29/2013	9/4/2013
bo	6. Heating, Ventilating, and Air Conditioning	Requires buildings with SW capacity >= 1million but/h to have average efficiency of at least 90%. Updates Table 7.8 to reflect federal requirements for electric water heaters. Updates the reference standard for swimming pool water heaters to ASHRAE Standard 146.	7/26/2013	7/30/2013	7/29/2013	9/4/2013
bp	6. Heating, Ventilating, and Air Conditioning	Adds efficiency requirements (Btu/h-hp) to Table 6.8.1G for evaporative condensers with ammonia refrigerants	7/26/2013	7/30/2013	7/29/2013	7/31/2013
bq	6. Heating, Ventilating, and Air Conditioning	Improve efficiency of commercial refrigeration systems	1/26/2013	1/29/2013	2/11/2013	2/12/2013
br	10. Other Equipment	Updates motor efficiency tables	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bs	6. Heating, Ventilating, and Air Conditioning	Reduce occupancy threshold for demand controlled ventilation from greater than 40 people per 1000 ft2 to equal to or greater than 25 people per 1000 ft2 with exemptions for certain occupancies.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
bt	6. Heating, Ventilating, and Air Conditioning	Reduces the threshold at which energy recovery is required. Relaxed in some climate zones.	6/26/2013	6/26/2013	6/28/2013	7/24/2013
bv	9. Lighting	Reduces the threshold at which skylights and daylighting controls are required for high bay spaces.	6/26/2013	6/26/2013	6/28/2013	7/1/2013
bw	5. Building Envelope	Modifies orientation requirements and adds SHGC tradeoff	7/26/2013	7/30/2013	7/29/2013	8/28/2013
bx	9. Lighting	Clarification of exceptions to occupancy sensor requirements	1/26/2013	1/29/2013	2/11/2013	2/12/2013
by	9. Lighting	Improves and enhances lighting controls requirements. Establishes table of lighting controls applicable to each space type. Corrects daylighting threshold.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ca	5. Building Envelope	Adds control requirements for heating systems in vestibules	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cb	6. Heating, Ventilating, and Air Conditioning	This addendum requires night setback 10F heating & 5F cooling and removes exception for systems less than 10,000 cfm min for optimum start	7/26/2013	7/30/2013	7/29/2013	8/28/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
cc	6. Heating, Ventilating, and Air Conditioning	Adds efficiency requirements (Btu/h-hp) to Table 6.8.1G for evaporative condensers with R-507A	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cd	6. Heating, Ventilating, and Air Conditioning	Provides definition for piping to include all accessories in series with pipe such as pumps, valves, strainers, air separators, etc. This is meant to clarify that these accessories need to be insulated.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ce	Appendix G	Establishes a baseline system type for retail occupancies less than 3 stories in Appendix G	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cf	Appendix G	Establishes baseline WWR in Appendix G for strip malls.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
ch	6. Heating, Ventilating, and Air Conditioning	Improved air and water cooled chiller efficiencies in Table 6.8.1C. Exempts water cooled positive displacement chillers with leaving condenser temperature >= 115 deg.F. (typically heat reclaim chillers).	6/26/2013	2/26/2013	6/28/2013	7/1/2013
ck	6. Heating, Ventilating, and Air Conditioning	Requires VAV dual maximum damper position when DDC system is present	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cl	6. Heating, Ventilating, and Air Conditioning	Table 6.8.1A and B. Improves IEER requirements for air-cooled air conditioners and heat pumps and EER requirements for water and evaporatively-cooled air-conditioners and heat pumps.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cn	Appendix G	Establishes modeling rules for laboratories with 100% OA in Appendix G	6/26/2013	6/26/2013	6/28/2013	7/1/2013
co	9. Lighting	Comprehensive update of LPDs in Table 9.5.1 - Building Area Method	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cp	5. Building Envelope	Corrects non-residential U-factor and R-value requirements for steel joist floors in CZ3	6/26/2013	6/26/2013	6/28/2013	7/1/2013
cr	9. Lighting	Makes a number of adjustments to Table 9.6.1 Space-by-space LPD	7/26/2013	7/30/2013	7/29/2013	7/31/2013
ct	Appendix G	Identifies heated only storage systems 9 and 10 in Appendix G as being assigned one system per thermal zone.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cv	Appendix G	Establishes baseline system types in Appendix G for Assembly occupancies.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cy	6. Heating, Ventilating, and Air Conditioning	More stringent energy recovery for 24/7 occupancies	7/26/2013	7/30/2013	7/29/2013	7/31/2013
cz	6. Heating, Ventilating, and Air Conditioning	Increases boiler efficiency for residential sized (NAECA covered) equipment, <3,000 Btu/h	7/26/2013	7/30/2013	7/29/2013	7/31/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
da	5. Building Envelope	Relaxes air leakage requirements for high-speed doors for vehicle access and material transport	7/26/2013	7/30/2013	7/29/2013	8/28/2013
db	5. Building Envelope	Corrects residential U-factor and R-value requirements for steel joist floors in CZ3	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dc	9. Lighting	Clarifies automatic lighting and switched receptacle control in guest rooms as applied to individual spaces.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dd	5. Building Envelope	Clarifies roof insulation requirements, differentiating between roof recovering (on top of existing roof covering) and replacement of roof covering.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
de	6. Heating, Ventilating, and Air Conditioning	Relaxes design requirements for waterside economizers for computer rooms	7/26/2013	7/302013	7/29/2013	7/31/2013
dg	5. Building Envelope	Updates reference to ANSI/CRRC-l Standard 2012 (cool roof ratings)	7/26/2013	7/30/2013	7/29/2013	7/31/2013
di	6. Heating, Ventilating, and Air Conditioning	Establishes limits on using electric or fossil fuel to humidify or dehumidify between 30% & 60% RH except certain applications. Requires deadband on humidity controls.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dj	9. Lighting	Additional lighting power allowance for electrical/mechanical rooms provided there is separate control for additional lighting.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dk	9. Lighting	Eliminates the exemption for wattage used in spaces where lighting is specifically designed for those with age-related eye conditions or other medical conditions related to the eye, where special lighting or light levels might be needed.	7/26/2013	7/30/2013	7/29/2013	8/28/2013
dl	9. Lighting	Modifies hotel and motel guest room lighting power density	7/26/2013	7/30/2013	7/29/2013	8/28/2013
dn	6. Heating, Ventilating, and Air Conditioning	Reduces the limits on hot gas bypass as a means of cooling capacity control.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
do	6. Heating, Ventilating, and Air Conditioning	Update references to AHRI 550, AMCA 500, ANSI Z21.10.3 & Z21.47, ASHRAE 90.1 & 62.1, NEMA MG 1, & NFPA 70 &96	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dp	6. Heating, Ventilating, and Air Conditioning	Corrects the definition of walk-in-cooler to be consistent with federal requirements.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dq	6. Heating, Ventilating, and Air Conditioning	Deletes sizing requirements for pipes >24 in.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dr	5. Building Envelope	Clarifies definition of building entrances to exclude electrical room, mechanical rooms, and other utility service entrances.	7/26/2013	7/30/2013	7/29/2013	7/31/2013

