ANSI/ASHRAE Standard 90.1-2007
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2004)
Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F

ASHRAE STANDARD

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 IESNA Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance 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. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site, http://www.ashrae.org, or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada).

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a. interpretation of the contents of this Standard,
b. participation in the next review of the Standard,
c. offering constructive criticism for improving the Standard, or
d. permission to reprint portions of the Standard.

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ANSI/ASHRAE/IESNA Standard 90.1-2007
Energy Standard for Buildings Except Low-Rise Residential Buildings (SI Edition)

NOTE

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

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FOREWORD

The original Standard 90 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 technology and energy prices began changing more rapidly, however, 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. Starting with 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 will be included in the new edition every three years. This procedure allows users to have some certainty about when new editions will be published.

This 2007 edition of the standard has several new features and includes changes resulting from the continuous maintenance proposals from the public. The committee welcomes suggestions for improving the standard. Users of the standard are encouraged and invited to use the continuous maintenance procedure to suggest changes. A form for submittal of a proposed change is included in the back of this standard. The committee will take formal action on every proposal received.

The project committee is continually considering changes and proposing addenda for public review. When addenda are approved, notices will be published on the ASHRAE and IESNA Web sites. Users are encouraged to sign up for the free ASHRAE and IESNA Internet Listserv for this standard to receive notice of all public reviews and approved and published addenda and errata.

This edition corrects all known typographical errors in the 2004 standard. It also includes the content of 31 addenda that were processed by the committee and approved by the ASHRAE and IESNA Boards of Directors. For brief descriptions and the publication dates of the addenda to 90.1-2004, see Appendix F.

1. PURPOSE

The purpose of this standard is to provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings.

2. SCOPE

2.1 This standard provides:

a. minimum energy-efficient requirements for the design and construction of:
   1. new buildings and their systems
   2. new portions of buildings and their systems
   3. new systems and equipment in existing buildings

b. criteria for determining compliance with these requirements.

2.2 The provisions of this standard apply to:

a. the envelope of buildings, provided that the enclosed spaces are
   1. heated by a heating system whose output capacity is greater than or equal to 10 W/m^2 or
   2. cooled by a cooling system whose sensible output capacity is greater than or equal to 15 W/m^2, and

b. the following systems and equipment used in conjunction with buildings:
   1. heating, ventilating, and air conditioning,
   2. service water heating,
   3. electric power distribution and metering provisions,
   4. electric motors and belt drives, and
   5. lighting.

2.3 The provisions of this standard do not apply to

a. single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular),
b. buildings that do not use either electricity or fossil fuel, or
c. equipment and portions of building systems that use energy primarily to provide for industrial, manufacturing, or commercial processes.

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

2.5 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.

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. (See *manual*.)

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.

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

boiler, packaged: a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls; 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.

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

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, turnstile, vestibule, or other form of portal that is ordinarily used to gain access to the building by its users and occupants.

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:

> ***building envelope, exterior:*** the elements of a building that separate conditioned spaces from the exterior.
>
> ***building envelope, semi-exterior:*** 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, or to or from unconditioned spaces, or to or from conditioned spaces.

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 through which heat flows and that is included in the component U-factor calculations other than air films and insulation.

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

C-factor (thermal conductance): 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. Units of *C* are $W/m^2 \cdot K$. Note that the C-factor does not include soil or air films.

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*.)

clerestory: that part of a building that rises clear of the roofs or other parts and whose walls contain windows for lighting the interior.

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.

conditioned floor area: see *floor area*.

conditioned space: see *space*.

conductance: see *thermal conductance*.

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

control: to regulate the operation of equipment.

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

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.

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

cooled space: see *space*.

cooling degree-day: 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 outdoor wet-bulb temperature for sizing cooling systems and evaporative heat rejection systems such as cooling towers.

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*.

degree-day: the difference in temperature between the outdoor mean temperature over a 24-hour period and a given base temperature. For the purposes of determining building envelope requirements, the classifications are defined as follows:

> ***cooling degree-day base 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 (CDD18):*** 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 kilowatts over an interval) recorded for a building or facility in a selected time frame.

demand control ventilation (DCV): a ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy.

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

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

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

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

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

nonswinging: roll-up, sliding, and all other doors that are not swinging doors.

swinging: 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*.)

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.

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.

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 lumens per watt.

efficiency: performance at specified rating conditions.

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. Customary measurement units are British thermal units (kWh·MJ).

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 in 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.

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.

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*.

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, expressed in W/m·K.

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

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

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

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

fan system motor nameplate kilowatts: the sum of the motor nameplate kilowatts (kW) 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, skylights, doors that are more than one-half glass, and glass block walls. (See *building envelope* and *door.*)

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*.)

fenestration, vertical: see *fenestration* and *skylight*.

fixture: the component of a luminaire that houses the lamp or lamps, 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, envelope: 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 $kJ/m^2{\cdot}K$ or (2) 102 $kJ/m^2{\cdot}K$ 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) that 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 area*, 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.

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

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

general lighting: see *lighting, general.*

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

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

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

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

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

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.

heated space: see *space*.

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

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 degree-day: see *degree-day.*

heating seasonal performance factor (HSPF): the total heating output of a heat pump during its normal annual usage period for heating (in 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 US 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.

indirectly conditioned space: see *space.*

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

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

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* (kVA) 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.

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

lighting power allowance:

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

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

low-rise residential buildings: single-family houses, multi-family 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.

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 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.

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.

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.

nameplate kW: the nominal motor kW 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 ARI Standard Rating Conditions.

nonswinging door: see *door.*

north-oriented: facing within 45 degrees of true north (northern 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.

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

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

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

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

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

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

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

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.

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.

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 kW) 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 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.*

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 lamp wattage: see *lamp wattage, rated.*

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.

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.

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.

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.

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° 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 is:

1. constructed with a metal, structural, weathering surface,
2. has no ventilated cavity, and
3. 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:

   a. metal roofing in direct contact with the steel framing members
   b. insulation between the metal roofing and the steel framing members
   c. insulated metal roofing panels installed as described in 1 or 2

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

1. installed above (outside of) the roof structure and
2. 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*.)

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.

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 the 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 the 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 (in Wh) divided by the total electric energy input during the same period (in Wh).

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

semiheated floor area: see *floor area*.

semiheated space: see *space*.

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.

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, as used herein, 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: see *fenestration.*

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.

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:

1. ***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.
2. ***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 3.1.
3. ***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:
   a. 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
   b. 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:

nonresidential conditioned space,

residential conditioned space, and

nonresidential and residential semiheated space.

(See *nonresidential*, *residential*, and *space*.)

steel-framed wall: see *wall*.

steel-joist floor: see *floor*.

TABLE 3.1 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

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

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

swinging door: see *door.*

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

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

tandem wiring: pairs of luminaires operating with lamps in each luminaire powered from a single ballast contained in one of the luminaires.

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

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: see *C-factor.*

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. Units of *R* are m^2·K/W.

thermal transmittance: see *U-factor.*

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.

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.

U-factor (thermal transmittance): 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. Units of *U* are $W/m^2 \cdot K$.

unmet load hour: an hour in which one or more zones is outside of the thermostat setpoint range.

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.

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.

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.

vertical fenestration: see *fenestration*.

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

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 an *HC* exceeding (1) 143 $kJ/m^2 \cdot K$ or (2) 102 $kJ/m^2 \cdot K$, 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 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.*

zone, HVAC: 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).

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
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASTM	American Society for Testing and Materials
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
DDC	direct digital control
DOE	U.S. Department of Energy
Ec	combustion efficiency
EER	energy efficiency ratio
EF	energy factor

ENVSTD	Envelope System Performance Compliance Program
Et	thermal efficiency
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
IESNA	Illuminating Engineering Society of North America
IPLV	integrated part-load value
K	kelvin
kg	kilogram
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
lb	pound
lin	linear
LPD	lighting power density
m	meter
m^2·K/W	square meter per kelvin per watt
MICA	Midwest Insulation Contractors Association
NAECA	U.S. National Appliance Energy Conservation Act of 1987
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
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
VLT	visible light transmittance
W	watt
Wh	watt-hour
W/m^2	watts per square meter
W/m^2·°C	watts per square meter per degree Celsius
W/m·K	watts per meter per kelvin
W/m^2·K	watts per square meter per kelvin
Wh/m^2·K	watt-hours per square meter 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 Sections 5, 6, 7, 8, 9, and 10 or Section 11.

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.

Exceptions: 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:

a. 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 US Secretary of the Interior need not comply with these requirements.

b. 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 the applicable requirements of Sections 5, 6, 7, 8, 9, and 10, as provided in Section 4.2.1.3, and such compliance 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 and 8.7.2.

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

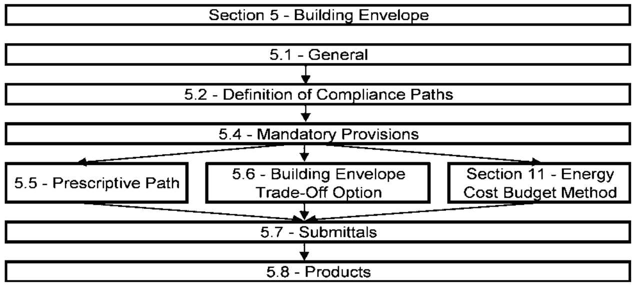
c. slab/foundation wall after slab/foundation insulation is in place but before concealment

d. fenestration after all glazing materials are in place

e. mechanical systems and equipment and insulation after installation but before concealment

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

5.1.2.3 In climate zones 3 through 8, a space may be designated as either *semiheated* or *unconditioned* 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:

a. installation of storm windows over existing glazing
b. 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
c. *alterations* to roof/ceiling, wall, or floor cavities, which are insulated to full depth with insulation having a minimum nominal value of R-0.02/mm.
d. *alterations* to walls and floors, where the existing structure is without framing cavities and no new framing cavities are created
e. replacement of a roof membrane where either the roof sheathing or roof insulation is not exposed or, if there is existing roof insulation, below the roof deck
f. replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided, however, that an existing vestibule that separates a conditioned space from the exterior shall not be removed
g. replacement of existing fenestration, provided, however, 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 US 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 B-1 or Table B-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 B-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 B-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 B-3, use this table to determine the required climate zone number and, when a climate zone letter is also required, use Table B-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 B-2 or B-3, use Table B-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; and Section 5.8, Product Information and Installation Requirements; and either

a. 5.5, Prescriptive Building Envelope Option, provided that

   1. the *vertical fenestration area* does not exceed 40% of the *gross wall area* for each *space-conditioning category* and
   2. the *skylight fenestration area* does not exceed 5% of the *gross roof area* for each *space-conditioning category,* or

b. 5.6, Building Envelope Trade-Off Option.

5.2.2 Projects using the Energy Cost Budget Method (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 5.8.1.9.

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 Building Envelope Sealing. The following areas of the *building envelope* shall be sealed, caulked, gasketed, or weather-stripped to minimize air leakage:

a. joints around *fenestration* and *door* frames
b. junctions between *walls* and foundations, between *walls* at building corners, between *walls* and structural *floors* or *roofs*, and between *walls* and *roof* or *wall* panels
c. openings at penetrations of utility services through *roofs*, *walls*, and *floors*
d. site-built *fenestration* and *doors*
e. building assemblies used as ducts or plenums
f. joints, seams, and penetrations of vapor retarders
g. all other openings in the *building envelope*

5.4.3.2 Fenestration and Doors. Air leakage for *fenestration* and *doors* shall be determined in accordance with NFRC 400. 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 5.0 L/s·m^2 for glazed swinging entrance doors and for revolving doors and 2.0 L/s·m^2 for all other products.

Exceptions:

a. Field-fabricated fenestration and doors.
b. For garage *doors*, air leakage determined by test at standard test conditions in accordance with ANSI/ DASMA 105 shall be an acceptable alternate for compliance with air leakage requirements.

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 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:

a. *Building entrances* with revolving *doors*.
b. *Doors* not intended to be used as a *building entrance.*
c. *Doors* opening directly from a *dwelling unit.*
d. *Building entrances* in buildings located in climate zone 1 or 2.
e. *Building entrances* in buildings located in climate zone 3 or 4 that are less than four stories above grade and less than 1000 m^2 in area.
f. *Building entrances* in buildings located in climate zone 5, 6, 7, or 8 that are less than 100 m^2 in area.
g. *Doors* that open directly from a *space* that is less than 300 m^2 in area and is separate from the *building entrance.*

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.)

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

1. 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.
2. 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.

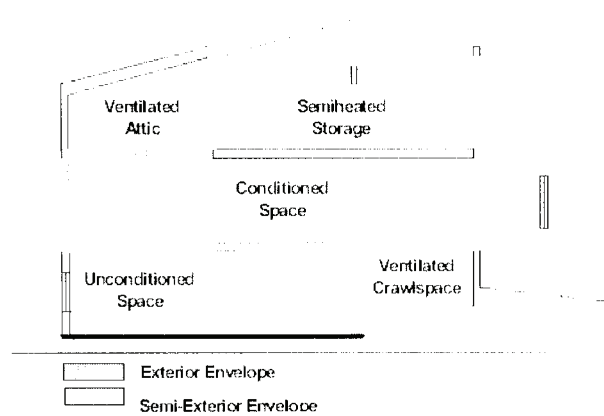


Figure 5.5 Exterior and semi-exterior building envelope.