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TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
dt	9. Lighting	Added exceptions for control of exterior lighting integral to signage. Requires certain types of exterior lighting exempt from LPD requirements to be separately controlled.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dv	6. Heating, Ventilating, and Air Conditioning	Establishes chiller and boiler fluid flow isolation requirements so there is no flow through the equipment when not in use.	7/26/2013	7/30/2013	7/29/2013	7/31/2013
dw	6. Heating, Ventilating, and Air Conditioning	Revises high limit shutoff for air economizers. Add sensor accuracy requirements.	7/26/2013	7/30/2013	7/29/2013	7/31/2013

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NOTE

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

(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 building performance rating method is a modification of the Energy Cost Budget (ECB) Method in Section 11 and is intended for use in rating the energy efficiency of building designs that exceed the requirements of this standard. This appendix does NOT offer an alternative compliance path for minimum standard compliance; that is the intent of Section 11, Energy Cost Budget Method. Rather, this appendix is provided for those wishing to use the methodology developed for this standard to quantify performance that substantially exceeds the requirements of Standard 90.1. It shall be used for evaluating the performance of all such proposed designs, including alterations and additions to existing buildings, except designs with no mechanical systems.

G1.2 Performance Rating. This performance rating method requires conformance with the following provisions:

All requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met. These sections contain the mandatory provisions of the standard and are prerequisites for this rating method. The improved performance of the proposed building design is calculated in accordance with provisions of this appendix using the following formula:

Percentage improvement
= 100 × (Baseline building performance
– Proposed building performance) / Baseline building performance

Informative Notes:

1. Both the proposed building performance and the baseline building performance shall include all end-use load components, such as receptacle and process loads.
2. 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 Trade-Off Limits. When the proposed modifications apply to less than the whole building, only parameters related to the systems to be modified shall be allowed to vary. Parameters relating to unmodified existing conditions or to future building components shall be identical for determining both the baseline building performance and the proposed building performance. Future building components shall meet the prescriptive requirements of Sections 5.5, 6.5, 7.5, 9.5, and 9.6.

G1.4 Documentation Requirements. Simulated performance shall be documented, and documentation shall be submitted to the rating authority. The information shall be submitted in a report and shall include the following:

a. A brief description of the project, the key energy efficiency improvements, 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 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 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 which 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 envelope assemblies, NFRC ratings for fenestration, end-uses identified in 1. Design Model, paragraph [a], in Table G3.1).
l. Input and output report(s) from the simulation program or compliance software 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 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 method(s) employed, document the predicted energy savings by energy type, the energy cost savings, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.
p. The reduction in proposed building performance associated with on-site renewable energy.

G2. SIMULATION GENERAL REQUIREMENTS

G2.1 Performance Calculations. The proposed building performance and baseline building performance shall be calculated using the following:

a. the same simulation program
b. the same weather data
c. the same energy rates

G2.2 Simulation Program. The simulation program shall be a computer-based program for the analysis of energy consumption in buildings (a program such as, but not limited to, DOE-2, BLAST, or EnergyPlus). The simulation program shall include calculation methodologies for the building components being modeled. For components that cannot be modeled by the simulation program, the exceptional calculation methods requirements in Section G2.5 shall be used.

G2.2.1 The simulation program shall be approved by the rating authority and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year
b. hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, 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 cooling equipment
g. air-side economizers with integrated control
h. baseline building design characteristics specified in Section G3

G2.2.2 The simulation program shall have the ability to either (1) directly determine the proposed building performance and baseline building performance or (2) produce hourly reports of energy use by an energy source suitable for determining the proposed building performance and baseline building performance using a separate calculation engine.

G2.2.3 The simulation program shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with generally accepted engineering standards and handbooks (for example, *ASHRAE Handbook—Fundamentals*) for both the proposed design and baseline building design.

G2.2.4 The simulation program shall be tested according to ASHRAE Standard 140, except Sections 7 and 8, and the results shall be furnished by the software provider.

G2.3 Climatic Data. The simulation program shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the proposed design is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site. The selected weather data shall be approved by the rating authority.

G2.4 Renewable, Recovered, and Purchased Energy

G2.4.1 On-Site Renewable Energy and Site-Recovered Energy. Site-recovered energy shall not be considered purchased energy and shall be subtracted from the proposed design energy consumption prior to calculating the proposed building performance. On-site renewable energy generated by systems included on the building permit that is used by the building shall be subtracted from the proposed design energy consumption prior to calculating the proposed building performance.

G2.4.2 Annual Energy Costs. The design energy cost and baseline energy cost shall be determined using either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration (EIA) for commercial building customers, but rates from different sources may not be mixed in the same project. Where on-site renewable energy or site-recovered energy is used, the baseline building design shall be based on the energy source used as the backup energy source or the baseline system energy source in that category if no backup energy source has been specified.

Informative Note: The above provision allows users to gain credit for features that yield load management benefits. Where such features are not present, users can simply use state average unit prices from EIA, which are updated annually and readily available on EIA's web site (http://www.eia.doe.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 if approved by the Rating Authority. If 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:

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 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 be based on usage, number of floors, conditioned floor area, and climate

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 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 using Baseline System types 9 and 10 shall not be simulated with mechanical cooling. c. When the performance rating method is applied to buildings in which energy-related features have not yet been designed (e.g., a lighting system), those yet-to-be-designed features shall be described in the proposed design exactly as they are defined in the baseline building design. Where the space classification for a space is not known, the space shall be categorized as an office space.	The baseline building design shall be modeled with the same number of floors and identical conditioned floor area as the proposed design.
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 setpoints 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.	Same as proposed building design
3. Space Use Classification	
Usage shall be specified using the building type or space type lighting classifications in accordance with Section 9.5.1 or 9.6.1. The user shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories. More than one building type category may be used in a building if it is a mixed-use facility. If space type categories are used, the user may simplify the placement of the various space types within the building model, provided that building-total areas for each space type are accurate.	Same as proposed building design

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

No. Proposed Building Performance	Baseline Building Performance
4. Schedules	
Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, 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 setpoints and schedules as well as temperature control throttling range shall be the same for proposed and baseline building designs. **HVAC Fan Schedules.** Schedules for HVAC fans that provide outdoor air for ventilation shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours. **Exceptions:** 1. Where no heating and/or cooling system is to be installed, and a heating or cooling system is being simulated only to meet the requirements described in this table, heating and/or cooling system fans shall not be simulated as running continuously during occupied hours but shall be cycled on and off to meet heating and cooling loads during all hours. 2. HVAC fans shall remain on during occupied and unoccupied hours in spaces that have health- and safety-mandated minimum ventilation requirements during unoccupied hours. 3. HVAC fans shall remain on during occupied and unoccupied hours in systems primarily serving computer rooms.	Same as proposed building design **Exceptions:** 1. Setpoints 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 Section 5.2.3 of ASHRAE Standard 55, "Elevated Air Speed," or Appendix D of Standard 55, "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 the approval of the rating authority. Measures that may warrant use of different schedules include, but are not limited to, automatic lighting controls, automatic natural ventilation controls, automatic demand control ventilation controls, and automatic controls that reduce service water heating loads. In no case shall schedules differ where the controls are manual (e.g., manual operation of light switches or manual operation of windows).
5. Building Envelope	
a. All components of the building envelope in the proposed design shall be modeled as shown on architectural drawings or as built for existing building envelopes. **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 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 an 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. 3. The exterior roof surface shall be modeled using the aged solar reflectance and thermal emittance determined in accordance with Section 5.5.3.1.1(a). Where aged test data are unavailable, the roof surface may be modeled with a reflectance of 0.30 and a thermal emittance of 0.90.	Equivalent dimensions shall be assumed for each exterior envelope component type as in the proposed design; i.e., the total gross area of exterior walls shall be the same in the proposed and baseline building designs. 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 and baseline building designs. 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 program evaluator 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 the following common, lightweight assembly types and shall match the appropriate assembly maximum U-factors in Tables 5.5-1 through 5.5-8: • Roofs—Insulation entirely above deck • Above-grade walls—Steel framed • Floors—Steel joist • Opaque door types shall match the proposed design and conform to the U-factor requirements from the same tables. • Slab-on-grade floors shall match the F-factor for unheated slabs from the same tables. *(Continued on next page)*

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

No. Proposed Building Performance	Baseline Building Performance
5. Building Envelope (Cont.)	
4. Manual fenestration shading devices, such as blinds or shades, shall be modeled or not modeled, the same as in the baseline. Automatically controlled fenestration shades or blinds shall be modeled. Permanent shading devices, such as fins, overhangs, and light shelves, shall be modeled. 5. Automatically controlled dynamic glazing may be modeled. Manually controlled dynamic glazing shall use the average of the minimum and maximum SHGC and VT. b. Infiltration shall be modeled using the same methodology, air leakage rate, and adjustments for weather and building operation in both the proposed design and the baseline 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 75 Pa shall be 2.03 L/s·m^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. **Exception:** When whole-building air leakage testing, in accordance with ASTM E779, is specified during design and completed after construction, the proposed design air leakage rate of the building envelope shall be as measured.	c. **Vertical Fenestration Areas.** For building area types included in Table G3.1.1-1, vertical fenestration areas for new buildings and additions shall equal that in Table G3.1.1-1 based on gross above-grade exterior wall area. 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 the maximum allowed in Tables 5.5-1 through 5.5-8, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the proposed design. The fenestration area for an existing building shall equal the existing fenestration area prior to the proposed work and shall be distributed on each face of the building in the same proportions as the existing building. For portions of those tables where there are no SHGC requirements, the SHGC shall be equal to that determined in accordance with Section C3.6(c). The VT shall be equal to that determined in accordance with Section C3.6(c). d. **Vertical Fenestration Assemblies.** Fenestration for new buildings, existing buildings, and additions shall comply with the following: • Fenestration U-factors shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. • Fenestration SHGCs shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. • 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 building design or the maximum allowed in Tables 5.5-1 through 5.5-8, whichever is smaller. If the skylight area of the proposed building design is greater than the maximum area allowed in Tables 5.5-1 through 5.5-8, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the maximum allowed in Tables 5.5-1 through 5.5-8. Skylight orientation and tilt shall be the same as in the proposed building design. Skylight U-factor and SHGC properties shall match the appropriate requirements in s 5.5-1 through 5.5-8. f. **Roof Solar Reflectance and Thermal Emittance.** 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 using a solar reflectance of 0.30 and a thermal emittance of 0.90. g. **Roof Albedo.** All roof surfaces shall be modeled with a reflectivity of 0.30.