TABLE 5.5-1 Building Envelope Requirements for Climate Zone 1 (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-0.360	R-2.6 c.i.	U-0.273	R-3.5 c.i.	U-1.240	R-0.7 ci
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-7.268	NR
Attic and Other	U-0.192	R-5.3	U-0.153	R-6.7	U-0.459	R-2.3
Walls, Above-Grade						
Mass	U-3.293	NR	U-0.857[a]	R-1.0 c.i.[a]	U-3.293	NR
Metal Building	U-0.642	R-2.3	U-0.642	R-2.3	U-6.700	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
Walls, 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	U-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-3.975		U-3.975	
Nonswinging	U-8.233		U-8.233		U-8.233	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-6.81	SHGC-0.25 all	U-6.81	SHGC-0.25 all	U-6.81	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-6.81		U-6.81		U-6.81	
Metal framing (entrance door)[c]	U-6.81		U-6.81		U-6.81	
Metal framing (all other)[c]	U-6.81		U-6.81		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–11.24	$SHGC_{all}$–0.36	U_{all}–11.24	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–11.24	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–0.16	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–10.79	$SHGC_{all}$–0.34	U_{all}–10.79	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–10.79	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–7.72	$SHGC_{all}$–0.36	U_{all}–7.72	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–7.72	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a]Exception to Section A3.1.3.1 applies.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-1.240	R-0.7 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.948	R-1.1
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-0.857[a]	R-1.0 c.i.[a]	U-0.701	R-1.3 c.i.	U-3.293	NR
Metal Building	U-0.642	R-2.3	U-0.642	R-2.3	U-1.045	R-1.1
Steel-Framed	U-0.705	R-2.3	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
Walls, Below-Grade						
Below-Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.606	R-1.1 c.i.	U-0.496	R-1.5 c.i.	U-1.825	NR
Steel-Joist	U-0.296	R-3.3	U-0.296	R-3.3	U-0.390	R-2.3
Wood-Framed and Other	U-0.288	R-3.3	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-1.766	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-3.975		U-3.975	
Nonswinging	U-8.233		U-2.839		U-8.233	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-4.26		U-4.26		U-6.81	
Metal framing (curtainwall/storefront)[c]	U-3.97	SHGC-0.25 all	U-3.97	SHGC-0.25 all	U-6.81	SHGC-NR all
Metal framing (entrance door)[c]	U-6.25		U-6.25		U-6.81	
Metal framing (all other)[c]	U-4.26		U-4.26		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–11.24	$SHGC_{all}$–0.36	U_{all}–11.24	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–11.24	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–10.79	$SHGC_{all}$–0.39	U_{all}–10.79	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–10.79	$SHGC_{all}$–0.34	U_{all}–10.79	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–7.72	$SHGC_{all}$–0.36	U_{all}–7.72	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–7.72	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a]Exception to Section A3.1.3.1 applies.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.982	R-0.9 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
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-0.642	R-2.3	U-0.642	R-2.3	U-1.045	R-1.1
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
Walls, Below-Grade						
Below-Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.606	R-1.1	U-0.496	R-1.5	U-1.825	NR
Steel-Joist	U-0.296	R-3.3	U-0.296	R-3.3	U-0.390	R-2.3
Wood-Framed and Other	U-0.288	R-3.3	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-1.558	R-1.8 for 600 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Nonswinging	U-8.233		U-2.839		U-8.233	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-3.69		U-3.69		U-6.81	
Metal framing (curtainwall/storefront)[c]	U-3.41	SHGC-0.25 all	U-3.41	SHGC-0.25 all	U-6.81	SHGC-NR all
Metal framing (entrance door)[c]	U-5.11		U-5.11		U-6.81	
Metal framing (all other)[c]	U-3.69		U-3.69		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–6.64	$SHGC_{all}$–0.39	U_{all}–6.64	$SHGC_{all}$–0.36	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.64	$SHGC_{all}$–0.19	U_{all}–6.64	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–7.38	$SHGC_{all}$–0.65	U_{all}–7.38	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–7.38	$SHGC_{all}$–0.34	U_{all}–7.38	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.92	$SHGC_{all}$–0.39	U_{all}–3.92	$SHGC_{all}$–0.36	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.92	$SHGC_{all}$–0.19	U_{all}–3.92	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.982	R-0.9 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.0.153	R-6.7	U-0.153	R-6.7	U-0.300	R-3.3
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-0.142	R-2.3	U-0.642	R-2.3	U-0.761	R-1.8
Steel-Framed	U-0.365	R-2.3 + R-1.3	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.	U-0.504	R-2.3
Walls, Below-Grade						
Below-Grade Wall	C-6.473	NR	C-0.678	R-1.3 c.i.	C-6.473	NR
Floors						
Mass	U-0.496	R-1.5 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-0.390	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-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-3.975		U-3.975	
Nonswinging	U-2.839		U-2.839		U-8.233	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-2.27		U-2.27		U-6.81	
Metal framing (curtainwall/storefront)[c]	U-2.84	SHGC-0.40 all	U-2.84	SHGC-0.40 all	U-6.81	SHGC-NR all
Metal framing (entrance door)[c]	U-4.83		U-4.83		U-6.81	
Metal framing (all other)[c]	U-3.12		U-3.12		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–6.64	$SHGC_{all}$–0.49	U_{all}–5.56	$SHGC_{all}$–0.36	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.64	$SHGC_{all}$–0.39	U_{all}–5.56	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–7.38	$SHGC_{all}$–0.65	U_{all}–7.38	$SHGC_{all}$–0.62	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–7.38	$SHGC_{all}$–0.34	U_{all}–7.38	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.92	$SHGC_{all}$–0.49	U_{all}–3.29	$SHGC_{all}$–0.36	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.92	$SHGC_{all}$–0.39	U_{all}–3.29	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.677	R-1.3 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
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-0.513	R-2.0 c.i.	U-0.453	R-2.3 c.i.	U-0.857[a]	R-1.0 c.i.[a]
Metal Building	U-0.642	R-2.3	U-0.324	R-2.3 + R-2.3	U-0.698	R-1.9
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.	U-0.291	R-2.3 + R-1.3 c.i.	U-0.504	R-2.3
Walls, Below-Grade						
Below-Grade Wall	C-0.678	R-1.3 c.i.	C-0.678	R-1.3 c.i.	C-6.473	NR
Floors						
Mass	U-0.420	R-1.8 c.i.	U-0.363	R-2.2 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 Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, % of Wall						
Nonmetal framing (all)[b]	U-1.99		U-1.99		U-6.81	
Metal framing (curtainwall/storefront)[c]	U-2.56	SHGC-0.40 all	U-2.56	SHGC-0.40 all	U-6.81	SHGC-NR all
Metal framing (entrance door)[c]	U-4.54		U-4.54		U-6.81	
Metal framing (all other)[c]	U-3.12		U-3.12		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–6.64	$SHGC_{all}$–0.49	U_{all}–6.64	$SHGC_{all}$–0.49	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.64	$SHGC_{all}$–0.39	U_{all}–6.64	$SHGC_{all}$–0.39	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–6.25	$SHGC_{all}$–0.77	U_{all}–6.25	$SHGC_{all}$–0.77	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.25	$SHGC_{all}$–0.62	U_{all}–6.25	$SHGC_{all}$–0.62	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.92	$SHGC_{all}$–0.49	U_{all}–3.92	$SHGC_{all}$–0.49	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.92	$SHGC_{all}$–0.39	U_{all}–3.92	$SHGC_{all}$–0.39	U_{all}–7.72	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a]Exception to Section A3.1.3.1 applies.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.527	R-1.8 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.153	R-6.7	U-0.153	R-6.7	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[a]	R-1.0 c.i.[a]
Metal Building	U-0.642	R-2.3	U-0.324	R-2.3 + R-2.3	U-0.642	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-0.291	R-2.3 + R-1.3 c.i.	U-0.291	R-2.3 + R-1.3 c.i.	U-0.504	R-2.3
Walls, Below-Grade						
Below-Grade Wall	C-0.678	R-1.3 c.i.	C-0.678	R-1.3c.i.	C-6.473	NR
Floors						
Mass	U-0.363	R-2.2 c.i.	U-0.321	R-2.6 c.i.	U-0.780	R-0.7 c.i.
Steel-Joist	U-0.214	R-5.3	U-0.183	R-6.7	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-0.935	R-1.8 for 600 mm	F-0.900	R-2.6 for 600 mm	F-1.264	NR
Heated	F-1.489	R-2.6 for 600 mm	F-1.191	R-3.5 for 1200 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 Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-1.99		U-1.99		U-3.69	
Metal framing (curtainwall/storefront)[c]	U-2.56	SHGC-0.40 all	U-2.56	SHGC-0.40 all	U-3.41	SHGC-NR all
Metal framing (entrance door)[c]	U-4.54		U-4.54		U-5.11	
Metal framing (all other)[c]	U-3.12		U-3.12		U-3.69	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–6.64	$SHGC_{all}$–0.49	U_{all}–5.56	$SHGC_{all}$–0.46	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.64	$SHGC_{all}$–0.49	U_{all}–5.56	$SHGC_{all}$–0.36	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–4.94	$SHGC_{all}$–0.71	U_{all}–4.20	$SHGC_{all}$–0.65	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–4.94	$SHGC_{all}$–0.58	U_{all}–4.20	$SHGC_{all}$–0.55	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.92	$SHGC_{all}$–0.49	U_{all}–3.29	$SHGC_{all}$–0.49	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.92	$SHGC_{all}$–0.49	U_{all}–3.29	$SHGC_{all}$–0.39	U_{all}–7.72	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a] Exception to Section A3.1.3.1 applies.
[b] Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c] Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.527	R-1.8 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.192	R-5.3
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-0.324	R-2.3 + R-2.3	U-0.324	R-2.3 + R-2.3	U-0.642	R-2.3
Steel-Framed	U-0.365	R-2.3 + R-1.3 c.i.	U-0.240	R-2.3 + R-2.7 c.i.	U-0.705	R-2.3
Wood-Framed and Other	U-0.291	R-2.3 + R-1.3 c.i.	U-0.291	R-2.3 +R-1.3 c.i.	U-0.504	R-2.3
Walls, 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-0.363	R-2.2 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-0.183	R-6.7	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	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	Residential Assembly Max. U	Residential Assembly Max. SHGC	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-1.99	SHGC-0.45 all	U-1.99	SHGC-NR all	U-3.69	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-2.27		U-2.27		U-3.41	
Metal framing (entrance door)[c]	U-4.54		U-4.54		U-5.11	
Metal framing (all other)[c]	U-2.56		U-2.56		U-3.69	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–6.64	$SHGC_{all}$–0.68	U_{all}–6.64	$SHGC_{all}$–0.64	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.64	$SHGC_{all}$–0.64	U_{all}–6.64	$SHGC_{all}$–0.64	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–4.94	$SHGC_{all}$–0.77	U_{all}–3.46	$SHGC_{all}$–0.77	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–4.94	$SHGC_{all}$–0.71	U_{all}–3.46	$SHGC_{all}$–0.77	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.92	$SHGC_{all}$–0.68	U_{all}–3.92	$SHGC_{all}$–0.64	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.92	$SHGC_{all}$–0.64	U_{all}–3.92	$SHGC_{all}$–0.64	U_{all}–7.72	$SHGC_{all}$–NR

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

[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.

[c]Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

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-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.360	R-2.6 c.i.
Metal Building	U-0.278	R-2.3 + R-3.3	U-0.278	R-2.3 + R-3.3	U-0.409	R-2.8
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-0.404	R-2.7 c.i.	U-0.295	R-4.4 c.i.	U-0.592	R-1.7 c.i.
Metal Building	U-0.324	R-2.3 + R-2.3	U-0.324	R-2.3 + R-2.3	U-0.642	R-2.3
Steel-Framed	U-0.365	R-2.3 + R-1.3 c.i.	U-0.212	R-2.3 + R-3.3 c.i.	U-0.479	R-2.3 + R-0.7 c.i.
Wood-Framed and Other	U-0.203	R-2.3 +R-2.7 c.i.	U-0.203	R-2.3 + R-2.7 c.ic.	U-0.504	R-2.3
Walls, Below-Grade						
Below-Grade Wall	C-0.678	R-1.3 c.i.	C-0.425	R-2.2 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-0.496	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-0.188	R-5.3	U-0.188	R-5.3	U-0.188	R-5.3
Slab-On-Grade Floors						
Unheated	F-0.900	R-2.6 for 600 mm	F-0.883	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-2.839	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-1.99		U-1.99		U-3.69	
Metal framing (curtainwall/storefront)[c]	U-2.27	SHGC-0.45 all	U-2.27	SHGC-NR all	U-3.41	SHGC-NR all
Metal framing (entrance door)[c]	U-4.54		U-4.54		U-5.11	
Metal framing (all other)[c]	U-2.56		U-2.56		U-3.69	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–5.56	$SHGC_{all}$–NR	U_{all}–5.56	$SHGC_{all}$–NR	U_{all}–7.38	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–5.56	$SHGC_{all}$–NR	U_{all}–5.56	$SHGC_{all}$–NR	U_{all}–7.38	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–3.46	$SHGC_{all}$–NR	U_{all}–3.46	$SHGC_{all}$–NR	U_{all}–6.25	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.46	$SHGC_{all}$–NR	U_{all}–3.46	$SHGC_{all}$–NR	U_{all}–6.25	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.29	$SHGC_{all}$–NR	U_{all}–3.29	$SHGC_{all}$–NR	U_{all}–4.60	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.29	$SHGC_{all}$–NR	U_{all}–3.29	$SHGC_{all}$–NR	U_{all}–4.60	$SHGC_{all}$–NR

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

[b] Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.

[c] Metal framing includes metal framing with or without thermal break. The “all other” subcategory includes operable windows, fixed windows, and non-entrance doors.

Exceptions to Section 5.5.3:

a. For assemblies significantly different from those in Appendix A, calculations shall be performed in accordance with the procedures required in Appendix A.
b. For multiple assemblies within a single *class of construction* for a single *space-conditioning category*, compliance shall be shown for either (1) the most restrictive requirement or (2) 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 or shall comply with the insulation values specified in Section 5.5.3.1.1 and Table 5.5.3.1. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-0.9, whichever is less.

5.5.3.1.1 High Albedo Roofs. For *roofs*, other than *roofs* over ventilated attics or *roofs* over *semi-heated spaces* or *roofs* over *conditioned spaces* that are not *cooled spaces*, where the exterior surface has

a. a solar reflectance of 0.70 when tested in accordance with ASTM C1549, ASTM E903, or ASTM E1918 and, in addition, a minimum thermal emittance of 0.75 when tested in accordance with ASTM C1371 or ASTM E408 or
b. a minimum Solar Reflective Index of 82 when determined in accordance with the Solar Reflectance Index method in ASTM E1980,

the insulation value for the roof shall comply with the values in Table 5.5.3.1. The values for solar reflectance and thermal emittance shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the Cool Roof Rating Council CRRC-1 Product Rating Program, and shall be labeled and certified by the manufacturer.

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

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

5.5.3.3 Below-Grade Wall Insulation. *Below-grade walls* shall have a *rated R-value of insulation* not less that 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.

TABLE 5.5.3.1 High Albedo Roof Insulation

Climate Zone	Opaque Elements (Roofs)	Nonresidential		Residential	
		Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
1	Insulation entirely above deck	U-0.466	R-2.1 c.i.	U-0.460	R-2.1 c.i.
	Metal building	U-0.477	R-2.3	U-0.477	R-2.3
	Attic and other[a]	U-0.250	R-4.2	U-0.199	R-5.3
2	Insulation entirely above deck	U-0.432	R-2.3 c.i.	U-0.432	R-2.3 c.i.
	Metal building	U-0.443	R-2.3	U-0.443	R-2.3
	Attic and other[a]	U-0.238	R-4.4	U-0.182	R-5.3
3	Insulation entirely above deck	U-0.420	R-2.3 c.i.	U-0.420	R-2.3 c.i.
	Metal building	U-0.432	R-2.8	U-0.432	R-2.8
	Attic and other[a]	U0.227	R-4.4	U-0.182	R-5.3
4, 5, 6, 7, 8	All roof opaque elements	NP	NP	NP	NP

NP = Not permitted.
[a]Excludes roofs over ventilated attics, or roofs over semiheated spaces, or roofs over conditioned spaces that are not cooled spaces.

5.5.4 Fenestration

5.5.4.1 General. Compliance with *U-factors* and *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* or *SHGC*. It is not acceptable to do an area-weighted average across multiple *classes of construction* or multiple *space-conditioning categories*.

5.5.4.2 Fenestration Area

5.5.4.2.1 Vertical Fenestration Area. The total *vertical fenestration area* shall be less than 40% of the *gross wall area*.

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

5.5.4.2.2 Skylight Fenestration Area. The total *skylight area* shall be less than 5% of the *gross roof area*.

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 for the appropriate *fenestration area*.

5.5.4.4 Fenestration Solar Heat aGain Coefficient (SHGC)

5.5.4.4.1 SHGC of Vertical Fenestration. *Vertical fenestration* shall have an *SHGC* not greater than that specified for "all" orientations in Tables 5.5-1 through 5.5-8 for the appropriate total *vertical fenestration area*.

Exceptions:

a. 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.

b. 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 *PF* shall be reduced by multiplying it by a factor of O_s, which is derived as follows:

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

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%

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

c. *Vertical fenestration* that is located on the street side of the street-level story only, provided that

1. the street side of the street-level story does not exceed 6 m in height,
2. the *fenestration* has a continuous overhang with a weighted average *PF* greater than 0.5, and
3. 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.

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

5.5.4.4.2 SHGC of Skylights. *Skylights* shall have an *SHGC* not greater than that specified for "all" orientations in Tables 5.5-1 through 5.5-8 for the appropriate total *skylight area*.

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 The *envelope performance factor* considers only the *building envelope* components.

5.6.1.2 Schedules of operation, lighting power, equipment power, occupant density, and mechanical systems shall be the same for both the proposed building and the budget building.

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.

5.8 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.C.

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.

5.8.2 Fenestration and Doors

5.8.2.1 Rating of Fenestration Products. The U-factor, SHGC, 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 Products. All manufactured *fenestration* products shall have a permanent nameplate, installed by the *manufacturer*, listing the U-factor, SHGC, and air leakage rate.

Exception: When the *fenestration* product does not have such nameplate, the installer or supplier of such *fenestration* shall provide a signed and dated certification for the installed fenestration listing the U-factor, SHGC, and the air leakage rate.

5.8.2.3 Labeling of Doors. The *U-factor* and the air leakage rate for all manufactured *doors* installed between *conditioned space*, *semi-heated space*, *unconditioned space*, and exterior *space* shall be identified on a permanent nameplate installed on the product by the *manufacturer.*

Exception: When doors do not have such a nameplate, the installer or supplier of any such doors shall provide a signed and dated certification for the installed doors listing the *U-factor* and the air leakage rate.

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

Exceptions:

a. 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*.

b. U-factors from Section A8.2 shall be an acceptable alternative for determining compliance with the U-factor criteria for *vertical fenestration*.

c. U-factors from Section A7 shall be an acceptable alternative for determining compliance with the U-factor criteria for *opaque doors*.

d. For garage doors, ANSI/DASMA105 shall be an acceptable alternative for determining *U-factors*.

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

Exceptions:

a. *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.*

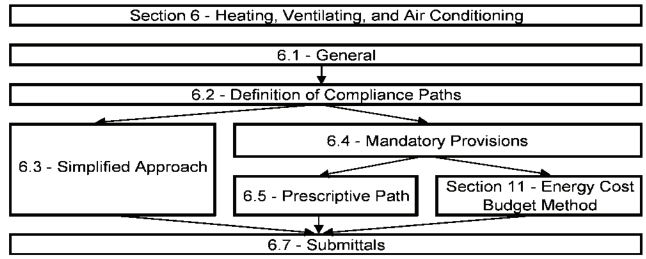
b. *SHGC* of the center-of-glass shall be an acceptable alternative for determining compliance with the *SHGC* requirements for the overall *fenestration area*. *SHGC* shall be determined using a spectral data file determined in accordance with NFRC 300. SHGC shall be verified and certified by the *manufacturer.*

c. *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.*

d. *SHGC* from Section A8.2 shall be an acceptable alternative for determining compliance with the *SHGC* criteria for *vertical fenestration*.

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

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, or ventilating 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, or ventilating needs of *additions* to *existing buildings* shall comply with the requirements of this section as described in Section 6.2.

Exception: When HVAC to an *addition* is provided by existing *HVAC 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, and Air Conditioning in Existing Buildings

6.1.1.3.1 New HVAC equipment as a direct replacement of existing HVAC 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

a. 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;

b. where a replacement or *alteration* of *equipment* requires extensive revisions to other *systems*, *equip-*

ment, or elements of a *building*, and such replaced or altered equipment is a like-for-like replacement;

c. for a refrigerant change of existing *equipment*;

d. for the relocation of existing *equipment*; or

e. for ducts and pipes where there is insufficient space or access to meet these requirements.

6.2 Compliance Path(s)

6.2.1 Compliance with Section 6 shall be achieved by meeting all requirements for Section 6.1, General; Section 6.7, Submittals; Section 6.8, Minimum Equipment Efficiency; and either

a. Section 6.3, Simplified Approach Option for HVAC Systems; or

b. Section 6.4, Mandatory Provisions; and Section 6.5, Prescriptive Path.

6.2.2 Projects using the Energy Cost Budget Method (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. 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. 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 6.8.1A (air conditioners), Table 6.8.1B (heat pumps), or Table 6.8.1D (packaged terminal and room air conditioners and heat pumps) for the applicable equipment category.

c. The *system* shall have an air economizer where indicated in Table 6.5.1, with controls as indicated in Tables 6.5.1.1.3A and 6.5.1.1.3B and with either barometric or powered relief sized to prevent overpressurization of the building. Where the cooling *efficiency* meets or exceeds the *efficiency* requirement in Table 6.3.2, no economizer is required. *Outdoor air* dampers for economizer use shall be provided with blade and jamb seals.

d. Heating (if any) shall be provided by a unitary packaged or split-system heat pump that meets the applicable *efficiency* requirements shown in Table 6.8.1B (heat pumps) or Table 6.8.1D (packaged terminal and room air conditioners and heat pumps), a fuel-fired furnace that meets the applicable *efficiency* requirements shown in Table 6.8.1E (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 6.8.1F (boilers).

e. The *outdoor air* quantity supplied by the system shall be less than or equal to 1400 L/s and less than 70% of the supply air quantity at minimum *outdoor air* design conditions unless an energy recovery ventilation system is provided in accordance with the requirements in Section 6.5.6.

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

TABLE 6.3.2 Eliminate Required Economizer by Increasing Cooling Efficiency

Unitary Systems with Heat Pump Heating

System Size (kW)	Mandatory Minimum COP_c[a]	Climate Zones: 5 to 8	4	3	2	Test Procedure[c]
		Minimum Cooling Efficiency Required (COP_c)[a]				
≥19 and <40	2.96	N/A[b]	3.55	3.40	3.25	ARI 340/360
≥40 and <70	2.72	N/A[b]	3.31	3.16	3.05	
≥70 and <223	2.64	N/A[b]	3.19	3.08	2.93	

Other Unitary Systems

System Size (kW)	Mandatory Minimum COP_c[a]	Climate Zones: 5 to 8	4	3	2	Test Procedure[c]
		Minimum Cooling Efficiency Required (COP_c)[a]				
≥19 and <40	3.02	N/A[b]	3.66	3.52	3.37	ARI 340/360
≥40 and <70	2.84	N/A[b]	3.37	3.24	3.11	
≥70 and <223	2.78	N/A[b]	3.28	3.14	3.02	

[a] Each COP_c shown should be reduced by 0.0586 for units with a heating section other than electric resistance heat.
[b] Elimination of required economizer is not allowed.
[c] Section 12 contains complete specification of the referenced test procedure, including the referenced year version of the test procedure.

g. 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. Two means of meeting this requirement are (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 outside air temperature is less than 4°C. Heat pumps whose minimum efficiency is regulated by NAECA and whose HSPF rating both meets the requirements shown in Table 6.8.1B and includes all usage of internal electric resistance heating are exempted from the control requirements of this part (Section 6.3.2[g]).
h. The *system* controls shall not permit reheat or any other form of simultaneous heating and cooling for humidity control.
i. *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 0.5 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.
j. Except for piping within *manufacturers'* units, HVAC piping shall be insulated in accordance with Table 6.8.3. 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.
k. Ductwork and plenums shall be insulated in accordance with Tables 6.8.2A and 6.8.2B and shall be sealed in accordance with Table 6.4.4.2A.
l. Construction documents shall require a ducted *system* to be air balanced in accordance with industry-accepted procedures.
m. Where separate heating and cooling equipment serves the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling.
n. Exhausts with a design capacity of over 140 L/s on *systems* that do not operate continuously shall be equipped with gravity or motorized dampers that will automatically shut when the *systems* are not in use.
o. *Systems* with a design supply air capacity greater than 5000 L/s shall have *optimum start controls.*

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 6.8.1A through 6.8.1G 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 6.8.1A—Air Conditioners and Condensing Units
b. Table 6.8.1B—Heat Pumps
c. Table 6.8.1C—Water-Chilling Packages (see Section 6.4.1.2 for water-cooled centrifugal water-chilling packages that are designed to operate at nonstandard conditions)
d. Table 6.8.1D—Packaged Terminal and Room Air Conditioners and Heat Pumps
e. Table 6.8.1E—Furnaces, Duct Furnaces, and Unit Heaters
f. Table 6.8.1F—Boilers
g. Table 6.8.1G—Heat Rejection Equipment

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.

6.4.1.2 Minimum Equipment Efficiencies—Listed Equipment—Nonstandard Conditions. Water-cooled centrifugal water-chilling packages that are not designed for operation at ARI Standard 550/590 test conditions (and, thus, cannot be tested to meet the requirements of Table 6.8.1C) of 6.7°C leaving chilled-water temperature and 29.4°C entering condenser-water temperature with 15.3 L/min·kW condenser-water flow shall have a minimum full-load COP and a minimum *NPLV* rating as shown in the tables referenced below.

a. Centrifugal chillers <528 kW shall meet the minimum full-load COP and IPLV/NPLV in Table 6.8.1H.
b. Centrifugal chillers ≥528 kW and <1055 kW shall meet the minimum full-load COP and IPLV/NPLV in Table 6.8.1I.
c. Centrifugal chillers ≥1055 kW shall meet the minimum full-load COP and IPLV/NPLV in Table 6.8.1J.

The table values are only applicable over the following full-load design ranges:

- Leaving Chiller-Water Temperature: 4.4°C to 8.9°C
- Entering Condenser-Water Temperature: 23.9°C to 29.4°C
- Condenser-Water Temperature Rise: 2.8°C to 8.3°C

Chillers designed to operate outside of these ranges or applications utilizing fluids or solutions with secondary coolants (e.g., glycol solutions or brines) with a freeze point of –2.8°C or lower for freeze protection are not covered by this standard.

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 as follows:

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, or
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, or
d. if no certification program exists for a covered product, the equipment *efficiency* ratings shall be supported by data furnished by the *manufacturer*, or
e. where components such as indoor or outdoor coils from different *manufacturers* are used, the system designer shall specify component efficiencies whose combined *efficiency* meets the minimum equipment *efficiency* requirements in Section 6.4.1.

6.4.1.5 Labeling

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

6.4.1.5.2 Packaged Terminal Air Conditioners. Packaged terminal air conditioners and heat pumps with sleeve sizes less than 0.4 m high and 1.0 m wide shall be factory labeled as follows: *Manufactured for replacement applications only: not to be installed in new construction projects.*

6.4.2 Load Calculations. Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with generally accepted engineering standards and handbooks acceptable to the *adopting authority* (for example, *ASHRAE Handbook—Fundamentals*).

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 Section 6.4.3.1, 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

a. the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one *orientation* for 15 contiguous meters or more, and
b. 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:

a. Thermostats that require manual changeover between heating and cooling modes.
b. 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:

a. *HVAC systems* intended to operate continuously.
b. *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.

6.4.3.3.2 Setback Controls. Heating systems located in climate zones 2–8 shall be equipped with controls that have the capability to automatically restart and temporarily operate the system as required to maintain *zone* temperatures above a heating setpoint adjustable down to 13°C or lower. Cooling systems located in climate zones 1b, 2b, and 3b shall be equipped with controls that have the capability to automatically restart and temporarily operate the system as required to maintain *zone* temperatures below a cooling setpoint adjustable up to 32°C or higher or to prevent high space humidity levels.

Exception: Radiant floor and ceiling heating *systems*.

6.4.3.3.3 Optimum Start Controls. Individual heating and cooling air distribution systems with a total design supply air capacity exceeding 5000 L/s, served by one or more supply fans, shall have *optimum start controls*. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied setpoint and the amount of time prior to scheduled occupancy.

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 m^2 of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with *isolation devices* capable of automatically shutting off the supply of conditioned air and *outdoor air* to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting the requirements of Section 6.4.3.3.1, Automatic Shutdown. 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 the following:

a. Exhaust air and *outdoor air* connections to isolation *zones* when the fan system to which they connect is 2400 L/s and smaller.
b. Exhaust airflow from a single isolation *zone* of less than 10% of the design airflow of the exhaust system to which it connects.
c. *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 Gravity Hoods, Vents, and Ventilators. All *outdoor air* supply and exhaust hoods, vents, and ventilators shall be equipped with motorized dampers that will automatically shut when the spaces served are not in use.

Exceptions:

a. Gravity (nonmotorized) dampers are acceptable in buildings less than three stories in height above grade and for buildings of any height located in climate zones 1, 2, and 3.
b. Ventilation systems serving *unconditioned spaces*.

6.4.3.4.3 Shutoff Damper Controls. Both *outdoor air* supply 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* dampers shall be capable of automatically shutting off during preoccupancy building warm-up, cool down, and *setback,* except when *ventilation* reduces energy costs (e.g., night purge) or when ventilation must be supplied to meet code requirements.

Exceptions:

a. Gravity (nonmotorized) dampers are acceptable in buildings less than three stories in height and for buildings of any height located in climate zones 1, 2, and 3.
b. Gravity (nonmotorized) dampers are acceptable in systems with a design *outdoor air* intake or exhaust capacity of 140 L/s or less.

6.4.3.4.4 Dampers. Where *outdoor air* supply and exhaust air dampers are required by Section 6.4.3.4, they shall have a maximum leakage rate when tested in accordance with AMCA Standard 500 as indicated in Table 6.4.3.4.4.

6.4.3.4.5 Ventilation Fan Controls. Fans with motors greater than 0.5 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.

6.4.3.5 Heat Pump Auxiliary Heat Control. Heat pumps equipped with internal electric resistance heaters shall

TABLE 6.4.3.4.4 Maximum Damper Leakage

Climate Zones	Maximum Damper Leakage at 250 Pa (L/s per m^2 of damper area)	
	Motorized	Nonmotorized
1, 2, 6, 7, 8	20	Not allowed
All others	50	100[a]

[a] Dampers smaller than 0.6 m in either dimension may have leakage of 200 L/s per m^2.

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.

Exceptions: Heat pumps whose minimum *efficiency* is regulated by NAECA and whose HSPF rating both meets the requirements shown in Table 6.8.1B and includes all usage of internal electric resistance heating.

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

6.4.3.7 Humidification and Dehumidification. 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:

a. Zones served by desiccant systems, used with direct evaporative cooling in series.
b. Systems serving zones where specific humidity levels are required, such as museums and hospitals, and approved by the *authority having jurisdiction*.

6.4.3.8 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.

6.4.3.9 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 40 people per 100 m^2 of floor area and served by systems with one or more of the following:

a. an air-side economizer,
b. automatic modulating control of the outdoor air damper, or
c. a design outdoor airflow greater than 1400 L/s.

Exceptions:

a. Systems with energy recovery complying with Section 6.5.6.1.
b. Multiple-zone systems without DDC of individual zones communicating with a central control panel.
c. Systems with a design outdoor airflow less than 600 L/s.
d. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 600 L/s.

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 6.8.2A and 6.8.2B.

Exceptions:

a. Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with Section 6.4.1.
b. Ducts or plenums located in heated spaces, *semi-heated spaces*, or cooled spaces.
c. 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.
d. 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 Table 6.8.3.

Exceptions:

a. Factory-installed piping within HVAC equipment tested and rated in accordance with Section 6.4.1.
b. Piping that conveys fluids having a design operating temperature range between 16°C and 41°C, inclusive.
c. Piping that conveys fluids that have not been heated or cooled through the use of nonrenewable energy (such as roof and condensate drains, domestic cold water supply, natural gas piping, or refrigerant liquid piping) or where heat gain or heat loss will not increase energy usage.

d. Hot-water piping between the shutoff valve and the coil, not exceeding 1.2 m in length, when located in *conditioned spaces*.

e. Pipe unions in heating systems (steam, steam condensate, and hot water).

6.4.4.2 Ducts and Plenum Leakage

6.4.4.2.1 Duct Sealing. Ductwork and plenums shall be sealed in accordance with Table 6.4.4.2A (Table 6.4.4.2B provides definitions of seal levels), as required to meet the requirements of Section 6.4.4.2.2 and with standard industry practice (see Informative Appendix E).

6.4.4.2.2 Duct Leakage Tests. Ductwork that is designed to operate at static pressures in excess of 750 Pa 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. Duct systems with pressure ratings in excess of 750 Pa shall be identified on the drawings. The maximum permitted duct leakage shall be

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

where

L_{max} = maximum permitted leakage in L/s·m^2 duct surface area;

C_L = duct leakage class, m L/s·m^2 at 1 Pa,

8 for rectangular sheetmetal, rectangular fibrous, and round flexible ducts,

4 for round/flat oval sheetmetal or fibrous glass ducts; and

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

TABLE 6.4.4.2A Minimum Duct Seal Level[a]

Duct Location	Duct Type			
	Supply		Exhaust	Return
	≤500 Pa[b]	>500 Pa[b]		
Outdoor	A	A	C	A
Unconditioned spaces	B	A	C	B
Conditioned spaces[c]	C	B	B	C

[a] See Table 6.4.4.2B description of seal level.
[b] Duct design static pressure classification.
[c] Includes indirectly conditioned spaces such as return air plenums.

TABLE 6.4.4.2B Duct Seal Levels

Seal Level	Sealing Requirements[a]
A	All transverse joints, longitudinal seams, and duct wall penetrations. 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.
B	All transverse joints, longitudinal seams. 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.
C	Transverse joints only.

[a] Longitudinal seams are joints oriented in the direction of airflow. Transverse joints are connections of two duct sections oriented perpendicular to airflow. Duct wall penetrations are openings made by any screw fastener, pipe, rod, or wire. Spiral lock seams in a round or flat oval duct need not be sealed. All other connections are considered transverse joints, including but not limited to spin-ins, taps, and other branch connections, access door frames and jambs, duct connections to equipment, etc.

6.4.5 Completion Requirements. Completion requirements are as described in Section 6.7.2.

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 6.5.1.4.

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

a. Individual fan-cooling units with a supply capacity less than the minimum listed in Table 6.5.1.
b. Systems that include nonparticulate air treatment as required by Section 6.2.1 in Standard 62.1.
c. 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.
d. Systems that include a condenser heat recovery system required by Section 6.5.6.2.
e. Systems that serve *residential* spaces where the system capacity is less than five times the requirement listed in Table 6.5.1.
f. 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.
g. Systems expected to operate less than 20 hours per week.
h. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework systems.
i. Where the cooling *efficiency* meets or exceeds the *efficiency* requirements in Table 6.3.2.

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

TABLE 6.5.1 Minimum System Size for Which an Economizer is Required

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	≥19 kW

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 for specific climates shall be chosen from Table 6.5.1.1.3A. High-limit shutoff control settings for these control types shall be those listed in Table 6.5.1.1.3B.

6.5.1.1.4 Dampers. Both return air and *outdoor air* dampers shall meet the requirements of Section 6.4.3.3.4.

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 to avoid recirculation into the building.

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.

Exception: Systems in which a water economizer is used and where dehumidification requirements cannot be met using *outdoor air* temperatures of 10°C dry bulb/7°C

TABLE 6.5.1.1.3A High-Limit Shutoff Control Options for Air Economizers

Climate Zones	Allowed Control Types	Prohibited Control Types
1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	Fixed dry bulb Differential dry bulb Electronic enthalpy[a] Differential enthalpy Dew-point and dry-bulb temperatures	Fixed enthalpy
1a, 2a, 3a, 4a	Fixed dry bulb Fixed enthalpy Electronic enthalpy[a] Differential enthalpy Dew-point and dry-bulb temperatures	Differential dry bulb
All other climates	Fixed dry bulb Differential dry bulb Fixed enthalpy Electronic enthalpy[a] Differential enthalpy Dew-point and dry-bulb temperatures	

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

TABLE 6.5.1.1.3B High-Limit Shutoff Control Settings for Air Economizers

Device Type	Climate	Required High Limit (Economizer Off When):	
		Equation	**Description**
Fixed dry bulb	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 5a, 6a, 7a All other zones	$T_{OA} > 24°C$ $T_{OA} > 21°C$ $T_{OA} > 18°C$	Outdoor air temperature exceeds 24°C Outdoor air temperature exceeds 21°C Outdoor air temperature exceeds 18°C
Differential dry bulb	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	All	$h_{OA} > 47$ kJ/kg[a]	Outdoor air enthalpy exceeds of dry air[a]
Electronic enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outdoor air temperature/RH exceeds the "A" setpoint curve[b]
Differential enthalpy	All	$h_{OA} > h_{RA}$	Outdoor air enthalpy exceeds return air enthalpy
Dew-point and dry-bulb temperatures	All	$DP_{oa} > 18°C$ or $T_{oa} > 24°C$	Outdoor air dry bulb exceeds 24°C or outside dew point exceeds 13°C (65 gr/lb)

[a] At altitudes substantially different than sea level, the Fixed Enthalpy limit shall be set to the enthalpy value at 24°C and 50% relative humidity. As an example, at approximately 1830 melevation the fixed enthalpy limit is approximately 53.5 kJ/kg.
[b] Setpoint "A" corresponds to a curve on the psychrometric chart that goes through a point at approximately 24°C and 40% relative humidity and is nearly parallel to dry-bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.

wet bulb must satisfy 100% of the expected system cooling load at 7°C dry bulb/4°C wet bulb.

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 or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

6.5.1.3 Integrated Economizer Control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

Exceptions:

a. Direct expansion systems that include controls that reduce the quantity of *outdoor air* required to prevent coil frosting at the lowest step of compressor unloading, provided this lowest step is no greater than 25% of the total system capacity.
b. Individual direct expansion units that have a rated cooling capacity less than 19 kW and use nonintegrated economizer controls that preclude simultaneous operation of the economizer and mechanical cooling.
c. Systems in climate zones 1, 2, 3a, 4a, 5a, 5b, 6, 7, and 8.

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

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

6.5.2 Simultaneous Heating and Cooling Limitation

6.5.2.1 Zone Controls. *Zone* thermostatic controls shall be capable of operating in sequence the supply of heating and cooling energy to the *zone*. Such controls shall prevent

1. *reheating*,
2. *recooling*,
3. 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
4. other simultaneous operation of heating and cooling systems to the same *zone*.

Exceptions:

a. *Zones* for which the volume of air that is reheated, recooled, or mixed is no greater than the larger of the following:
    1. the volume of *outdoor air* required to meet the ventilation requirements of Section 6.2 of Standard 62.1 for the *zone*,
    2. 2 L/s·m^2 of the *zone* conditioned floor area,
    3. 30% of the zone design peak supply rate,
    4. 140 L/s—this exception is for zones whose peak flow rate totals no more than 10% of the total fan system flow rate, or
    5. 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.
b. *Zones* where special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates are such that VAV systems are impractical.
c. *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.*

6.5.2.2 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 12°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 humidistatic 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:

a. The system is capable of reducing supply air volume to 50% or less of the design airflow rate or the minimum rate specified in Section 6.2 of Standard 62.1, whichever is larger, before simultaneous heating and cooling takes place.
b. The individual fan cooling unit has a design cooling capacity of 23 kW or less and is capable of unloading to 50% capacity before simultaneous heating and cooling takes place.
c. 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.
d. Systems serving spaces where specific humidity levels are required to satisfy process needs, such as computer rooms, museums, surgical suites, and buildings with refrigerating systems, such as supermarkets, refrigerated warehouses, and ice arenas. This exception also applies to other applications for which fan volume controls in accordance with Exception (a) are proven to be impractical to the enforcement agency.
e. 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.
f. 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. Systems with hydronic cooling and humidification systems 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.

6.5.3 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 6.5.3.2.

6.5.3.1 Fan System Power Limitation

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 6.5.3.1.1A. This includes supply fans, return/relief fans, exhaust fans, and fan-powered terminal units associated with systems providing heating or cooling capability.

Exceptions:

a. Hospital 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**.**
b. Individual exhaust fans with motor nameplate kW of 0.75 kW or less.
c. Fans exhausting air from fume hoods. ***Note:*** If this exception is taken, no related exhaust side credits shall be taken from Table 6.5.3.1.1B and the Fume Hood Exhaust Exception Deduction must be taken from Table 6.5.3.1.1B.

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

TABLE 6.5.3.1.1A Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan System Motor Nameplate kW	Allowable Nameplate Motor kW	kW $\leq L/S_S \cdot 0.0017$	kW $\leq L/S_S \cdot 0.0024$
Option 2: Fan System input kW	Allowable Fan System input kW	input $kW_i \leq L/S_S \cdot 0.0015 + A$	input $kW_i \leq L/S_S \cdot 0.0021 + A$

[a] where
L/S_S = the maximum design supply airflow rate to conditioned spaces served by the system in liters per second
kW = the maximum combined motor nameplate kW
input kW_i = the maximum combined fan input kW
A = sum of ($PD \times L/S_D$/650100)
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1.1B in Pa.
CFM_D = the design airflow through each applicable device from Table 6.5.3.1.1B in liters per second

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	125 Pa
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
Heat recovery device	Pressure drop of device at fan system design condition
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	38 Pa
Deductions	
Fume Hood Exhaust Exception (required if 6.5.3.1.1 Exception [c] is taken)	–250 Pa

Exceptions:

a. 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.

b. For fans 4.5 kW and larger, where the first available motor larger than the input kW has a nameplate rating with 30% of the input kW, the next larger nameplate motor size may be selected.