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

<table>
<tr><th>No.</th><th>Proposed Building Performance</th><th>Baseline Building Performance</th></tr>
<tr><td colspan="2">6. Lighting</td><td></td></tr>
<tr><td colspan="2">Lighting power in the proposed design shall be determined as follows:
a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model.
b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4.
c. Where lighting neither exists nor is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type.
d. Lighting system power shall include all lighting system components shown or provided for on the plans (including lamps and ballasts and task and furniture-mounted fixtures).
Exception: For multifamily dwelling units, hotel/motel guest rooms, and other spaces in which lighting systems are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for the proposed and baseline building designs in the simulations.
e. Lighting power for parking garages and building facades shall be modeled.
f. The lighting schedules in the proposed building design shall reflect the mandatory automatic lighting control requirements in Section 9.4.1 (e.g., programmable controls or occupancy sensors).
Exception: Automatic daylighting controls required by Section 9.4.1 shall be modeled directly in the proposed building design or through schedule adjustments determined by a separate daylighting analysis approved by the rating authority.
g. Automatic lighting controls included in the proposed building design but not required by Section 9.4.1 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. As an alternative to modeling such lighting controls, the proposed building design lighting power may be reduced by the sum of all additional allowances per Section 9.6.2(c) and Table 9.6.2, which are calculated individually as the lighting power under control multiplied by cf, where cf is the appropriate control factor given in Table 9.6.2 corresponding to the space type and the lighting controls designed to be used.</td><td>a. Lighting power in the baseline building design shall be determined using the same categorization procedure (Building Area Method or Space-by-Space Method) and categories 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 9.6.2(c) shall not be included in the baseline building design.
b. Mandatory automatic lighting controls required by Section 9.4.1 shall be modeled the same as the proposed building design.</td></tr>
<tr><td colspan="2">7. Thermal Blocks—HVAC Zones Designed</td><td></td></tr>
<tr><td colspan="2">Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate thermal block.
Exception: Different HVAC zones may be combined to create a single thermal block or identical thermal blocks to which multipliers are applied, provided that all of the following conditions are met:
1. The space use classification is the same throughout the thermal block.
2. All HVAC zones in the thermal block that are adjacent to glazed exterior walls 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.</td><td>Same as proposed building design</td></tr>
</table>

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 5 m from an exterior wall. Perimeter spaces shall be those located within 5 m of an exterior wall. b. Separate thermal blocks shall be assumed for spaces adjacent to glazed exterior 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 5 m or less from a glazed perimeter wall, except that floor area within 5 m 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 building 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 building 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, 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 building. The proposed building 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 specified, the system characteristics shall be identical to the system modeled in the baseline building design. d. Where no cooling system exists or no cooling system has been specified, the cooling system shall be identical to the system modeled in the baseline building design. **Exception to (d):** Spaces using baseline HVAC system types 9 and 10.	The HVAC system(s) 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 type(s). If the proposed design includes computer room humidification then the computer room humidification system, schedules, and setpoints in the baseline building design shall be the same as in the proposed design. For systems serving computer rooms, the baseline shall not have reheat for the purpose of dehumidification. Fossil fuel systems shall be modeled using natural gas as their fuel source. **Exception:** For fossil fuel systems where natural gas is not available for the proposed building site as determined by the rating authority, the baseline HVAC system(s) shall be modeled using propane as their fuel source.

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

No. Proposed Building Performance	Baseline Building Performance
11. Service Hot-Water Systems	
The service hot-water 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 hot-water system exists, the proposed design shall reflect the actual system type using actual component capacities and efficiencies. b. Where a service hot-water system has been specified, the service hot-water model shall be consistent with design documents. c. Where no service hot-water system exists or has been specified but the building will have service hot-water loads, a service hot-water system shall be modeled that matches the system in the baseline building design and serves the same hot-water loads. d. For buildings that will have no service hot-water loads, no service hot-water 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.	The service hot-water system in the baseline building design shall conform with the following conditions: a. Where the complete service hot-water system exists, the baseline building design shall be as specified in Table G3.1.1-2 using the actual component capacities. b. Where a new service hot-water system has been specified, the heating method shall be as specified in Table G3.1.1-2. The 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. c. Where no service hot-water system exists or has been specified but the building will have service hot-water loads, a service water system(s) using the heating method as specified in Table G3.1.1-2 and matching minimum efficiency requirements of Section 7.4.2 shall be assumed and modeled identically in the proposed and baseline building designs. d. For buildings that will have no service hot-water loads, no service hot-water heating shall be modeled. e. Where a combined system has been specified to meet both space heating and service water heating loads, the baseline building system shall use separate systems meeting the minimum efficiency requirements applicable to each system individually. f. For large, 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.5.6.2, a system meeting the requirements of that section shall be included in the baseline building design regardless of the exceptions to Section 6.5.6.2. **Exception:** If a condenser heat recovery system meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with Section 6.5.6.2, and no heat-recovery system shall be included in the proposed or baseline building designs. g. Service hot-water energy consumption shall be calculated explicitly based upon the volume of service hot water required and the entering makeup water and the leaving service hot-water temperatures. Entering water temperatures shall be estimated based upon the location. Leaving temperatures shall be based upon the end-use requirements. h. Where recirculation pumps are used to ensure prompt availability of service hot water at the end use, the energy consumption of such pumps shall be calculated explicitly. *(Continued on next page)*

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

<table>
<tr><th>No. Proposed Building Performance</th><th>Baseline Building Performance</th></tr>
<tr><td>11. Service Hot-Water Systems (cont.)</td><td></td></tr>
<tr><td></td><td>i. Service water loads and usage shall be the same for both the baseline building design and the proposed design and shall be documented by the calculation procedures described in Section 7.2.1.
Exceptions:
1. Service hot-water usage can be demonstrated to be reduced by documented water conservation measures that reduce the physical volume of service water required. Examples include low-flow shower heads. Such reduction shall be demonstrated by calculations.
2. Service hot-water energy consumption can be demonstrated to be reduced by reducing the required temperature of service mixed water, by increasing the temperature, or by increasing the temperature of the entering makeup water. Examples include alternative sanitizing technologies for dishwashing and heat recovery to entering makeup water. Such reduction shall be demonstrated by calculations.
3. Service hot-water usage 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.
j. Gas storage water heaters shall be modeled using natural gas as their fuel source.
Exception: 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 source.</td></tr>
<tr><td>12. Receptacle and Other Loads</td><td></td></tr>
<tr><td>Receptacle and process loads, such as those for office and other equipment, shall be estimated based on the building type or space type category and shall be assumed to be identical in the proposed and baseline building designs, except as specifically authorized by the rating authority. These loads shall be included in simulations of the building and shall be included when calculating the baseline building performance and proposed building performance.</td><td>Other systems, such as motors 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. Where there are specific efficiency requirements listed in Sections 5 through 10, these systems or components shall be modeled as having the lowest efficiency allowed by those requirements.Where no efficiency requirements exist, power and energy rating or capacity of the equipment shall be identical between the baseline building and the proposed design with the following exception: variations of the power requirements, schedules, or control sequences of the equipment modeled in the baseline building from those in the proposed design shall be allowed by the rating authority based upon documentation that the equipment installed in the proposed design represents a significant verifiable departure from documented 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.</td></tr>
<tr><td>13. Modeling Limitations to the Simulation Program</td><td></td></tr>
<tr><td>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.</td><td>Same as proposed building design</td></tr>
</table>