6.5.3.2 VAV Fan Control (Including Systems Using Series Fan Power Boxes)

6.5.3.2.1 Part-Load Fan Power Limitation. Individual VAV fans with motors 7.3 kW and larger shall meet one of the following:

a. The fan shall be driven by a mechanical or electrical variable-speed drive.
b. The fan shall be a vane-axial fan with variable-pitch blades.
c. The fan shall have other controls and devices that will result in fan motor demand of no more than 30% of design wattage at 50% of design air volume when static pressure setpoint equals one-third of the total design static pressure, based on *manufacturers'* certified fan data.

6.5.3.2.2 Static Pressure Sensor Location. Static pressure sensors used to control VAV fans shall be placed in a position such that the controller setpoint is no greater than one-third the total design fan static pressure, except for systems with zone reset control complying with Section 6.5.3.2.3. If this results in the sensor being located downstream of major duct splits, multiple sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.

6.5.3.2.3 Setpoint Reset. For systems with DDC of individual zone boxes 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.

6.5.4 Hydronic System Design and Control. HVAC hydronic systems having a total *pump system power* exceeding 7.5 kW shall meet provisions of Sections 6.5.4.1 through 6.5.4.4.

6.5.4.1 Hydronic Variable Flow Systems. HVAC pumping systems 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 pumps serving variable flow systems having a pump head exceeding 300 kPa and motor exceeding 37 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 required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure.

Exceptions:

a. 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 60 kW or less.

b. Systems that include no more than three control valves.

6.5.4.2 Pump Isolation. When a chilled-water plant includes more than one chiller, provisions shall be made so that the flow in the chiller plant can be automatically reduced, correspondingly, when a chiller is shut down. Chillers referred to in this section, piped in series for the purpose of increased temperature differential, shall be considered as one chiller.

When a boiler plant includes more than one boiler, provisions shall be made so that the flow in the boiler plant can be automatically reduced, correspondingly, when a boiler is shut down.

6.5.4.3 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:

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

6.5.4.4 Hydronic (Water Loop) Heat Pump Systems. Each hydronic heat pump shall have a two-position automatic valve interlocked to shut off water flow when the compressor is off.

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, open 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 6.8.1A through 6.8.1D.

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

Exceptions:

a. Condenser fans serving multiple refrigerant circuits.
b. Condenser fans serving flooded condensers.
c. Installations located in climate zones 1 and 2.
d. Up to one-third of the fans on a condenser or tower with multiple fans, where the lead fans comply with the speed control requirement.

6.5.6 Energy Recovery

6.5.6.1 Exhaust Air Energy Recovery. Individual fan systems that have both a design supply air capacity of 2400 L/s or greater and have a minimum *outdoor air* supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% 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 at design conditions. Provision shall be made to bypass or control the heat recovery system to permit air economizer operation as required by Section 6.5.1.1.

Exceptions:

a. Laboratory systems meeting Section 6.5.7.2.
b. Systems serving spaces that are not cooled and that are heated to less than 16°C.
c. Systems exhausting toxic, flammable, paint, or corrosive fumes or dust.
d. Commercial kitchen hoods used for collecting and removing grease vapors and smoke.
e. Where more than 60% of the *outdoor air* heating energy is provided from site-recovered or site-solar energy.
f. Heating systems in climate zones 1 through 3.
g. Cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8.
h. Where the largest exhaust source is less than 75% of the design outdoor airflow.
i. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.

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:

a. 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.
b. Facilities that provide 60% of their service water heating from *site-solar* or *site-recovered energy* or from other sources.

6.5.7 Exhaust Hoods

6.5.7.1 Kitchen Hoods. Individual kitchen exhaust hoods larger than 2500 L/s shall be provided with makeup air sized for at least 50% of exhaust air volume that is

a. unheated or heated to no more than 16°C and
b. uncooled or cooled without the use of mechanical cooling.

Exceptions:

a. Where hoods are used to exhaust ventilation air that would otherwise exfiltrate or be exhausted by other fan systems.

b. Certified grease extractor hoods that require a face velocity no greater than 18 m/s.

6.5.7.2 Fume Hoods. Buildings with fume hood systems having a total exhaust rate greater than 7500 L/s shall include at least one of the following features:

a. VAV hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50% or less of design values.
b. Direct makeup (auxiliary) air supply equal to at least 75% of the exhaust rate, heated no warmer than 1°C below room setpoint, cooled to no cooler than 2°C above room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
c. Heat recovery systems to precondition makeup air from fume hood exhaust in accordance with Section 6.5.6.1, Exhaust Air Energy Recovery, without using any exception.

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.

Exception: Unitary packaged systems with cooling capacities not greater than 26.4 kW.

6.6 Alternative Compliance Path (Not Used)

6.7 Submittals

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

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 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 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

a. for pumps with pump motors of 7.5 kW or less or

TABLE 6.5.9 Hot Gas Bypass Limitation

Rated Capacity	Maximum Hot Gas Bypass Capacity (% of Total Capacity)
≤70 kW	50%
>70 kW	25%

b. when throttling results in no greater than 5% of the nameplate kW draw, or 2.25 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

TABLE 6.8.1A Electronically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, air cooled	<19 kW[c]	All	Split system	10.0 SEER (before 1/23/2006) 3.81 SCOP (as of 1/23/2006)	ARI 210/240
			Single package	9.7 SEER (before 1/23/2006) 3.81 SCOP (as of 1/23/2006)	
Through-the-wall, air cooled	≤8.8 kW[c]	All	Split system	2.93 SCOP (before 1/23/2006) 3.19 SCOP(as of 1/23/2006) 3.52 SCOP(as of 1/23/2010)	
			Single package	2.84 SCOP (before 1/23/2006) 3.11 SCOP(as of 1/23/2006) 3.52 SCOP(as of 1/23/2010)	
Air conditioners, air cooled	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	3.02 COP (before 1/1/2010) 3.28 COP (as of 1/1/2010)	ARI 340/360
		All other	Split system and single package	2.96 COP (before 1/1/2010) 3.22 COP (as of 1/1/2010)	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	2.84 COP (before 1/1/2010) 3.22 COP (as of 1/1/2010)	
		All other	Split system and single package	2.78 COP (before 1/1/2010) 3.16 COP (as of 1/1/2010)	
	≥70 kW and <223 kW	Electric resistance (or none)	Split system and single package	2.78 COP (before 1/1/2010) 2.93 COP (as of 1/1/2010) 2.84 IPLV	
		All other	Split system and single package	2.72 COP (before 1/1/2010) 2.87 COP (as of 1/1/2010) 2.78 IPLV	
	≥223 kW	Electric resistance (or none)	Split system and single package	2.70 COP (before 1/1/2010) 2.84 COP (as of 1/1/2010) 2.75 IPLV	
		All other	Split system and single package	2.64 COP (as of 1/1/2010) 2.78 COP (as of 1/1/2010) 2.69 IPLV	

TABLE 6.8.1A Electronically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements *(continued)*

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, water and evaporatively cooled	<19 kW	All	Split system and single package	3.35 COP	ARI 210/240
	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	3.37 COP	ARI 340/360
		All other	Split system and single package	3.31 COP	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	3.22 COP	
		All other	Split system and single package	3.16 COP	
	≥70 kW	Electric resistance (or none)	Split system and single package	2.70 COP 3.02 IPLV	
		All other	Split system and single package	2.64 COP 2.96 IPLV	
Condensing units, air cooled	≥40 kW	–		2.96 COP 3.28 IPLV	ARI 365
Condensing units, water or evaporatively cooled	≥40 kW	–		3.84 COP 3.84 IPLV	

[a] IPLVs and part-load rating conditions are only applicable to equipment with capacity modulation.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air cooled (cooling mode)	<19 kW[c]	All	Split system	2.93 $SCOP_c$ (before 1/23/2006) 3.81 SCOP (as of 1/23/2006)	ARI 210/240
			Single package	2.84 $SCOP_c$ (before 1/23/2006) 3.81 SCOP (as of 1/23/2006)	
Through-the-wall (air cooled, cooling mode)	≤8.8 kW[c]	All	Split system	2.93 $SCOP_c$ (before 1/23/2006) 3.19 $SCOP_c$ (as of 1/23/2006) 3.52 $SCOP_c$ (as of 1/23/2010)	
			Single package	2.84 $SCOP_c$ (before 1/23/2006) 3.11 $SCOP_c$ (as of 1/23/2006) 3.52 $SCOP_c$ (as of 1/23/2010)	
Air cooled (cooling mode)	≥19 kW and <40 kW	Electric resistance (or none)	Split system and single package	2.96 COP_C (before 1/1/2010) 3.22 COP_C (as of 1/1/2010)	ARI 340/360
		All other	Split system and single package	2.90 COP_C (before 1/1/2010) 3.16 COP_C (as of 1/1/2010)	
	≥40 kW and <70 kW	Electric resistance (or none)	Split system and single package	2.72 COP_C (before 1/1/2010) 3.10 COP_C (as of 1/1/2010)	
		All other	Split system and single package	2.66 COP_C (before 1/1/2010) 3.04 COP_C (as of 1/1/2010)	
	≥70 kW	Electric resistance (or none)	Split system and single package	2.64 COP_C (before 1/1/2010) 2.78 COP_C (as of 1/1/2010) 2.70 IPLV	
		All other	Split system and single package	2.58 COP_C (before 1/1/2010) 2.72 COP_C (as of 1/1/2010) 2.64 IPLV	
Water source (cooling mode)	<5 kW	All	30.0°C entering water	3.28 COP_C	ISO-13256-1
	≥5 kW and <19 kW	All	30.0°C entering water	3.52 COP_C	ISO-13256-1
	≥19 kW and <40 kW	All	30.0°C entering water	3.52 COP_C	ISO-13256-1
Groundwater source (cooling mode)	<40 kW	All	15°C entering water	4.75 COP_C	ISO-13256-1
Ground source (cooling mode)	<40 kW	All	25°C entering water	3.93 COP_C	ISO-13256-1
Air cooled (heating mode)	<40 kW[c] (cooling capacity)	—	Split system	1.99 $SCOP_H$ (before 1/23/2006) 2.25 $SCOP_H$ (as of 1/23/2006)	ARI 210/240
			Single package	1.93 $SCOP_H$ (before 1/23/2006) 2.25 $SCOP_H$ (as of 1/23/2006)	
Through-the-wall, (air cooled, heating mode)	≤8.8 kW[c] (cooling capacity)	—	Split system	1.99 $SCOP_H$ (before 1/23/2006) 2.08 $SCOP_H$ (as of 1/23/2006) 2.17 $SCOP_H$ (as of 1/23/2010)	
			Single package	1.93 $SCOP_H$ (before 1/23/2006) 2.05 $SCOP_H$ (as of 1/23/2006) 2.17 $SCOP_H$ (as of 1/23/2010)	

TABLE 6.8.1B Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements *(continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air cooled (heating mode)	≥19 kW and <40 kW (cooling capacity)	—	8.3°C db/6.1°C wboutdoor air	3.2 COP_H (before 1/1/2010) 3.3 COP_H (as of 1/1/2010)	ARI 340/360
			–8.3°C db/–9.4°C wboutdoor air	2.2 COP_H	
	≥40 kW (cooling capacity)	—	8.3°C db/6.1°C wb outdoor air	3.1 COP_H (before 1/1/2010) 3.2 COP_H (as of 1/1/2010)	
			–8.3°C db/–9.4°C wb outdoor air	2.0 COP_H	
Water source (heating mode)	<40 kW (cooling capacity)	—	20.0°C entering water	4.2 COP_H	ISO-13256-1
Groundwater source (heating mode)	<40 kW (cooling capacity)	—	10°C entering water	3.6 COP_H	ISO-13256-1
Ground source (heating mode)	<40 kW (cooling capacity)	—	0.0°C entering water	3.1 COP_H	ISO-13256-1

[a] IPLVs and part-load rating conditions are only applicable to equipment with capacity modulation.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1C Water Chilling Packages–Minimum Efficiency Requirements

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air cooled, with condenser, electrically operated	All capacities	—	2.80 COP 3.05 IPLV	ARI 550/590
Air cooled, without condenser, electrically operated	All capacities	—	3.10 COP 3.45 IPLV	
Water cooled, electrically operated, positive displacement (reciprocating)	All capacities	—	4.20 COP 5.05 IPLV	ARI 550/590
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	<528 kW	—	4.45 COP 5.20 IPLV	ARI 550/590
	≥528 kW and <1055 kW	—	4.90 COP 5.60 IPLV	
	≥1055 kW	—	5.50 COP 6.15 IPLV	
Water cooled, electrically operated, centrifugal	<528 kW	—	5.00 COP 5.25 IPLV	ARI 550/590
	≥528 kW and <1055 kW	—	5.55 COP 5.90 IPLV	
	≥1055 kW	—	6.10 COP 6.40 IPLV	
Air-cooled absorption single effect	All capacities	—	0.60 COP	ARI 560
Water-cooled absorption single effect	All capacities	—	0.70 COP	
Absorption double effect, indirect-fired	All capacities	—	1.00 COP 1.05 IPLV	
Absorption double effect, direct-fired	All capacities	—	1.00 COP 1.00 IPLV	

[a] The chiller equipment requirements do not apply for chillers used in low-temperature applications where the design leaving fluid temperature is <4.4°C.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1D 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) new construction	All capacities	35.0°Cdb outdoor air	3.66 – (0.213 × Cap/1000)[c] COP	ARI 310/380
PTAC (cooling mode) replacements[b]	All capacities	35.0°C db outdoor air	3.19 – (0.213 × Cap/1000)[c] COP	
PTHP (cooling mode) new construction	All capacities	35.0°C db outdoor air	3.60 – (0.213 × Cap/1000)[c] COP	
PTHP (cooling mode) replacements[b]	All capacities	35.0°C db outdoor air	3.16 – (0.213 × Cap/1000)[c] COP	
PTHP (heating mode) new construction	All capacities		3.2 – (0.026 × Cap/1000)[c] COP	
PTHP (heating mode) replacements[b]	All capacities		2.9 – (0.026 × Cap/1000)[c] COP	
SPVAC (cooling mode)	<19 kW	35.0°C db/23.9°C wb outdoor air	2.64 COP	ARI 390
	≥19 kW and <40 kW	35.0°C db/23.9°C wb outdoor air	2.61 COP	
	≥40 kW and <70 kW	35.0°C db/23.9°C wb outdoor air	2.52 COP	
SPVHP (cooling mode)	<19 kW	35.0°C db/23.9°C wb outdoor air	2.64 COP	
	≥19 kW and <40 kW	35.0°C db/23.9°C wb outdoor air	2.61 COP	
	≥40 kW and <70 kW	35.0°C db/23.9°C wb outdoor air	2.52 COP	
SPVHP (heating mode)	<19 kW	8.3.0°C db/6.1°C wb outdoor air	3.0 COP	
	≥19 kW and <40 kW	8.3.0°C db/6.1°C wb outdoor air	3.0 COP	
	≥40 kW and <70 kW	8.3.0°C db/6.1°C wb outdoor air	2.9 COP	

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Room air conditioners, with louvered sides	<1.8 kW	—	2.84 COP	ANSI/AHAM RAC-1
	≥1.8 kW and <2.3 kW		2.84 COP	
	≥2.3 kW and <4.1 kW		2.87 COP	
	≥4.1 kW and <5.9 kW		2.84 COP	
	≥5.9 kW		2.49 COP	
Room air conditioners, without louvered sides	<2.3 kW	—	2.64 COP	
	≥2.3 kW and <5.9 kW		2.49 COP	
	≥5.9 kW		2.49 COP	
Room air-conditioner heat pumps with louvered sides	<5.9 kW	—	2.65 COP	
	≥5.9 kW		2.49 COP	
Room air-conditioner heat pumps without louvered sides	<4.1 kW	—	2.49 COP	
	≥4.1 kW		2.34 COP	
Room air conditioner, casement only	All capacities	—	2.55 COP	
Room air conditioner, casement–slider	All capacities	—	2.78 COP	

[a] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] Replacement units must be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 0.45 m high and less than 1.0 m wide.
[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 6.8.1E 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[a]	Test Procedure[b]
Warm air furnace, gas-fired	<66 kW	Maximum capacity[d]	78% AFUE or 80% E_t[f]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥66 kW		80% E_c[f]	ANSI Z21.47
Warm air furnace, oil-fired	<66 kW	Maximum capacity[c]	78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or UL 727
	≥66 kW		81% E_t[e]	UL 727
Warm air duct furnaces, gas-fired	All capacities	Maximum capacity[d]	80% E_c[g,h]	ANSI Z83.8
Warm air unit heaters, gas-fired	All capacities	Maximum capacity[d]	80% E_c[g,h]	ANSI Z83.8
Warm air unit heaters, oil-fired	All capacities	Maximum capacity[d]	80% E_c[f,h]	UL 731

[a] E_t = thermal *efficiency*. See test procedure for detailed discussion.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[c] Minimum and maximum ratings as provided for and allowed by the unit's controls.
[d] Combination units not covered by NAECA (three-phase power or cooling capacity greater than or equal to 19 kW) may comply with either rating.
[e] 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.
[f] E_c = combustion *efficiency* (100% less flue losses). See test procedure for detailed discussion.
[h] 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. A vent damper is an acceptable alternative to a flue damper for those unit heaters where combustion air is drawn from the conditioned space.

TABLE 6.8.1F Gas- and Oil-Fired Boilers, Minimum Efficiency Requirements

Equipment Type[a]	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency[b,c]	Efficiency as of 3/2/2010 (Date 3 yrs after ASHRAE Board Approval)	Efficiency as of 3/2/2020 (Date 13 yrs after ASHRAE Board Approval)	Test Procedure
Boilers, hot water	Gas-fired	<88 kW	80% AFUE	80% AFUE	80% AFUE	10 CFR Part 430
		≥88 kW and ≤733 kW	75% E_t	80% E_t	80% E_t	10 CFR Part 431
		>733 kW[a]	80% E_c	82% E_c	82% E_c	
	Oil-fired[e]	<88 kW	80% AFUE	80% AFUE	80% AFUE	10 CFR Part 430
		≥88 kW and ≤733 kW	78% E_t	82% E_t	82% E_t	10 CFR Part 431
		>88 kW[a]	83% E_c	84% E_c	84% E_c	
Boilers, steam	Gas-fired	<88 kW	75% AFUE	75% AFUE	75% AFUE	10 CFR Part 430
	Gas-fired—all, except natural draft	≥88 kW and ≤733 kW	75% E_t	79% E_t	79% E_t	10 CFR Part 431
		>733 kW[a]	80% E_c	79% E_t	79% E_t	
	Gas-fired—natural draft	≥88 kW and ≤733 kW	75% E_t	77% E_t	79% E_t	
		>733 kW[a]	80% E_c	77% E_t	79% E_t	
	Oil-fired[e]	<88 kW	80% AFUE	80% AFUE	80% AFUE	10 CFR Part 430
		≥88 kW and ≤733 kW	78% E_t	81% E_t	81% E_t	10 CFR Part 431
		>733 kW[a]	83% E_c	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).

TABLE 6.8.1G Performance Requirements for Heat Rejection Equipment

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition	Performance Required[a,b]	Test Procedure[c]
Propeller or axial fan cooling towers	All	35°C entering water 29°C leaving water 24°C wb *outdoor air*	≥3.23 L/s·kW	CTI ATC-105 and CTI STD-201
Centrifugal fan cooling towers	All	35°C entering water 29°C leaving water 24°C wb *outdoor air*	≥1.7 L/s·kW	CTI ATC-105 and CTI STD-201
Air-cooled condensers	All	52°C condensing temperature R-22 test fluid 88°C entering gas temperature 8°C subcooling 35°C entering db	≥69 COP	ARI 460

[a] For purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower divided by the fan nameplate rated motor power.
[b] For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.
[c] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1H Minimum Efficiencies for Centrifugal Chillers <150 tons

Centrifugal Chillers <528 kW

COP_{std} = 5.00; $IPLV_{std}$ = 5.25

			Condenser Flow Rate											
			0.036 L/s·kW		0.045 L/s·kW		0.054 L/s·kW		0.072 L/s·kW		0.090 L/s·kW		0.108 L/s·kW	
Leaving Chilled-Water Temperature (°C)	Entering Condenser-Water Temperature (°C)	LIFT[a] (°C)	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]
4.4	23.9	19.4	5.11	5.35	5.33	5.58	5.48	5.73	5.67	5.93	5.79	6.06	5.88	6.15
4.4	26.7	22.2	4.62	4.83	4.92	5.14	5.09	5.32	5.27	5.52	5.38	5.63	5.45	5.70
4.4	29.4	25.0	3.84	4.01	4.32	4.52	4.58	4.79	4.84	5.06	4.98	5.20	5.06	5.29
5.0	23.9	18.9	5.19	5.43	5.41	5.66	5.56	5.81	5.75	6.02	5.89	6.16	5.99	6.26
5.0	26.7	21.7	4.73	4.95	5.01	5.24	5.17	5.41	5.35	5.60	5.46	5.71	5.53	5.78
5.0	29.4	24.4	4.02	4.21	4.46	4.67	4.70	4.91	4.94	5.17	5.06	5.30	5.14	5.38
5.6	23.9	18.3	5.27	5.51	5.49	5.74	5.64	5.90	5.85	6.12	6.00	6.27	6.11	6.39
5.6	26.7	21.1	4.84	5.06	5.10	5.33	5.25	5.49	5.43	5.67	5.53	5.79	5.61	5.87
5.6	29.4	23.9	4.19	4.38	4.59	4.80	4.81	5.03	5.03	5.26	5.15	5.38	5.22	5.46
6.1	23.9	17.8	5.35	5.59	5.57	5.82	5.72	5.99	5.95	6.23	6.11	6.39	6.23	6.52
6.1	26.7	20.6	4.94	5.16	5.18	5.42	5.32	5.57	5.50	5.76	5.62	5.87	5.70	5.96
6.1	29.4	23.3	4.35	4.55	4.71	4.93	4.91	5.13	5.12	5.35	5.23	5.47	5.30	5.54
6.7	23.9	17.2	5.42	5.67	5.65	5.91	5.82	6.08	6.07	6.34	6.24	6.53	6.37	6.67
6.7	26.7	20.0	5.03	5.26	5.26	5.50	5.40	5.65	5.58	5.84	5.70	5.96	5.79	6.05
6.7	29.4	22.8	4.49	4.69	4.82	5.04	5.00	5.25	5.20	5.43	5.30	5.55	5.38	5.62
7.2	23.9	16.7	5.50	5.75	5.74	6.00	5.92	6.19	6.19	6.47	6.38	6.68	6.53	6.83
7.2	26.7	19.4	5.11	5.35	5.33	5.58	5.48	5.73	5.67	5.93	5.79	6.06	5.88	6.15
7.2	29.4	22.2	4.62	4.83	4.92	5.14	5.09	5.32	5.27	5.52	5.38	5.63	5.45	5.70
7.8	23.9	16.1	5.58	5.84	5.83	6.10	6.03	6.30	6.32	6.61	6.54	6.84	6.70	7.00
7.8	26.7	18.9	5.19	5.43	5.41	5.66	5.56	5.81	5.75	6.02	5.89	6.16	5.99	6.26
7.8	29.4	21.7	4.73	4.95	5.01	5.24	5.17	5.41	5.35	5.60	5.46	5.71	5.53	5.78
8.3	23.9	15.6	5.66	5.92	5.93	6.20	6.15	6.43	6.47	6.77	6.71	7.02	6.88	7.20
8.3	26.7	18.4	5.27	5.51	5.49	5.74	5.64	5.90	5.85	6.12	6.00	6.27	6.11	6.39
8.3	29.4	21.1	4.84	5.06	5.10	5.33	5.25	5.49	5.43	5.67	5.53	5.79	5.61	5.87
8.9	23.9	15.0	5.75	6.02	6.04	6.32	6.28	6.56	6.64	6.94	6.89	7.21	7.09	7.41
8.9	26.7	17.8	5.35	5.59	5.57	5.82	5.72	5.99	5.95	6.23	6.11	6.39	6.23	6.52
8.9	29.4	20.5	4.94	5.16	5.18	5.42	5.32	5.57	5.50	5.76	5.62	5.87	5.70	5.96
Condenser ΔT[b]			7.80		6.24		5.20		3.90		3.12		2.60	

[a] LIFT = entering condenser water temperature – leaving chilled-water temperature (°C)
[b] Condenser ΔT = leaving condenser-water temperature (°C) – entering condenser-water temperature (°C)
[c] All NPLV values shown are NPLV except at conditions of 0.054 L/s·kW condenser flow rate with 6.7°C leaving chilled-water temperature and 29.4°C entering condenser-water temperature, which is IPLV

$K_{adj} = 6.1507 - 0.54439(X) + 0.0203122(X)^2 - 0.00026591(X)^3$
where X = Condenser ΔT + LIFT
$COP_{adj} = K_{adj} \cdot COP_{std}$

TABLE 6.8.1I Minimum Efficiencies for Centrifugal Chillers ≥528 kW, < 1055 kW

Centrifugal Chillers ≥528 kW, <1055 kW

COP_{std} = 5.55; $IPLV_{std}$ = 5.90

			Condenser Flow Rate											
			0.036 L/s·kW		0.045 L/s·kW		0.054 L/s·kW		0.072 L/s·kW		0.090 L/s·kW		0.108 L/s·kW	
Leaving Chilled-Water Temperature (°C)	Entering Condenser-Water Temperature (°C)	LIFT[a] (°C)	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]
4.4	23.9	19.4	5.65	6.03	5.90	6.29	6.05	6.46	6.26	6.68	6.40	6.83	6.51	6.94
4.4	26.7	22.2	5.10	5.44	5.44	5.80	5.62	6.00	5.83	6.22	5.95	6.35	6.03	6.43
4.4	29.4	25.0	4.24	4.52	4.77	5.09	5.06	5.40	5.35	5.71	5.50	5.87	5.59	5.97
5.0	23.9	18.9	5.74	6.13	5.80	6.38	6.14	6.55	6.36	6.79	6.51	6.95	6.62	7.06
5.0	26.7	21.7	5.23	5.58	5.54	5.91	5.71	6.10	5.91	6.31	6.03	6.44	6.11	6.52
5.0	29.4	24.4	4.45	4.74	4.93	5.26	5.19	5.54	5.46	5.82	5.60	5.97	5.69	6.07
5.6	23.9	18.3	5.83	6.22	6.07	6.47	6.23	6.65	6.47	6.90	6.63	7.07	6.75	7.20
5.6	26.7	21.1	5.35	5.71	5.64	6.01	5.80	6.19	6.00	6.40	6.12	6.53	6.20	6.62
5.6	29.4	23.9	4.63	4.94	5.08	5.41	5.31	5.67	5.56	5.93	5.69	6.07	5.77	6.16
6.1	23.9	17.8	5.91	6.31	6.15	6.56	6.33	6.75	6.58	7.02	6.76	7.21	6.89	7.35
6.1	26.7	20.6	5.46	5.82	5.73	6.11	5.89	6.28	6.08	6.49	6.21	6.62	6.30	6.72
6.1	29.4	23.3	4.81	5.13	5.21	5.55	5.42	5.79	5.66	6.03	5.78	6.16	5.86	6.25
6.7	23.9	17.2	6.00	6.40	6.24	6.66	6.43	6.86	6.71	7.15	6.90	7.36	7.05	7.52
6.7	26.7	20.0	5.56	5.93	5.81	6.20	5.97	6.37	6.17	6.58	6.30	6.72	6.40	6.82
6.7	29.4	22.8	4.96	5.29	5.33	5.68	5.55	5.90	5.74	6.13	5.86	6.26	5.94	6.34
7.2	23.9	16.7	6.08	6.49	6.34	6.76	6.54	6.98	6.84	7.30	7.06	7.53	7.22	7.70
7.2	26.7	19.4	5.65	6.03	5.90	6.29	6.05	6.46	6.26	6.68	6.40	6.83	6.51	6.94
7.2	29.4	22.2	5.10	5.44	5.44	5.80	5.62	6.00	5.83	6.22	5.95	6.35	6.03	6.43
7.8	23.9	16.1	6.17	6.58	6.44	6.87	6.66	7.11	6.99	7.46	7.23	7.71	7.40	7.90
7.8	26.7	18.9	5.74	6.13	5.80	6.38	6.14	6.55	6.36	6.79	6.51	6.95	6.62	7.06
7.8	29.4	21.7	5.23	5.58	5.54	5.91	5.71	6.10	5.91	6.31	6.03	6.44	6.11	6.52
8.3	23.9	15.6	6.26	6.68	6.56	6.99	6.79	7.24	7.16	7.63	7.42	7.91	7.61	8.11
8.3	26.7	18.4	5.83	6.21	6.07	6.47	6.23	6.64	6.47	6.90	6.63	7.07	6.75	7.20
8.3	29.4	21.1	5.35	5.70	5.64	6.01	5.80	6.19	6.00	6.40	6.12	6.52	6.20	6.61
8.9	23.9	15.0	6.36	6.78	6.68	7.12	6.94	7.40	7.34	7.82	7.62	8.13	7.83	8.35
8.9	26.7	17.8	5.91	6.30	6.15	6.56	6.33	6.75	6.58	7.02	6.76	7.21	6.89	7.35
8.9	29.4	20.5	5.46	5.82	5.73	6.10	5.89	6.28	6.08	6.49	6.21	6.62	6.30	6.71
Condenser ΔT[b]			7.80		6.24		5.20		3.90		3.12		2.60	

[a] LIFT = entering condenser-water temperature – leaving chilled-water temperature (°C)
[b] Condenser ΔT = leaving condenser-water temperature (°C) – entering condenser-water temperature (°C)
[c] All NPLV values shown are NPLV except at conditions of 0.054 L/s·kW condenser flow rate with 6.7°C leaving chilled-water temperature and 29.4°C entering condenser-water temperature, which is IPLV

$K_{adj} = 6.1507 - 0.54439(X) + 0.0203122(X)^2 - 0.00026591(X)^3$

where X = Condenser ΔT + LIFT

$COP_{adj} = K_{adj} \cdot COP_{std}$

TABLE 6.8.1J Minimum Efficiencies for Centrifugal Chillers ≥1055 kW

Centrifugal Chillers ≥1055 kW COP_{std} = 6.10; $IPLV_{std}$ = 6.40														
			Condenser Flow Rate											
			0.036 L/s·kW		0.045 L/s·kW		0.054 L/s·kW		0.072 L/s·kW		0.090 L/s·kW		0.108 L/s·kW	
Leaving Chilled-Water Temperature (°C)	Entering Condenser-Water Temperature (°C)	LIFT[a] (°C)	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]
4.4	23.9	19.4	6.23	6.55	6.50	6.83	6.68	7.01	6.91	7.26	7.06	7.42	7.17	7.54
4.4	26.7	22.2	5.63	5.91	6.00	6.30	6.20	6.52	6.43	6.76	6.56	6.89	6.65	6.98
4.4	29.4	25.0	4.68	4.91	5.26	5.53	5.58	5.86	5.90	6.20	6.07	6.37	6.17	6.48
5.0	23.9	18.9	6.33	6.65	6.60	6.93	6.77	7.12	7.02	7.37	7.18	7.55	7.30	7.67
5.0	26.7	21.7	5.77	6.06	6.11	6.42	6.30	6.62	6.52	6.85	6.65	6.99	6.74	7.08
5.0	29.4	24.4	4.90	5.15	5.44	5.71	5.72	6.01	6.02	6.33	6.17	6.49	6.27	6.59
5.6	23.9	18.3	6.43	6.75	6.69	7.03	6.87	7.22	7.13	7.49	7.31	7.68	7.44	7.82
5.6	26.7	21.1	5.90	6.20	6.21	6.53	6.40	6.72	6.61	6.95	6.75	7.09	6.84	7.19
5.6	29.4	23.9	5.11	5.37	5.60	5.88	5.86	6.16	6.13	6.44	6.28	6.59	6.37	6.69
6.1	23.9	17.8	6.52	6.85	6.79	7.13	6.98	7.33	7.26	7.63	7.45	7.83	7.60	7.98
6.1	26.7	20.6	6.02	6.32	6.31	6.63	6.49	6.82	6.71	7.05	6.85	7.19	6.94	7.30
6.1	29.4	23.3	5.30	5.57	5.74	6.03	5.98	6.28	6.24	6.55	6.37	6.70	6.46	6.79
6.7	23.9	17.2	6.61	6.95	6.89	7.23	7.09	7.45	7.40	7.77	7.61	8.00	7.77	8.16
6.7	26.7	20.0	6.13	6.44	6.41	6.73	6.58	6.92	6.81	7.15	6.95	7.30	7.05	7.41
6.7	29.4	22.8	5.47	5.75	5.87	6.17	6.10	6.40	6.33	6.66	6.47	6.79	6.55	6.89
7.2	23.9	16.7	6.71	7.05	6.99	7.35	7.21	7.58	7.55	7.93	7.78	8.18	7.96	8.36
7.2	26.7	19.4	6.23	6.55	6.50	6.83	6.68	7.01	6.91	7.26	7.06	7.42	7.17	7.54
7.2	29.4	22.2	5.63	5.91	6.00	6.30	6.20	6.52	6.43	6.76	6.56	6.89	6.65	6.98
7.8	23.9	16.1	6.80	7.15	7.11	7.47	7.35	7.72	7.71	8.10	7.97	8.37	8.16	8.58
7.8	26.7	18.9	6.33	6.65	6.60	6.93	6.77	7.12	7.02	7.37	7.18	7.55	7.30	7.67
7.8	29.4	21.7	5.77	6.06	6.11	6.42	6.30	6.62	6.52	6.85	6.65	6.99	6.74	7.08
8.3	23.9	15.6	6.91	7.26	7.23	7.60	7.49	7.87	7.89	8.29	8.18	8.59	8.39	8.82
8.3	26.7	18.4	6.43	6.75	6.69	7.03	6.87	7.22	7.13	7.49	7.31	7.68	7.44	7.82
8.3	29.4	21.1	5.90	6.20	6.21	6.53	6.40	6.72	6.61	6.95	6.75	7.09	6.84	7.19
8.9	23.9	15.0	7.01	7.37	7.36	7.74	7.65	8.04	8.09	8.50	8.41	8.83	8.64	9.08
8.9	26.7	17.8	6.52	6.85	6.79	7.13	6.98	7.33	7.26	7.63	7.45	7.83	7.60	7.98
8.9	29.4	20.5	6.02	6.32	6.31	6.63	6.49	6.82	6.71	7.05	6.85	7.19	6.94	7.30
Condenser ΔT[b]			7.80		6.24		5.20		3.90		3.12		2.60	

[a] LIFT = entering condenser-water temperature – leaving chilled-water temperature (°C)

[b] Condenser ΔT = leaving condenser-water temperature (°C) – entering condenser-water temperature (°C)

[c] All NPLV values shown are NPLV except at conditions of 0.054 L/s·kW condenser flow rate with 6.7°C leaving chilled-water temperature and 29.4°C entering condenser-water temperature, which is IPLV

$K_{adj} = 6.1507 - 0.54439(X) + 0.0203122(X)^2 - 0.00026591(X)^3$

where X = Condenser ΔT + LIFT

$COP_{adj} = K_{adj} \cdot COP_{std}$

6.8.2 Duct Insulation Tables

TABLE 6.8.2A 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°F at the installed thickness.
[b] Includes crawlspaces, both ventilated and nonventilated.
[c] Includes return air plenums with or without exposed roofs above.

TABLE 6.8.2B 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 Minimum Pipe Insulation Thickness[a]

Fluid Design Operating Temp. Range (°C)	Insulation Conductivity		Nominal Pipe or Tube Size (in.)				
	Conductivity (W/m·K)	Mean Rating Temp. °C	<25	25 to <40	40 to <100	100 to <200	≥200
Heating Systems (Steam, Steam Condensate, and Hot Water)[b,c]							
>177	0.046–0.049	121	6.4	7.6	7.6	10.2	10.2
122–177	0.042–0.046	93	3.8	6.4	7.6	7.6	7.6
94–121	0.039–0.043	66	3.8	3.8	5.1	5.1	5.1
61–93	0.036–0.042	52	2.5	2.5	2.5	3.8	3.8
41–60	0.032–0.040	38	1.3	1.3	2.5	2.5	2.5
Domestic and Service Hot-Water Systems							
41+	0.032–0.040	38	1.3	1.3	2.5	2.5	2.5
Cooling Systems (Chilled Water, Brine, and Refrigerant)[d]							
4–16	0.032–0.040	38	1.3	1.3	2.5	2.5	2.5
<4	0.032–0.040	38	1.3	2.5	2.5	2.5	3.8

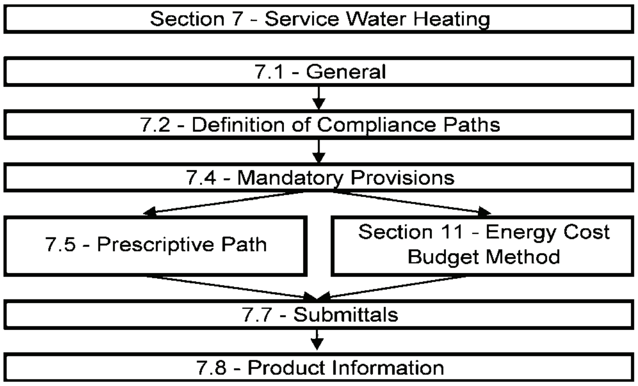
[a] For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:
$T = r\{(1 + t/r)^{K/k} - 1\}$
where T = minimum insulation thickness (cm), r = actual outside radius of pipe (cm), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (W/m·K); 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] Piping insulation is not required between the control valve and coil on run-outs when the control valve is located within 1.2 m of the coil and the pipe size is 25 mm or less.