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

No. Proposed Building Performance	Baseline Building Performance
14. Exterior Conditions	
a. **Shading by Adjacent Structures and Terrain.** The effect that structures and significant vegetation or topographical features have on the amount of solar radiation being received by a structure shall be adequately reflected in the computer analysis. All elements whose effective height is greater than their distance from a proposed building and whose width facing the proposed building is greater than one-third that of the proposed building shall be accounted for in the analysis. b. **Ground Temperatures for Below-Grade Wall and Basement Floor Heat-Loss Calculations.** It is acceptable to use either an annual average ground temperature or monthly average ground temperatures for calculation of heat loss through below-grade walls and basement floors. c. **Water Main Temperatures for Service Water Heating Calculations.** It is acceptable to use either an annual water main supply temperature or monthly average water main supply temperatures for calculating service water heating. If annual or monthly water main supply temperatures are not available from the local water utility, annual average ground temperatures may be used.	Same as proposed building 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 building transformers exceed the efficiency requirements of Table 8.4.4. If modeled, the efficiency requirements from Table 8.4.4 shall be used. The ratio of the capacity to peak electrical load of the transformer shall be the same as the ratio in the proposed design.

TABLE G3.1.1-1 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 (≤465 m^2)	19%
Office (465 to 4650 m^2)	31%
Office (>4650 m^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%

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.

TABLE G3.1.1-2 Baseline Service Hot-Water System

Building Area Type	Baseline Heating Method
Automotive facility	Gas storage 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
Gymnasium	Gas storage water heater
Health-care clinic	Gas storage water heater
Hospital	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 building	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	Gas storage water heater
All Others	Gas storage water heater

zone as specified in Table G3.1.1-3 and 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.

Exceptions:

1. Use additional system type(s) for nonpredominant conditions (i.e., residential/nonresidential or heating source) if those conditions apply to more than 1900 m^2 of conditioned floor area.
2. If the baseline HVAC system type is 5, 6, 7, 8, 9, 10, 11, 12, or 13 use separate single-zone systems conforming with the requirements of System 3 or System 4 (depending on building heating source) for any spaces that have occupancy or process loads or schedules that differ significantly from the rest of the building. Peak thermal loads that differ by 31.2 W/m^2 or more from the average of other spaces served by the system or schedules that differ by more than 40 equivalent full-load hours per week from other spaces served by the system are considered to differ significantly. Examples where this exception may be applicable include, but are not limited to, natatoriums and continually occupied security areas. This exception does not apply to computer rooms.
3. For laboratory spaces in a building having a total laboratory exhaust rate greater than 2400 L/s, use a single system of type 5 or 7 serving only those spaces. The lab exhaust fan shall be modeled as constant horsepower reflecting constant-volume stack discharge with outdoor air bypass.
4. For kitchens with a total exhaust hood airflow rate greater than 2400 L/s, use system type 5 or 7 with 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 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 6.5.7.1.3 for the numbers and types of hoods and appliances provided for the in the proposed design.
5. 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.
6. If the baseline HVAC system type is 9 or 10, all spaces that are mechanically cooled in the proposed building design shall be assigned to a separate baseline system determined by using the area and heating source of the mechanically cooled spaces.
7. Computer rooms in buildings with a total computer room peak cooling load >590 kW or a total computer room peak cooling load >175 kW where the baseline HVAC system type is 7 or 8 shall use System 11. All other computer rooms shall use System 3 or 4.
8. For hospitals, depending on building type, use System 5 or 7 in all climate zones.

TABLE G3.1.1-3 Baseline HVAC System Types

Building Type	Climate Zones 3b, 3c, and 4–8	Climate Zones 1–3a
Residential	System 1—PTAC	System 2—PTHP
Public assembly <11.148 m^2	System 3—PSZ-AC	System 4—PSZ-HP
Public assembly ≥11.148 m^2	System 12—SZ-CV-HW	System 13—SZ-CV-ER
Nonresidential and 3 floors or fewer and <2300 m^2	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <2300 m^2 or 5 floors or fewer and 2300 m^2 to 14,000 m^2	System 5—Packaged VAV with reheat	System 6—Packaged VAV with PFP boxes
Nonresidential and more than 5 floors or >14,000 m^2	System 7—VAV with reheat	System 8—VAV with PFP boxes
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

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 Exception (1) to Section G3.1.1.
3. For laboratory spaces in a building having a total laboratory exhaust rate greater than 2400 L/s, use a single system of type 5 or 7 serving only those spaces.
4. For hospitals, depending on building type, use System 5 or 7 in all climate zones.
5. Public assembly building types include houses of worship, auditoriums, movie theaters, performance theaters, concert halls, arenas, enclosed stadiums, ice rinks, gymnasiums, convention centers, exhibition centers, and natatoriums.

G3.1.1-4 Baseline System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
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.
12. SZ-CV-HW	Single zone	Constant volume	Chilled water	Hot-water fossil fuel boiler
13. SZ-CV-ER	Single zone	Constant volume	Chilled water	Electric resistance

Notes:
1. For purchased chilled water and purchased heat, see G3.1.1.3.
2. Where the proposed design heating source is electric or other, the heating type shall be electric resistance. Where the proposed design heating source is fossil fuel, fossil/electric hybrid, or purchased heat, the heating type shall be hot-water fossil fuel boiler.

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 and baseline building designs. Hot water or steam costs shall be based on actual utility rates, and on-site boilers, electric heat, and furnaces shall not be modeled in the baseline building design.

G3.1.1.2 Purchased Chilled Water. For systems using purchased chilled water, the cooling source shall be modeled as purchased chilled water in both the proposed and baseline building designs. Purchased chilled water costs shall be based on actual utility rates, and on-site chillers and direct expansion equipment shall not be modeled in the baseline building design.

G3.1.1.3 Baseline HVAC System Requirements for Systems Utilizing Purchased Chilled Water and/or Purchased Heat. If the proposed building 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 building 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 and baseline building design.

G3.1.1.3.2 Purchased Chilled Water Only. If the proposed building 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 boiler(s).
c. System 3 and 4 shall be constant-volume single-zone air handlers with fossil fuel furnace(s).
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 building 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 baseline and proposed designs.

G3.1.1.4 Modeling Building Envelope Infiltration. The air leakage rate of the building envelope (I_{75Pa}) at a pressure differential of 75 Pa shall be converted to appropriate units for the simulation program using one of the following formulas:

For methods describing infiltration as a function of floor area,

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

For methods describing infiltration as a function of exterior wall area,

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

When using the measured air leakage rate of the building envelope at a pressure differential of 75 Pa 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 expressed in L/s·m^2 at a fixed building pressure differential of 75 Pa

Q = volume of air in L/s flowing through the whole-building envelope when subjected to an indoor/outdoor pressure differential of 75 Pa, in accordance with ASTM E 779

S = total area of the envelope air pressure boundary (expressed in m^2), including the lowest floor, any below- or above-grade walls, and roof (or ceiling) (including windows and skylights), separating the interior conditioned space from the unconditioned environment measured

I_{FLR} = adjusted air leakage rate (expressed in L/s·m^2) of the building envelope at a reference wind speed of 4.47 m/s and the total gross floor area

A_{FLR} = total gross floor area, m^2

I_{EW} = adjusted air leakage rate (expressed in L/s·m^2) of the building envelope at a reference wind speed of 4.47 m/s and the above ground exterior wall area

A_{EW} = total above-grade exterior wall area, m^2

Exception: A multizone airflow model alternate method to model building envelope infiltration may be used provided the following criteria are met:

1. If 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 infiltration rate of the building envelope at 75 Pa, 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 Section 6.4. Chillers shall use Path A efficiencies as shown in Table 6.8.1-3 where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy. For Baseline HVAC Systems 1, 2, 3, 4, 5, and 6, calculate the minimum $COP_{nfcooling}$ and $COP_{nfheating}$ using the equation for the applicable performance rating as indicated in Tables 6.8.1-1 through 6.8.1-4. Where a full- and part-load efficiency rating is provided in Tables 6.8.1-1 through 6.8.1-4, the full-load equation below shall be used:

$$COP_{nfcooling} = 9.13E\text{-}4 \times COP_C \times Q + 1.15 \times COP_c$$

$$COP_{nfcooling} = -0.0885 \times SCOP_C^2 + 1.295 \times SCOP_c$$
(applies to cooling efficiency only)

$$COP_{nfheating} = 5.05E\text{-}4 \times COP_{H8.3} \times Q + 1.062 \times COP_{H8.3}$$
(applies to heat-pump heating efficiency only)

$$COP_{nfheating} = -0.3446 \times SCOP_H^2 + 2.434 \times SCOP_H$$

where $COP_{nfcooling}$ and $COP_{nfheating}$ are the packaged HVAC equipment cooling and heating energy efficiency, respectively, to be used in the baseline building, which excludes supply fan power, and Q is the AHRI-rated cooling capacity in kW.

COP_c, $SCOP_c$, $COP_{H8.3}$, and $SCOP_H$ shall be at AHRI test conditions. Fan energy shall be modeled separately according to Section G3.1.2.10.

G3.1.2.2 Equipment Capacities. The equipment capacities (i.e. system coil capacities) for the baseline building design shall be based on sizing runs for each orientation (per Table G3.1, No. 5a) and shall be oversized by 15% for cooling and 25% for heating, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating.

G3.1.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine baseline equipment capacities shall be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.

G3.1.2.3 Unmet Loads. Unmet load hours for the proposed design or baseline building designs shall not exceed 300 (of the 8760 hours simulated). Alternatively, unmet load hours exceeding these limits may be accepted at the discretion 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 Preheat Coils. If the HVAC system in the proposed design has a preheat coil and a preheat coil can be modeled in the baseline system, the baseline system shall be modeled with a preheat coil controlled in the same manner as the proposed design.

G3.1.2.5 Fan System Operation. Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. If the supply fan is modeled as cycling and fan energy is included in the energy-efficiency rating of the equipment, fan energy shall not be modeled explicitly. Supply, return, and/or exhaust fans will remain on during occupied and unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.

G3.1.2.6 Ventilation. Minimum ventilation system outdoor air intake flow shall be the same for the proposed and baseline building designs.

Exceptions:

1. When modeling demand-control ventilation in the proposed design when its use is not required by Section 6.3.2(q) or Section 6.4.3.10.
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 Table 6-2 in Standard 62.1. 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 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. If the minimum outdoor air intake flow in the proposed design is provided in excess of the amount required by the rating authority or building official then the baseline building design shall be modeled to reflect the greater of that required by the rating authority or building official 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.

G3.1.2.7 Economizers. Outdoor air economizers shall not be included in baseline HVAC Systems 1, 2, 9, and 10. Outdoor air economizers shall be included in baseline HVAC Systems 3 through 8, and 11, 12, and 13 based on climate as specified in Table G3.1.2.7.

Exceptions: Economizers shall not be included for systems meeting one or more of the exceptions listed below.

1. Systems that include gas-phase air cleaning to meet the requirements of Section 6.1.2 in Standard 62.1. This exception shall be used only if the system in the proposed design does not match the building design.
2. Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems. This exception shall only be used if the

TABLE G3.1.2.7 Climate Conditions under which Economizers are Included for Comfort Cooling for Baseline Systems 3 through 8 and 11, 12, and 13

Climate Zone	Conditions
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 G3.1.2.8 Economizer High-Limit Shutoff

Climate Zone	High-Limit Shutoff
1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	24°C
2a, 3a, 4a	47 kJ/kg
5a, 6a, 7a	21°C
Others	18°C

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 G3.1.2.7.1.

G3.1.2.7.1 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 water-side economizer meeting the requirements of Section 6.5.1.2 in the baseline building design. If the simulation software cannot model an integrated water-side economizer, then an air-side economizer shall be modeled.

G3.1.2.8 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb fixed switch with setpoint temperatures in accordance with the values in Table G3.1.2.8.

G3.1.2.9 Design Airflow Rates

G3.1.2.9.1 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-air temperature difference of 11°C or the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. If return or relief fans are specified in the proposed design, the baseline building design shall also be modeled with fans serving the same functions and sized for the baseline system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.