[d] 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.

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 Path(s)

7.2.1 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.

Exception: 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:

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 pipe between the storage tank and a heat trap in a nonrecirculating storage *system*
d. pipes that are 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:

a. Where public health standards require 24-hour pump operation.
b. 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

$$(3.7 \times 10^6 \times pmd + 117) / n ,$$

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.*

7.6 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.

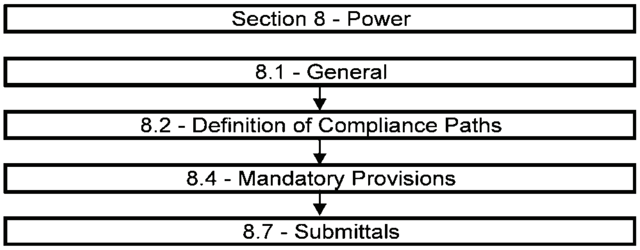
7.8 Product Information

TABLE 7.8 Performance Requirements for Water Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure[b]
Electric water heaters	≤12 kW	Resistance ≥75.7 L	0.93–0.00132V EF	DOE 10 CFR Part 430
	>12 kW	Resistance ≥75.7 L	$20 + 35\sqrt{V}$ SL, W	ANSI Z21.10.3
	≤24 Amps and ≤250 Volts	Heat Pump	0.93–0.00132V EF	DOE 10 CFR Part 430
Gas storage water heaters	≤22.98 kW	≥75.7 L	0.62–0.0019V EF	DOE 10 CFR Part 430
	>22.98 kW	<309.75 W/L	80% E_t $(Q/800 + 110\sqrt{V})$ SL, W	ANSI Z21.10.3
Gas instantaneous water heaters	>14.66 kW and <58.62 kW	≥309.75 W/L and <7.57 L	0.62–0.0019V EF	DOE 10 CFR Part 430
	≥58.62 kW	≥309.75 W/L and <37.85 L	80% E_t	ANSI Z21.10.3
	≥58.62 kW	≥309.75 W/L and ≥37.85 L	80% E_t $(Q/800 + 110\sqrt{V})$ SL, W	
Oil storage water heaters	≤30.78 kW	≥75.7 L	0.59–0.0019V EF	DOE 10 CFR Part 430
	>30.78 kW	<309.75 W/L	78% E_t $(Q/800 + 110\sqrt{V})$ SL, W	ANSI Z21.10.3
Oil instantaneous water heaters	≤61.55 kW	≥309.75 W/L and <7.57 L	0.59–0.0019V EF	DOE 10 CFR Part 430
	>61.55 kW	≥309.75 W/L and <37.85 L	80% E_t	ANSI Z21.10.3
	>61.55 kW	≥309.75 W/L and ≥37.85 L	78% E_t $(Q/800 + 110\sqrt{V})$ 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	ANSI Z21.10.3
Hot-water supply boilers, gas		≥309.75 W/L and ≥37.85 L	80% E_t $(Q/800 + 110\sqrt{V})$ SL, W	
Hot-water supply boilers, oil		≥309.75 W/L and ≥37.85 L	78% E_t $(Q/800 + 110\sqrt{V})$ SL, W	
Pool heaters, oil and gas	All		78% E_t	ASHRAE 146
Heat pump pool heaters	All		4.0 COP	ASHRAE 146
Unfired storage tanks	All		R-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 gallons. In the SL equation, *V* is the rated volume in gallons and *Q* is the nameplate input rate in W.
[b] Section 12 contains a complete specification, including the year version, of the referenced test procedure.
[c] 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.

8. POWER



8.1 General. This section applies to all building power distribution *systems.*

8.2 Compliance Path(s)

8.2.1 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

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.

8.5 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.

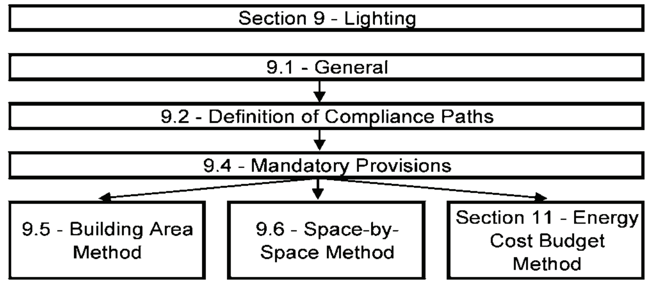
c. Names and addresses of at least one qualified *service agency.*

d. A complete narrative of how each system is intended to operate.

(Enforcement agencies should only check to be sure 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 facades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies

c. exterior building grounds lighting provided through the *building's* electrical *service*

Exceptions:

a. emergency lighting that is automatically off during normal *building* operation

b. lighting within *dwelling units*

c. lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation

d. decorative gas lighting systems

9.1.2 Lighting Alterations. The replacement of lighting *systems* in any building space shall comply with the *LPD* requirements of Section 9 applicable to that space. New lighting *systems* shall comply with the applicable *LPD* requirements of Section 9. Any new *control devices* as a direct replacement of existing *control devices* shall comply with the specific requirements of Section 9.4.1.2(b).

Exception: *Alterations* that replace less than 50% of the *luminaires* in a *space* need not comply with these requirements provided that such *alterations* do not increase the installed interior lighting power.

9.1.3 Installed Interior Lighting Power. The *installed interior lighting power* shall include all power used by the *luminaires*, including *lamps*, *ballasts*, *transformers*, and *control devices* except as specifically exempted in Section 9.2.2.3.

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 shall be based solely on the lighting system with the highest wattage.

9.1.4 Luminaire Wattage. Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following criteria:

a. The wattage of incandescent or tungsten-halogen luminaires with medium screw base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaire.
b. The wattage of luminaires with permanently installed or remote ballasts or *transformer*s 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.
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 or
    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 Path(s)

9.2.1 Lighting systems and equipment shall comply with Section 9.1, General; Section 9.4, Mandatory Provisions; and the prescriptive requirements of either

a. Section 9.5, Building Area Method; or
b. Section 9.6, Space-by-Space Method.

9.2.2 Prescriptive Requirements

9.2.2.1 The Building Area Method for determining the *interior lighting power allowance*, described in Section 9.5, is a simplified approach for demonstrating compliance.

9.2.2.2 The Space-by-Space 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*.

a. Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.
b. Lighting that is integral to *equipment* or instrumentation and is installed by its *manufacturer.*
c. Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical *equipment*.
d. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.
e. Lighting integral to food warming and food preparation *equipment.*
f. Lighting for plant growth or maintenance.
g. Lighting in spaces specifically designed for use by occupants with special lighting needs including visual impairment and other medical and age-related issues.
h. Lighting in *retail* display windows, provided the display area is enclosed by ceiling-height partitions.
i. Lighting in interior spaces that have been specifically designated as a registered interior *historic* landmark.
j. Lighting that is an integral part of advertising or directional signage.
k. Exit signs.
l. Lighting that is for sale or lighting educational demonstration systems.
m. Lighting for theatrical purposes, including performance, stage, and film and video production.
n. Lighting for television broadcasting in sporting activity areas.
o. Casino gaming areas.
p. Furniture-mounted supplemental task lighting that is controlled by automatic shutoff and complies with Section 9.4.1.4(d).

9.3 (Not Used)

9.4 Mandatory Provisions

9.4.1 Lighting Control

9.4.1.1 Automatic Lighting Shutoff. Interior lighting in *buildings* larger than 465 m^2 shall be controlled with an *automatic control device* to shut off *building* lighting in all spaces. This *automatic control device* shall function on either

a. a scheduled basis using a time-of-day operated control device that turns lighting off at specific programmed times—an independent program schedule shall be provided for areas of no more than 2323 m^2 but not more than one floor—or
b. an *occupant sensor* that shall turn lighting off within 30 minutes of an occupant leaving a space or
c. a signal from another control or alarm system that indicates the area is unoccupied.

Exceptions: The following shall not require an *automatic control device:*

a. Lighting intended for 24-hour operation.
b. Lighting in spaces where patient care is rendered.
c. Lighting in spaces where an automatic shutoff would endanger the safety or security of the room or building occupant(s).

9.4.1.2 Space Control. Each space enclosed by ceiling-height partitions shall have at least one *control device* to independently *control* the *general lighting* within the space. Each manual device shall be readily accessible and located so the occupants can see the controlled lighting.

a. A control device shall be installed that automatically turns lighting off within 30 minutes of all occupants leaving a space, except spaces with multi-scene control, in

   1. classrooms (not including shop classrooms, laboratory classrooms, and preschool through 12th grade classrooms),
   2. conference/meeting rooms, and
   3. employee lunch and break rooms.

   These spaces are not required to be connected to other automatic lighting shutoff controls.

b. For all other spaces, each *control device* shall be activated either manually by an occupant or automatically by sensing an occupant. Each *control device* shall *control* a maximum of 232 m^2 area for a space 929 m^2 or less and a maximum of 929 m^2 area for a space greater than 929 m^2 and be capable of overriding any time-of-day scheduled shutoff *control* for no more than four hours.

Exception: Remote location shall be permitted for reasons of safety or security when the 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.

9.4.1.3 Exterior Lighting Control. Lighting for all exterior applications not exempted in Section 9.1 shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours. Lighting not designated for dusk-to-dawn operation shall be controlled by either

a. a combination of a photosensor and a time switch or
b. an astronomical time switch.

Lighting designated for dusk-to-dawn operation shall be controlled by an astronomical time switch or photosensor. All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least ten hours.

Exception: Lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security, or eye adaptation.

9.4.1.4 Additional Control

a. *Display/Accent Lighting*—display or accent lighting shall have a separate *control device.*
b. *Case Lighting*—lighting in cases used for display purposes shall have a separate *control device*.
c. *Hotel and Motel Guest Room Lighting*—hotel and motel guest rooms and guest suites shall have a master *control device* at the main room entry that *controls* all *permanently installed luminaires* and switched receptacles.
d. *Task Lighting*—supplemental task lighting, including *permanently installed* undershelf or undercabinet lighting, shall have a *control device* integral to the *luminaires* or be controlled by a wall-mounted *control device* provided the *control device* is readily accessible and located so that the occupant can see the controlled lighting.
e. *Nonvisual Lighting*—lighting for nonvisual applications, such as plant growth and food warming, shall have a separate *control device*.
f. *Demonstration Lighting*—*lighting equipment* that is for sale or for demonstrations in lighting education shall have a separate *control device.*

9.4.2 Tandem Wiring. Luminaires designed for use with one or three linear fluorescent lamps greater than 30 W each shall use two-lamp tandem-wired ballasts in place of single-lamp ballasts when two or more luminaires are in the same space and on the same control device.

Exceptions:

a. Recessed luminaires more than 3 m apart measured center to center.
b. Surface-mounted or pendant luminaires that are not continuous.
c. Luminaires using single-lamp high-frequency electronic ballasts.
d. Luminaires using three-lamp high-frequency electronic or three-lamp electromagnetic ballasts.
e. Luminaires on emergency circuits.
f. Luminaires with no available pair.

9.4.3 Exit Signs. Internally illuminated exit signs shall not exceed 5 W per face.

9.4.4 Exterior Building Grounds Lighting. All exterior building grounds luminaires that operate at greater than 100 W shall contain lamps having a minimum efficacy of 60 lm/W unless the luminaire is controlled by a motion sensor or qualifies for one of the exceptions under Section 9.1.1 or 9.4.5.

9.4.5 Exterior Building Lighting Power. The total *exterior lighting power allowance* for all exterior building applications is the sum of the individual lighting power densities permitted in Table 9.4.5 for these applications plus an additional unrestricted allowance of 5% of that sum. Trade-offs are allowed only among exterior lighting applications listed in the Table 9.4.5 "Tradable Surfaces" section.

Exceptions: Lighting used for the following exterior applications is exempt when equipped with a *control device* independent of the control of the nonexempt lighting:

a. Specialized signal, directional, and marker lighting associated with transportation.
b. Advertising signage or directional signage.

TABLE 9.4.5 Lighting Power Densities for Building Exteriors

Tradable Surfaces (*LPD*s for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas may be traded.)	**Uncovered parking areas**		
		Parking lots and drives	**1.6** W/m^2
	Building grounds		
		Walkways less than 3 m wide	**3.3** W/linear meter
		Walkways 3 m wide or greater Plaza areas Special feature areas	**2.2** W/m^2
		Stairways	**10.8** W/m^2
	Building entrances and exits		
		Main entries	**98** W/linear meter of door width
		Other doors	**66** W/linear meter of door width
	Canopies and overhangs		
		Canopies (free standing and attached and overhangs)	**13.5** W/m^2
	Outdoor sales		
		Open areas (including vehicle sales lots)	**5.4** W/m^2
		Street frontage for vehicle sales lots in addition to "open area" allowance	**66** W/linear meter
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**		**2.2** W/m^2 for each illuminated wall or surface or **16.4** W/linear meter for each illuminated wall or surface length
	Automated teller machines and night depositories		**270** W per location plus **90** W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities		**13.5** 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		**5.4** W/m^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
	Drive-through windows at fast food restaurants		**400** W per drive-through
	Parking near 24-hour retail entrances		**800** W per main entry

c. Lighting integral to *equipment* or instrumentation and installed by its *manufacturer.*
d. Lighting for theatrical purposes, including performance, stage, film production, and video production.
e. Lighting for athletic playing areas.
f. Temporary lighting.
g. Lighting for industrial production, material handling, transportation sites, and associated storage areas.
h. Theme elements in theme/amusement parks.
i. Lighting used to highlight features of public monuments and registered *historic* landmark structures or *buildings.*

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 meters) 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.*

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/m²)
Automotive facility	10
Convention center	13
Courthouse	13
Dining: bar lounge/leisure	14
Dining: cafeteria/fast food	15
Dining: family	17
Dormitory	11
Exercise center	11
Gymnasium	12
Health-care clinic	11
Hospital	13
Hotel	11
Library	14
Manufacturing facility	14
Motel	11
Motion picture theater	13
Multifamily	8
Museum	12
Office	11
Parking garage	3
Penitentiary	11
Performing arts theater	17
Police/fire station	11
Post office	12
Religious building	14
Retail	16
School/university	13
Sports arena	12
Town hall	12
Transportation	11
Warehouse	9
Workshop	15

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

9.6 Alternative Compliance Path: Space-by-Space Method

9.6.1 Space-by-Space Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the Space-by-Space Method:

a. Determine the appropriate building type from Table 9.6.1. For building types not listed, selection of a reasonably equivalent type shall be permitted.
b. For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.
c. Determine the *interior lighting power allowance* by using the columns designated Space-by-Space Method in Table 9.6.1. Multiply the floor area(s) of the space(s) times the allowed *LPD* for the space type that most closely represents the proposed use of the space(s). The product is the *lighting power allowance* for the space(s). 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. Trade-offs among spaces 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.

An increase in the *interior lighting power allowance* is permitted in the following cases:

a. For spaces in which lighting is specified to be installed in addition to the general lighting for the purpose of decorative appearance, such as chandelier-type luminaries or sconces 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:

$$\text{Additional Interior Lighting Power Allowance} = 1000 \text{ watts} + (\text{Retail Area 1} \times 11\ W/m^2) + (\text{Retail Area 2} \times 18\ W/m^2) + (\text{Retail Area 3} \times 28\ W/m^2) + (\text{Retail Area 4} \times 45\ W/m^2)\ ,$$

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; and
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.*

9.7 Submittals (Not Used)

9.8 Product Information (Not Used)

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

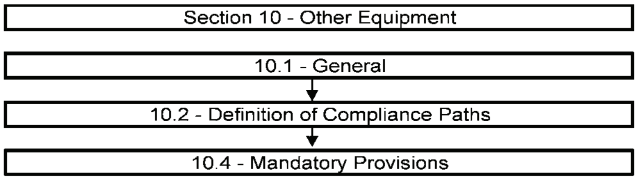
Common Space Types[a]	*LPD*, W/m²	Building-Specific Space Types	*LPD*, W/m²
Office—Enclosed	12	Gymnasium/Exercise Center	
Office—Open Plan	12	Playing Area	15
Conference/Meeting/Multipurpose	14	Exercise Area	10
Classroom/Lecture/Training	15	Courthouse/Police Station/Penitentiary	
For Penitentiary	14	Courtroom	20
Lobby	14	Confinement Cells	10
For Hotel	12	Judges' Chambers	14
For Performing Arts Theater	36	Fire Stations	
For Motion Picture Theater	12	Engine Room	9
Audience/Seating Area	10	Sleeping Quarters	3
For Gymnasium	4	Post Office—Sorting Area	13
For Exercise Center	3	Convention Center—Exhibit Space	14
For Convention Center	8	Library	
For Penitentiary	8	Card File and Cataloging	12
For Religious Buildings	18	Stacks	18
For Sports Arena	4	Reading Area	13
For Performing Arts Theater	28	Hospital	
For Motion Picture Theater	13	Emergency	29
For Transportation	5	Recovery	9
Atrium—First Three Floors	6	Nurses' Station	11
Atrium—Each Additional Floor	2	Exam/Treatment	16
Lounge/Recreation	13	Pharmacy	13
For Hospital	9	Patient Room	8
Dining Area	10	Operating Room	24
For Penitentiary	14	Nursery	6
For Hotel	14	Medical Supply	15
For Motel	13	Physical Therapy	10
For Bar Lounge/Leisure Dining	15	Radiology	4
For Family Dining	23	Laundry—Washing	6
Food Preparation	13	Automotive—Service/Repair	8
Laboratory	15	Manufacturing	
Restrooms	10	Low Bay (<25 ft Floor to Ceiling Height)	13
Dressing/Locker/Fitting Room	6	High Bay (≥25 ft Floor to Ceiling Height)	18
Corridor/Transition	5	Detailed Manufacturing	23
For Hospital	11	Equipment Room	13
For Manufacturing Facility	5	Control Room	5
Stairs—Active	6	Hotel/Motel Guest Rooms	12
Active Storage	9	Dormitory—Living Quarters	12
For Hospital	10	Museum	
Inactive Storage	3	General Exhibition	11
For Museum	9	Restoration	18
Electrical/Mechanical	16	Bank/Office—Banking Activity Area	16

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method *(continued)*

Common Space Types[a]	*LPD*, W/m^2	Building-Specific Space Types	*LPD*, W/m^2
Workshop	20	Religious Buildings	
Sales Area [for accent lighting, see Section 9.6.2(b)]	18	Worship Pulpit, Choir	26
		Fellowship Hall	10
		Retail	
		Sales Area [for accent lighting, see Section 9.6.3(c)]	18
		Mall Concourse	18
		Sports Arena	
		Ring Sports Area	29
		Court Sports Area	25
		Indoor Playing Field Area	15
		Warehouse	
		Fine Material Storage	15
		Medium/Bulky Material Storage	10
		Parking Garage—Garage Area	2
		Transportation	
		Airport—Concourse	6
		Air/Train/Bus—Baggage Area	11
		Terminal—Ticket Counter	16

[a] In cases where both a common space type and a building-specific type are listed, the building specific space type shall apply.