Exceptions:

1. For systems serving laboratory spaces, use a supply-air-to-room-air temperature difference of 9°C or the required ventilation air or makeup air, whichever is greater.
2. If the proposed design HVAC design 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/kg) used to calculate the proposed design airflow shall be used to calculate design airflow rates for the baseline building design.

G3.1.2.9.2 Baseline System Types 9 and 10. System design supply airflow rates for the baseline building design shall be based on the temperature difference between a supply air temperature setpoint of 41°C and the design space heating temperature setpoint, the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. If the Proposed Building Design includes a fan(s) 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 building design.

G3.1.2.10 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,

$$P_{fan} = (\text{cubic meters per second}) \times 1.4158e\text{-}4$$

For Systems 3 through 8, and 11, 12, and 13,

$$P_{fan} = \text{input kW/fan motor efficiency}$$

For Systems 9 and 10 (supply fan),

$$P_{fan} = \text{CFMs} \times 0.3$$

For Systems 9 and 10 (nonmechanical cooling fan if required by Section G3.1.2.9.2)

$$P_{fan} = \text{CFM}_{nmc} \times 0.054$$

where

P_{fan}	=	electric power to fan motor (watts)
input kW	=	input kilowatts of baseline fan motor from Table G3.1.2.10
fan motor efficiency	=	the efficiency from Table 10.8-2 for the next motor size greater than the input kW using a totally enclosed fan cooled motor at 1800 rpm.
CFMs	=	the baseline system maximum design supply fan airflow rate in L/s
CFM_{nmc}	=	the baseline nonmechanical cooling fan airflow in L/s

G3.1.2.10.1 The calculated system fan power shall be distributed to supply, return, exhaust, and relief fans in the same proportion as the proposed design.

TABLE G3.1.2.10 Baseline Fan Motor Power

Baseline Fan Motor Power		
Constant Volume Systems 3–4	**Variable Volume Systems 5–8**	**Variable Volume System 11**
$kW_i = L_S \cdot 0.0015 + A$	$kW_i = L_S \cdot 0.0021 + A$	$L_s \times 0.001 + A$

Notes:
1. Where A is calculated according to Section 6.5.3.1.1 using the pressure drop adjustment from the proposed building 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 Chiller(s)
≤1055 kW	1 water-cooled screw chiller
>1055 kW, <2110 kW	2 water-cooled screw chillers sized equally
≥2110 kW	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 2813 kW, all sized equally

G3.1.2.11 Exhaust Air Energy Recovery. Exhaust air energy recovery shall be modeled for the budget building design in accordance with Section 6.5.6.1.

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. The systems shall be controlled with multistage space thermostats and an outdoor air thermostat wired to energize auxiliary heat only on the last thermostat stage and when outdoor air temperature is less than 4°C.

G3.1.3.2 Type and Number of Boilers (Systems 1, 5, and 7). The boiler plant shall use the same fuel as the proposed design and shall be natural draft, except as noted in Section G3.1.1.1. The baseline building design boiler plant shall be modeled as having a single boiler if the baseline building design plant serves a conditioned floor area of 1400 m^2 or less and as having two equally sized boilers for plants serving more than 1400 m^2. Boilers shall be staged as required by the load.

G3.1.3.3 Hot-Water Supply Temperature (Systems 1, 5, 7, and 12). Hot-water design supply temperature shall be modeled as 82°C and design return temperature as 54°C.

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: 82°C at –7°C and below, 66°C at 10°C and above, and ramped linearly between 82°C and 66°C at temperatures between –7°C and 10°C.

G3.1.3.5 Hot-Water Pumps. The baseline building design hot-water pump power shall be 301 kW/1000 L/s. The pumping system shall be modeled as primary-only with continuous variable flow. Hot-water systems serving11,160 m^2 or more shall be modeled with variable-speed drives, and systems serving less than 11,160 m^2 shall be modeled as riding the pump curve.

Exception: The pump power for systems using purchased heat shall be222 kW/1000 L/s.

G3.1.3.6 Piping Losses (Systems 1, 5, 7, 8, and 11). Piping losses shall not be modeled in either the proposed or baseline building designs for hot water, chilled water, or steam piping.

G3.1.3.7 Type and Number of Chillers (Systems 7, 8, 11, 12, and 13). Electric chillers shall be used in the baseline building design regardless of the cooling energy source, e.g. direct fired absorption or absorption from purchased steam. The baseline building design's chiller plant shall be modeled with chillers having the number and type as indicated in Table G3.1.3.7 as a function of building peak cooling load.

Exception: Systems using purchased chilled water shall be modeled in accordance with Section G3.1.1.3.

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 6.7°C and return water temperature at 13°C.

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: 7°C at 27°C and above, 12°C at 16°C and below, and ramped linearly between 7°C and 12°C at temperatures between 27°C and 16°C.

Exception: If the baseline chilled-water system serves a computer room HVAC system, the supply chilled-water temperature shall be reset higher based on the HVAC system requiring the most cooling; i.e., the chilled-water setpoint is reset higher until one cooling-coil valve is nearly wide open. The maximum reset chilled-water supply temperature shall be 12°C.

G3.1.3.10 Chilled-Water Pumps (Systems 7, 8, and 11). The baseline building design pump power shall be 349 kW/1000 L/s. Chilled-water systems with a cooling capacity of 11,148 m^2 or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 11,148 m^2 cooling capacity shall be modeled as a primary/secondary systems with secondary pump riding the pump curve. For computer room systems using System 11 with an integrated water-side economizer, the baseline building design primary chilled-water pump power shall be increased 80 kW/1000 L/s for flow associated with the water-side economizer.

Exception: The pump power for systems using purchased chilled water shall be 960 kW/ 1000L/s.

G3.1.3.11 Heat Rejection (Systems 7, 8, 9, 12, and 13). The heat rejection device shall be an axial fan open circuit cooling tower with variable-speed fan control and shall 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 5.6°C.

$$\text{Approach}_{5.6°C\ Range} = 10.02 - (0.24 \times \text{WB})$$

where WB is the 0.4% evaporation design wet-bulb temperature in °C; valid for wet bulbs from 12.8°C to 32.2°C.

The tower shall be controlled to maintain a 21°C leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. The baseline building design condenser-water pump power shall be 310 kW/1000 L/s. For computer room systems using System 11 with an integrated water-side economizer, the baseline building design condenser water-pump power shall be increased 80 kW/1000 L/s for flow associated with the water-side economizer. Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller.

G3.1.3.12 Supply Air Temperature Reset (Systems 5 through 8). The air temperature for cooling shall be reset higher by 2.3°C under the minimum cooling load conditions.

G3.1.3.13 VAV Minimum Flow Setpoints (Systems 5 and 7). Minimum volume setpoints for VAV reheat boxes shall be 30%of zone peak airflow, the minimum outdoor airflow rate or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger.

> **Exception:** Systems serving laboratory spaces shall reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak airflow, the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards.

G3.1.3.14 Fan Power (Systems 6 and 8). Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design primary air (from the VAV air-handling unit) flow rate and shall be modeled with 0.74 W per L/s fan power. Minimum volume setpoints for fan-powered boxes shall be equal to 30% of peak design primary airflow rate or the rate required to meet the minimum outdoor air ventilation requirement, whichever is larger. The supply air temperature setpoint shall be constant at the design condition.

G3.1.3.15 VAV Fan Part-Load Performance (Systems 5 through 8 and 11). VAV system supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table G3.1.3.15.

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

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

$$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$$

where

P_{fan} = fraction of full-load fan power and
PLR_{fan} = fan part-load ratio (current L/s/design L/s).

Month 1, 5, 9—25%

Month 2, 6, 10—50%

Month 3, 7, 11—75%

Month 4, 8, 12—100%

G3.1.3.17 System 11 Supply Air Temperature and Fan Control. Minimum volume setpoint shall be 50% of the maximum design airflow rate, the minimum ventilation outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger.

Fan volume shall be reset from 100% airflow at 100% cooling load to minimum airflow at 50% cooling load. Supply air temperature setpoint shall be reset from minimum supply air temperature at 50% cooling load and above to space temperature at 0% cooling load. In heating mode supply air temperature shall be modulated to maintain space temperature, and fan volume shall be fixed at the minimum airflow.

G3.1.3.18 Dehumidification (Systems 3 through 8). If the proposed design HVAC system(s) 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.

NOTICE

INSTRUCTIONS FOR SUBMITTING A PROPOSED CHANGE TO THIS STANDARD UNDER CONTINUOUS MAINTENANCE

This standard is maintained under continuous maintenance procedures by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. SSPC consideration will be given to proposed changes within 13 months of receipt by the manager of standards (MOS).

Proposed changes must be submitted to the MOS in the latest published format available from the MOS. However, the MOS may accept proposed changes in an earlier published format if the MOS concludes that the differences are immaterial to the proposed change submittal. If the MOS concludes that a current form must be utilized, the proposer may be given up to 20 additional days to resubmit the proposed changes in the current format.

ELECTRONIC PREPARATION/SUBMISSION OF FORM FOR PROPOSING CHANGES

An electronic version of each change, which must comply with the instructions in the Notice and the Form, is the preferred form of submittal to ASHRAE Headquarters at the address shown below. The electronic format facilitates both paper-based and computer-based processing. Submittal in paper form is acceptable. The following instructions apply to change proposals submitted in electronic form.

Use the appropriate file format for your word processor and save the file in either a recent version of Microsoft Word (preferred) or another commonly used word-processing program. Please save each change proposal file with a different name (for example, “prop01.doc,” “prop02.doc,” etc.). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as word-processed or scanned documents.

For files submitted attached to an e-mail, ASHRAE will accept an electronic signature (as a picture; *.tif, or *.wpg) on the change submittal form as equivalent to the signature required on the change submittal form to convey non-exclusive copyright.

Submit an e-mail containing the change proposal files to:
change.proposal@ashrae.org

Alternatively, mail paper versions to:
ASHRAE
Manager of Standards
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Or fax them to:
Attn: Manager of Standards
404-321-5478

The form and instructions for electronic submittal may be obtained from the Standards section of ASHRAE’s Home Page, www.ashrae.org, or by contacting a Standards Secretary via phone (404-636-8400), fax (404-321-5478), e-mail (standards.section@ashrae.org), or mail (1791 Tullie Circle, NE, Atlanta, GA 30329-2305).

FORM FOR SUBMITTAL OF PROPOSED CHANGE TO AN ASHRAE STANDARD UNDER CONTINUOUS MAINTENANCE

NOTE: Use a separate form for each comment. Submittals (Microsoft Word preferred) may be attached to e-mail (preferred), or submitted in paper by mail or fax to ASHRAE, Manager of Standards, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: change.proposal@ashrae.org. Fax: +1-404/321-5478.

1. Submitter:

Affiliation:

Address: City: State: Zip: Country:

Telephone: Fax: E-Mail:

I hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

Submitter's signature: ____ Date: ____________________________

All electronic submittals must have the following statement completed:

I *(insert name)* ____, through this electronic signature, hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

2. Number and year of standard:

3. Page number and clause (section), subclause, or paragraph number:

4. I propose to: *(check one)*

[ ] Change to read as follows
[ ] Add new text as follows
[ ] Delete and substitute as follows
[ ] Delete without substitution

Use underscores to show material to be added (added) and strike through material to be deleted (~~deleted~~). Use additional pages if needed.

5. Proposed change:

6. Reason and substantiation:

7. Will the proposed change increase the cost of engineering or construction? If yes, provide a brief explanation as to why the increase is justified.

[ ] Check if additional pages are attached. Number of additional pages: _______

[ ] Check if attachments or referenced materials cited in this proposal accompany this proposed change. Please verify that all attachments and references are relevant, current, and clearly labeled to avoid processing and review delays. *Please list your attachments here:*

Rev. 1-7-2013

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.

ASHRAE · 1791 Tullie Circle NE · Atlanta, GA 30329 · www.ashrae.org

About ASHRAE

ASHRAE, founded in 1894, is an international building technology society with more than 50,000 members worldwide. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability. Through research, standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow's built environment today.

For more information or to become a member of ASHRAE, visit www.ashrae.org.

To stay current with this and other ASHRAE standards and guidelines, visit www.ashrae.org/standards.

Visit the ASHRAE Bookstore

ASHRAE offers its standards and guidelines in print, as immediately downloadable PDFs, on CD-ROM, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected standards are also offered in redline versions that indicate the changes made between the active standard and its previous version. 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.

Product code: 86275 7/14
Errata noted in the list dated 4/1/14 have been corrected.