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 Path(s)

10.2.1 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 shall comply with the requirements of the Energy Policy Act of 1992 where applicable, as shown in Table 10.8. Motors that are not included in the scope of the Energy Policy Act of 1992 have no performance requirements in this section.

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 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors[a]

	Minimum Nominal Full-Load Efficiency (%)					
	Open Motors			Enclosed Motors		
Number of Poles ⇒	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Kilowatts						
0.8 kW	—	82.5	80.0	75.5	82.5	80.0
1.1 kW	82.5	84.0	84.0	82.5	84.0	85.5
1.5 kW	84.0	84.0	85.5	84.0	84.0	86.5
2.2 kW	84.0	86.5	86.5	85.5	87.5	87.5
3.7 kW	85.5	87.5	87.5	87.5	87.5	87.5
5.6 kW	87.5	88.5	88.5	88.5	89.5	89.5
7.5 kW	88.5	89.5	90.2	89.5	89.5	89.5
11.1 kW	89.5	91.0	90.2	90.2	91.0	90.2
14.9 kW	90.2	91.0	91.0	90.2	91.0	90.2
18.7 kW	91.0	91.7	91.7	91.0	92.4	91.7
22.4 kW	91.0	92.4	92.4	91.0	92.4	91.7
29.8 kW	91.7	93.0	93.0	91.7	93.0	93.0
37.3 kW	92.4	93.0	93.0	92.4	93.0	93.0
44.8 kW	93.0	93.6	93.6	93.0	93.6	93.6
56.0 kW	93.0	94.1	93.6	93.0	94.1	93.6
74.6 kW	93.0	94.1	94.1	93.6	94.5	94.1
93.3 kW	93.6	94.5	94.1	94.5	94.5	94.1
111.9 kW	93.6	95.0	94.5	94.5	95.0	95.0
149.2 kW	94.5	95.0	94.5	95.0	95.0	95.0

[a] Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed-frequency small and medium AC squirrel-cage induction motors.

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.

11.1.4 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 11.3, does not exceed the *energy cost budget*, as calculated by the simulation program described in Section 11.2; 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.*

11.1.5 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.

11.2 Simulation General Requirements

11.2.1 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.*

11.2.1.1 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 11.2.5

11.2.1.2 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.

11.2.1.3 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*.

11.2.1.4 The simulation program shall be tested according to Standard 140, and the results shall be furnished by the software provider.

11.2.2 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*.

11.2.3 Purchased Energy Rates. Annual energy costs shall be determined using rates for purchased energy, such as electricity, gas, oil, propane, steam, and chilled water, and approved by the *adopting authority.*

Exception: On-site renewable energy sources or site-recovered energy shall not be considered to be purchased energy and shall not be included in the *design energy cost.* Where on-site renewable or site-recovered sources are 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.

11.2.4 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.*

11.2.5 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 the following 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.

11.3 Calculation of Design Energy Cost and Energy Cost Budget

11.3.1 The simulation model for calculating the design energy cost and the *energy cost budget* shall be developed in accordance with the requirements in Table 11.3.1.

TABLE 11.3.1 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.	
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.	

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
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 11.2.1.1(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*
5.	**Building Envelope**	
	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. a. 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. b. 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. c. For exterior roofs other than roofs with ventilated attics, the roof surface may be modeled with a reflectance of 0.45 if the reflectance of the proposed design roof is greater than 0.70 and its emittance is greater than 0.75. The reflectance and emittance shall be tested in accordance with the Exception to Section 5.5.3.1. All other roof surfaces shall be modeled with a reflectance of 0.3. d. Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices such as fins, overhangs, and lightshelves shall be modeled.	The *budget building design* shall have identical *conditioned floor area* and identical exterior dimensions and orientations as the *proposed building design*, except as noted in (a), (b), and (c) in this clause. 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. Roof albedo—All roof surfaces shall be modeled with a reflectivity of 0.3. c. Fenestration—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. Fenestration U-factor shall be the minimum required for the climate, and the SHGC shall be the maximum allowed for the climate and orientation. 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.

TABLE 11.3.1 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)
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).	Lighting power in the *budget building design* shall be determined using the same categorization procedure (building area or space function) and categories as the *proposed building design* with lighting power set equal to the maximum allowed for the corresponding method and category in either Section 9.5 or 9.6. Power for fixtures not included in the *LPD* calculation shall be modeled identically in the *proposed building design* and *budget building design*. Lighting controls shall be the minimum required.
7. Thermal Blocks—HVAC Zones Designed		
	Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate *thermal block*. **Exception:** Different HVAC zones may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied provided all of the following conditions are met: a. The space use classification is the same throughout the *thermal block*. b. 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. c. All of the zones are served by the same HVAC system or by the same kind of HVAC system.	Same as *proposed building design*
8. Thermal Blocks—HVAC Zones Not Designed		
	Where the HVAC zones and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines: a. Separate *thermal blocks* shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 5 m from an exterior wall. Perimeter spaces shall be those located closer than 5 m 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 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 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 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 Design

TABLE 11.3.1 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)
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. 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 11.3.2, the system descriptions in Table 11.3.2A and accompanying notes, and in accord with rules specified in Section 11.3.2 (a)–(j).
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 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.	The service hot-water system type and related performance in the *budget building design* shall be identical to the *proposed building design*. **Exceptions:** a. 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. b. For 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. 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*.
12. Miscellaneous Loads		
	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 11.3.1: 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.	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 11.3.1: 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.

TABLE 11.3.1 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 11.3.1. **Exception:** Components and systems in the *proposed building design* may be excluded from the simulation model provided: a. component energy usage does not affect the energy usage of systems and components that are being considered for trade-off; b. 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 11.3.1. 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*

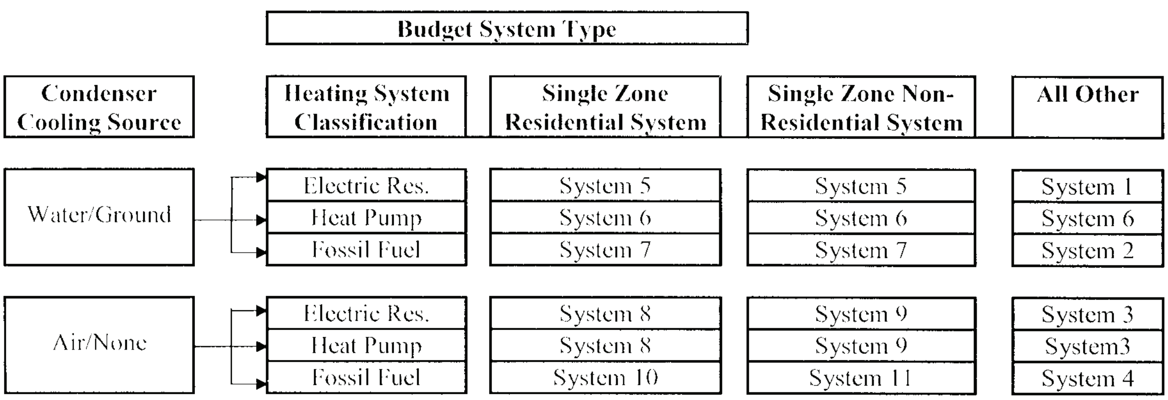


Figure 11.3.2 HVAC systems map.

11.3.2 HVAC Systems. The *HVAC system* type and related performance parameters for the *budget building design* shall be determined from Figure 11.3.2, the system descriptions in Table 11.3.2A and accompanying notes, and the following rules:

a. Components and parameters not listed in Figure 11.3.2 and Table 11.3.2A 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.

c. Where *efficiency* ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately. 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 11.3.2A.

d. Minimum *outdoor air* ventilation rates shall be the same for both the *budget building design* and *proposed building design*. Heat recovery shall be modeled for the *budget building design* in accordance with Section 6.5.6.1.

TABLE 11.3.2A 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	Constant volume[i]	Chilled water[e]	Electric resistance
6	Water-source heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump and boiler[g]
7	Four-pipe fan-coil	Constant volume[i]	Chilled water[e]	Hot-water fossil fuel boiler[f]
8	Packaged terminal heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump[h]
9	Packaged rooftop heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump[h]
10	Packaged terminal air conditioner	Constant volume[i]	Direct expansion	Hot-water fossil fuel boiler[f]
11	Packaged rooftop air conditioner	Constant volume[i]	Direct expansion	Fossil fuel furnace

[a] **VAV with parallel 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 Section 6.5.2.1 Exception (a)1. Supply air temperature setpoint shall be constant at the design condition [see Section 11.3.2 (h)].

[b] **VAV with reheat:** Minimum volume setpoints for VAV reheat boxes shall be 2.15 L/s·m^2 of floor area, or the minimum ventilation rate, whichever is larger, consistent with Section 6.5.2.1 Exception (a)2. Supply air temperature shall be reset based on zone demand from the design temperature difference to a 5.6°C temperature difference under minimum load conditions. Design airflow rates shall be sized for the reset supply air temperature, i.e., a 5.6°C temperature difference.

[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 (b) to Section 6.5.2.1. When the *proposed building design* system has a supply, return, or relief fan motor 18.5 kW or larger, the corresponding fan in the VAV system of the *budget building design* shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. 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 11.2.3. Otherwise, the *budget building design's* chiller plant shall be modeled with chillers having the number as indicated in Table 11.3.2B as a function of *budget building design* chiller plant load and type as indicated in Table 11.3.2C 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 6.5.4.3. Pump system power for each pumping system shall be the same as 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 23m 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 6.5.4.1. The heat rejection device shall be an axial fan cooling tower with two-speed fans if required in Section 6.5.5. Condenser water design supply temperature shall be 29°C or 5.6°C approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 5.6°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 and 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 6.5.4.3. Pump system power for each pumping system shall be the same as 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 6.5.4.1.

[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 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 6.5.4.4. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section 6.5.4.1.

[h] **Electric heat pump:** Electric air-source heat pumps shall be modeled with electric auxiliary heat. The system shall be controlled with a multi-stage 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] **Constant volume:** 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. If the fan is modeled as cycling and the fan energy is included in the energy *efficiency* rating of the equipment, fan energy shall not be modeled explicitly.

e. *Budget building* systems as listed in Table 11.3.2A 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 11.3.2D.

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 for the appropriate motor size for each fan.

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 building design* shall not differ from unmet load hours for the *budget building design* by more than 50 hours.

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:

1. Enter Figure 11.3.2 at "Water" if the *proposed building design* system condenser is water or evaporatively 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 11.3.2 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.

TABLE 11.3.2B 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 11.3.2C 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 11.3.2D Economizer High-Limit Shutoff

Economizer Type	High-Limit Shutoff
Air	Table 6.5.1.1.3B
Water (integrated)	When its operation will no longer reduce HVAC system energy
Water (nonintegrated)	When its operation can no longer provide the cooling load

12. NORMATIVE REFERENCES

Reference	Title
Air Movement and Control Association International, 30 West University Drive, Arlington Heights, IL 60004-1806	
AMCA 500-D-98	Test Methods for Louvers, Dampers, and Shutters
American National Standards Institute, 11 West 42nd Street, New York, NY 10036	
ANSI Z21.10.3-1998	Gas Water Heater, Volume 3, Storage, with Input Ratings above 75,000 Btu/h, Circulating and Instantaneous Water Heaters
ANSI Z21.47-2001	Gas-Fired Central Furnaces (Except Direct Vent and Separated Combustion System Furnaces)
ANSI Z83.8-2002	Gas Unit Heaters and Duct Furnaces
Association of Home Appliance Manufacturers, 20 North Wacker Drive, Chicago, IL 60606	
ANSI/AHAM RAC-1-87	Room Air Conditioners
Air-Conditioning and Refrigeration Institute, 4100 North Fairfax Drive, Suite 200, Arlington, VA 22203	
ARI 210/240-2003	Unitary Air Conditioning and Air-Source Heat Pump Equipment
ARI 310/380-2004	Packaged Terminal Air-Conditioners and Heat Pumps
ARI 340/360-2004	Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
ARI 365-2002	Commercial and Industrial Unitary Air-Conditioning Condensing Units
ARI 390-2003	Performance Rating of Single Packaged Vertical Air-Conditioners and Heat Pumps
ARI 460-2000	Remote Mechanical Draft Air Cooled Refrigerant Condensers
ARI 550/590-98 with Addenda through July 2002	Water-Chilling Packages Using the Vapor Compression Cycle
ARI 560-2000	Absorption Water Chilling and Water Heating Packages
American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1791 Tullie Circle, NE, Atlanta, GA 30329	
ANSI/ASHRAE Standard 62.1-2004	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE Standard 140-2004	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
ANSI/ASHRAE 146-1998	Method of Testing for Rating Pool Heaters
American Society for Testing and Materials, 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

Reference	Title
ASTM C1363-97	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM C1371-04	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers
ASTM C1549-04	Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer
ASTM E1980 (2001)	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low Sloped Opaque Surfaces
ASTM E408-71 (2002)	Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques
ASTM E903-96	Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
ASTM E1175-87 (2003)	Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere
ASTM E1918-97	Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-Sloped Surfaces in the Field
Cooling Technology Institute, 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 STD-201 (04)	Standard for Certification of Water Cooling Tower Thermal Performance
Hydronics Institute, Division of Gama, 35 Russo Place, P.O. Box 218, Berkeley Heights, NJ 07922	
BTS 2000.	Testing Standard Method to Determine Efficiency of Commercial Space Heating Boilers
International Organization for Standardization, 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
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
National Electrical Manufacturers Association, 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209	
ANSI/NEMA MG 1-1993	Motors and Generators
National Fire Protection Association, 1 Battery March Park, P.O. Box 9101, Quincy, MA 02269-9101	
NFPA 96-94	Ventilation Control and Fire Protection of Commercial Cooking Operations
National Fenestration Rating Council, 1300 Spring Street, Suite 500, Silver Springs, MD 20910	
NFRC 100-2004	Procedure for Determining Fenestration Product U-Factors
NFRC 200-2004	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence
NFRC 300-2004	Standard Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems

Reference	Title
NFRC 400-2004	Procedure for Determining Fenestration Product Air Leakage
Underwriters Laboratories, Inc., **333 Pfingsten Rd., Northbrook, IL 60062**	
UL 181A-94	Closure Systems for Use with Rigid Air Ducts and Air Connectors
UL 181B-95	Closure Systems for Use with Flexible Air Ducts and Air Connectors
UL 727-94	UL Standard for Safety—Oil Fired Central Furnaces
UL 731-95	UL Standard for Safety—Oil-Fired Unit Heaters
U.S. Department of Energy **1000 Independence Avenue, SW, Washington, DC 20585**	
10 CFR Part 430, App N	Uniform Test Method for Measuring the Energy Consumption of Furnaces
42 USC 6831, et seq., Public Law 102-486	Energy Policy Act of 1992

(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. It is not acceptable to use these *U-factors* if the insulation is not entirely above deck or not continuous.

TABLE A2.2 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* where the insulation is draped over the steel structure (purlins) and then compressed when the metal roof panels are attached to the steel structure (purlins). Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing.

A2.3.2 Rated R-Value of Insulation

A2.3.2.1 The first *rated R-value of insulation* is for insulation draped over purlins and then compressed when the metal roof panels are attached, or for insulation hung between the purlins. A minimum 25 mm thermal spacer block between the purlins and the metal roof panels is required when specified in Table A2.3.

A2.3.2.2 For double-layer installations, the second *rated R-value of insulation* is for insulation installed parallel to the purlins.

A2.3.2.3 For continuous insulation (e.g., insulation boards or blankets), it is assumed that the insulation is installed below the purlins and is uninterrupted by framing members. Insulation exposed to the *conditioned space* or *semiheated space* shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.

TABLE A2.3 Assembly U-Factors for Metal Building Roofs

Insulation System	Rated R-Value of Insulation	Total 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-1.0	R-2.0	R-3.0	R-4.0	R-4.9	R-5.9
Standing Seam Roofs with Thermal Spacer Blocks									
Single Layer	None	0	**U-7.258**	0.919	0.493	0.335	0.255	0.204	1.070
	R-1.1	1.1	**U-0.947**	0.489	0.330	0.249	0.200	0.167	0.143
	R-1.8	1.8	**U-0.550**	0.356	0.264	0.209	0.173	0.148	0.129
	R-1.9	1.9	**U-0.522**	0.344	0.257	0.205	0.170	0.146	0.128
	R-2.3	2.3	**U-0.471**	0.321	0.244	0.197	0.165	0.142	0.124
	R-2.8	2.8	**U-0.408**	0.291	0.226	0.185	0.156	0.135	0.119
	R-3.3	3.3	**U-0.369**	0.270	0.213	0.176	0.150	0.131	0.116
Double Layer	R-1.8 + R-1.8	3.5	**U-0.357**	0.264	0.209	0.174	0.148	0.129	0.115
	R-1.8 + R-1.9	3.7	**U-0.346**	0.258	0.205	0.171	0.146	0.128	0.113
	R-1.9 + R-1.9	3.9	**U-0.340**	0.255	0.203	0.169	0.145	0.127	0.113
	R-1.8 + R-2.3	4.1	**U-0.329**	0.248	0.199	0.167	0.143	0.125	0.112
	R-1.9 + R-2.3	4.2	**U-0.323**	0.245	0.197	0.165	0.142	0.124	0.111
	R-2.3 + R-2.3	4.6	**U-0.312**	0.238	0.193	0.162	0.140	0.123	0.109
	R-1.8 + R-3.3	5.1	**U-0.295**	0.228	0.186	0.157	0.136	0.120	0.107
	R-1.9 + R-3.3	5.3	**U-0.289**	0.225	0.184	0.156	0.135	0.119	0.107
	R-2.3 + R-3.3	5.6	**U-0.278**	0.218	0.179	0.152	0.132	0.117	0.105
	R-2.8 + R-3.3	6.2	**U-0.266**	0.211	0.175	0.149	0.130	0.115	0.103
	R-3.3 + R-3.3	6.7	**U-0.261**	0.207	0.172	0.147	0.128	0.114	0.102
Thru-Fastened without Thermal Spacer Blocks									
	R-1.8	1.8	**U-0.868**						
	R-1.9	1.9	**U-0.788**						
	R-2.3	2.3	**U-0.737**						
	R-2.8	2.8	**U-0.660**						
	R-3.3	3.3	**U-0.550**						
Filled Cavity with Thermal Spacer Blocks									
	R-3.3 + R-1.8	5.1	**U-0.232**	0.189	0.159	0.138	0.121	0.108	0.098

(Multiple R-values are listed in order from inside to outside.)

A2.3.3 U-factor. *U-factors* for *metal building roofs* shall be taken from Table A2.3 It is not acceptable to use these *U-factors* if additional insulated sheathing is not continuous.

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. 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. 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.

TABLE A2.4 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	
None	U-2.37
R-1.9	U-0.50
R-2.3	U-0.44
R-2.6	U-0.40
R-3.3	U-0.31
R-3.7	U-0.29
R-4.4	U-0.25
R-5.3	U-0.20
R-6.7	U-0.16

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 insula-

TABLE A2.4.2 Single-Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d* (Actual)		
	$d \le 200$ mm	$200 < d \le 250$ mm	$250 < d \le 300$ 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

tion 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 A9.2A.

A2.5.2 *U-factors* for *attic roofs* with steel joists shall be taken from Table A2.5. It is acceptable to use these *U-factors* for any *attic roof* with steel joists.

TABLE A2.5 Assembly U-Factors for Attic Roofs with Steel Joists (4.0 ft on Center)

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
R-0.0	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 *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. *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 A3.1B or A3.1C.

A3.1.2.2 The *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing other than 20 gauge 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 A3.1A or determined by the procedure in this subsection. It is acceptable to use the *U-factors* in Table A3.1A 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 A3.1B or A3.1C.

Exception: 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 "a," 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

TABLE A3.1A 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/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	**N/A**	**N/A**	**U-1.99**
Continuous Metal Framing at 600 mm on Center Horizontally				
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
140 mm	R-3.35	U-0.67	U-0.64	U-0.62
140 mm	R-3.68	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-4.84	U-0.60	U-0.58	U-0.56
140 mm	R-5.42	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-4.35	U-0.56	U-0.55	U-0.52
178 mm	R-4.68	U-0.53	U-0.51	U-0.49
191 mm	R-5.02	U-0.50	U-0.48	U-0.47
203 mm	R-5.35	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
51 mm	R-1.97	U-0.59	U-0.56	U-0.55
64 mm	R-1.67	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

TABLE A3.1A 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	**N/A**	**N/A**	**U-1.99**
25 mm Metal Clips at 600 mm on Center Horizontally and 400 mm Vertically *(continued)*				
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
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

TABLE A3.1B 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
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/m³.

TABLE A3.1C Assembly U-Factors, C-Factors, R_u, R_c, and *HC* for Concrete Block Walls

Product Size, mm	Density, kg/m³	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
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 A3.1C 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
	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
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

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 A3.1C.

A3.1.3.2 Determination of Mass Wall U-Factors. If not taken from Table A3.1A, *mass wall U-factors* shall be determined from Tables A3.1B, A3.1C, or A3.1D using the following procedure:

1. If the *mass wall* is uninsulated or only the cells are insulated:

    a. For concrete *walls*, determine the *U-factor* from Table A3.1B based on the concrete density and *wall* thickness.

    b. For concrete block *walls*, determine the *U-factor* from Table A3.1C based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.

2. If the *mass wall* has additional insulation:

    a. For concrete *walls*, determine the R_u from Table A3.1B based on the concrete density and *wall* thickness. Next, determine the effective R-value for the insulation/framing layer from Table A3.1D 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.

    b. For concrete block *walls*, determine the R_u from Table A3.1C 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 A3.1D 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.

A3.2.2 Rated R-Value of Insulation for Metal Building Walls

A3.2.2.1 The first *rated R-Value of insulation* is for insulation compressed between metal wall panels and the steel structure.

A3.2.2.2 For double-layer installations, the second *rated R-value of insulation* is for insulation installed from the inside, covering the girts.

A3.2.2.3 For continuous insulation (e.g., insulation boards) it is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members.

A3.2.2.4 Insulation exposed to the *conditioned space* or *semiheated space* shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.

A3.2.3 *U-Factors* for *Metal Building Walls*. U-factors for metal building walls shall be taken from Table A3.2. It is not acceptable to use these *U-factors* if additional insulation is not continuous.

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 gauge or 1.4 mm for 16 gauge. 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 vertical surfaces air film. The performance of the insulation/framing layer is calculated using the values in Table A-9.2B. 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.

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).

TABLE A3.1D 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 Assembly U-Factors for Metal Building Walls

Insulation System	Rated R-Value of Insulation	Total 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) Rated R-Value of Continuous Insulation					
				R-1.0	R-2.0	R-3.0	R-4.0	R-4.9	R-5.9
Single Layer of Mineral Fiber									
	None	0.0	**6.69**	0.91	0.49	0.33	0.26	0.20	0.17
	R-1.1	1.1	**1.04**	0.51	0.34	0.26	0.20	0.17	0.15
	R-1.8	1.8	**0.76**	0.43	0.30	0.23	0.19	0.16	0.14
	R-1.9	1.9	**0.70**	0.41	0.29	0.23	0.19	0.16	0.14
	R-2.3	2.3	**0.64**	0.39	0.28	0.22	0.18	0.15	0.13
Double Layer of Mineral Fiber									
(Second layer inside of girts)									
(Multiple layers are listed in order from inside to outside)									
	R-1.1 + R-2.3	3.4	**0.40**	N/A	N/A	N/A	N/A	N/A	N/A
	R-1.8 + R-2.3	4.1	**0.35**	N/A	N/A	N/A	N/A	N/A	N/A
	R-2.3 + R-2.3	4.6	**0.32**	N/A	N/A	N/A	N/A	N/A	N/A
	R-3.3 + R-2.3	5.6	**0.27**	N/A	N/A	N/A	N/A	N/A	N/A

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 A9.4C 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.

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 A3.3 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 mmdepth	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 mmdepth	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 mmdepth	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 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 mmdepth	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 or determined by the procedure described in this subsection.

A4.2.2 It is acceptable to use the *C-factors* in Table A4.2 for all *below-grade walls*.

A4.2.3 If not taken from Table A4.2, *below-grade wall C-factors* shall be determined from Tables A3.1B, A3.1C, or A3.1D 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 A3.1B based on the concrete density and *wall* thickness.
   2. For concrete block *walls*, determine the *C-factor* from Table A3.1C 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 A3.1B based on the concrete density and *wall* thickness. Next, determine the effective R-value for the insulation/framing layer from Table A3.1D 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 A3.1C 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 A3.1D based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the *C-factor* by adding the R_c and the effective R-value together and taking the inverse of the total.

A5. FLOORS

A5.1 General. The buffering effect of crawlspaces or parking garages shall not be included in *U-factor* calculations. See Section A6 for *slab-on-grade floors.*

A5.2 Mass Floors

A5.2.1 General. For the purpose of Section A1.2, the base assembly is *continuous insulation* over or under a solid concrete *floor*. The *U-factors* include R-0.16 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.

A5.2.3.2 It is not acceptable to use the *U-factors* in Table A5.2 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 A9.2A.

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.

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

TABLE A4.2 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

TABLE A5.2 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 Assembly U-Factors for Steel-Joist Floors

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed [See Table A9.2A])	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

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.

A5.4.3.2 It is not acceptable to use these *U-factors* if the framing is not wood.

A6. SLAB-ON-GRADE FLOORS

A6.1 General. For the purpose of Section A1.2, the base assembly is a slab 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·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:

1. *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.
2. *Vertical Insulation: continuous insulation* is applied directly to the slab exterior, extending downward from the top of the slab for the distance specified.
3. *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.

A6.3.2 These *F-factors* are acceptable for all *slab-on-grade floors*.

A7. OPAQUE DOORS

All *opaque doors* with *U-factors* determined, certified, and labeled in accordance with NFRC 100 shall be assigned those *U-factors*.

A7.1 Unlabeled Opaque Doors. Unlabeled *opaque doors* shall be assigned the following *U-factors*:

a. Uninsulated single-layer metal *swinging doors* or *non-swinging doors*, including single-layer uninsulated *access hatches* and uninsulated smoke vents: 8.2
b. Uninsulated double-layer metal *swinging doors* or *non-swinging 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 light 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 A8.1A and are allowed to use the *SHGC*s and VLTs in Table A8.1B. 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*, *SHGC*s, and VLTs in Table A8.2.

TABLE A5.4 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

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

	Rated R-Value of Insulation												
Insulation Description	**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 horizontal		1.05	1.03	1.01	0.99	0.98	0.98	0.98					
600 mm horizontal		1.00	0.97	0.93	0.90	0.88	0.87	0.87					
900 mm horizontal		0.97	0.93	0.88	0.84	0.82	0.80	0.80					
1200 mm horizontal		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 horizontal		1.84	1.76	1.73	1.70	1.67	1.67	1.66					
600 mm horizontal		1.72	1.64	1.57	1.50	1.46	1.44	1.43					
900 mm horizontal		1.64	1.54	1.45	1.36	1.32	1.29	1.28					
1200 mm horizontal		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

TABLE A8.1A 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
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

TABLE A8.1A Assembly U-Factors for Unlabeled Skylights *(continued)*

	Product Type	Sloped Installation						
		Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
	Frame Type	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type							
	Triple Glazing, *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 A8.1B Assembly SHGCs and Assembly Visible Light Transmittances (VLTs) 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	VLT	SHGC	VLT	SHGC	VLT
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 Light Transmittances (VLTs) for Unlabeled Vertical Fenestration

Frame Type	Glazing Type	Unlabeled Vertical Fenestration					
		Clear Glass			Tinted Glass		
		U-Factor	SHGC	VLT	U-Factor	SHGC	VLT
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	n.a.	n.a.	n.a.
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 roof*s: testing.
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 A9.2A 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.
3. *Steel-framed walls*: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2B 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.

TABLE A9.2A 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 A9.2B 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

A9.3.2 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.

A9.4.1.4 The R-value for cavity airspaces shall be taken from Table A9.4A based on the emissivity of the cavity from Table A9.4B. 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.

TABLE A9.4A 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 A9.4B Emittance Values of Various Surfaces and Effective Emittances of Air Spaces

Surface	Average Emittance *e*	Effective Emittance *e eff* of Air Space	
		One Surface *e*; Other, 0.9	Both Surfaces Emittance *e*
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (>0.5 g/m^2)	0.30	0.29	—
Aluminum foil, with condensate clearly visible (>2.0 g/m^2)	0.70	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galv., bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

A9.4.2 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 A9.4C.

c. For calculation purposes, the effective R-value for insulation installed in cavities in attic roofs with steel joists shall be taken from Table A9.2A.

d. For calculation purposes, the effective R-value for insulation installed in cavities in steel-framed walls shall be taken from Table A9.2B.

A9.4.3 Building Material Thermal Properties. R-values for *building materials* shall be taken from Table A9.4D. Concrete block R-values shall be calculated using the isothermal planes method or a two-dimensional calculation program, thermal conductivities from Table A9.4E, and dimensions from ASTM C90. The parallel path calculation method is not acceptable.

Exception: R-values for *building materials* or thermal conductivities determined from testing in accordance with Section A9.3.

A9.4.4 Building Material Heat Capacities. The *HC* of assemblies shall be calculated using published values for the unit weight and specific heat of all building material components that make up the assembly.

TABLE A9.4C 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, in.		**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 A9.4D 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

TABLE A9.4E 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

(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 B-1 or Table B-1 to determine the climate zone number and letter that are required for determining compliance regarding various sections and tables in this standard. Figure B-1 contains the county-by-county climate zone map for the United States. Table B-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

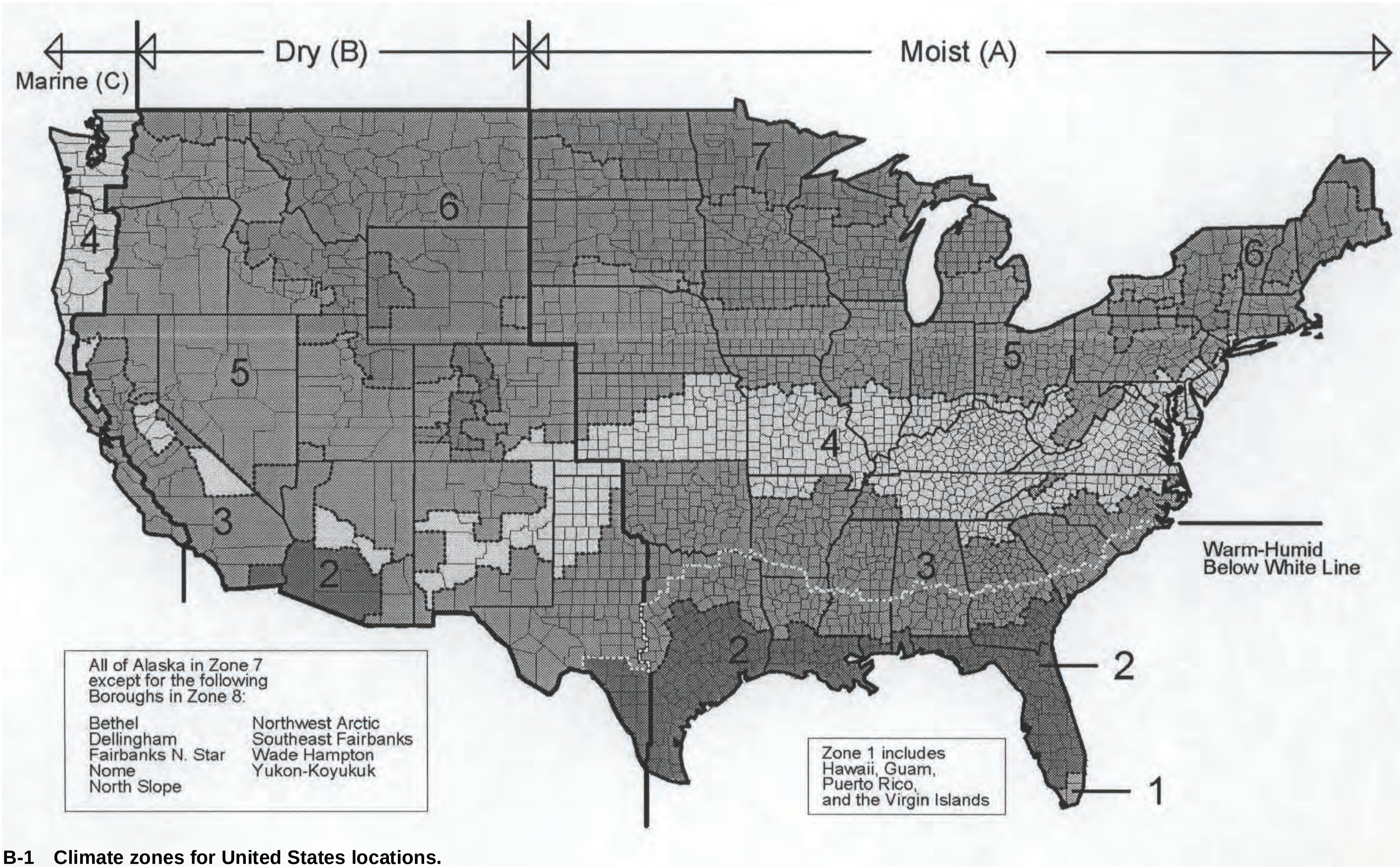


Figure B-1 Climate zones for United States locations.

TABLE B-1 US Climate Zones

State County	Zone
Alabama (AL)	
Zone 3a Except	
Baldwin	2A
Mobile	2A
Alaska (AK)	
Zone 7 Except	
Bethel (CA)	8
Dillingham (CA)	8
Fairbanks North Star	8
Nome (CA)	8
North Slope	8
Northwest Arctic	8
Southeast Fairbanks (CA)	8
Wade Hampton (CA)	8
Yukon-Koyukuk (CA)	8
Arizona (AZ)	
Zone 3B Except	
La Paz	2B
Maricopa	2B
Pima	2B
Pinal	2B
Yuma	2B
Gila	4B
Yavapai	4B
Apache	5B
Coconino	5B
Navajo	5B
Arkansas (AR)	
Zone 3A Except	
Baxter	4A
Benton	4A
Boone	4A
Carroll	4A
Fulton	4A
Izard	4A
Madison	4A
Marion	4A
Newton	4A
Searcy	4A
Stone	4A
(Arkansas cont.)	
Washington	4A
California (CA)	
Zone 3B Except	
Imperial	2B
Alameda	3C
Marin	3C
Mendocino	3C
Monterey	3C
Napa	3C
San Benito	3C
San Francisco	3C
San Luis Obispo	3C
San Mateo	3C
Santa Barbara	3C
Santa Clara	3C
Santa Cruz	3C
Sonoma	3C
Ventura	3C
Amador	4B
Calaveras	4B
Del Norte	4B
El Dorado	4B
Humboldt	4B
Inyo	4B
Lake	4B
Mariposa	4B
Trinity	4B
Tuolumme	4B
Lassen	5B
Modoc	5B
Nevada	5B
Plumas	5B
Sierra	5B
Siskiyou	5B
Alpine	6B
Mono	6B
Colorado (CO)	
Zone 5B Except	
Baca	4B
(Colorado cont.)	
Las Animas	4B
Otero	4B
Alamosa	6B
Archuleta	6B
Chaffee	6B
Conejos	6B
Costilla	6B
Custer	6B
Dolores	6B
Eagle	6B
Moffat	6B
Ouray	6B
Rio Blanco	6B
Saguache	6B
San Miguel	6B
Clear Creek	7
Grand	7
Gunnison	7
Hinsdale	7
Jackson	7
Lake	7
Mineral	7
Park	7
Pitkin	7
Rio Grande	7
Routt	7
San Juan	7
Summitt	7
Connecticut (CT)	
Zone 5A	
Delaware (DE)	
Zone 4A	
District of Columbia (DC)	
Zone 4A	
Florida (FL)	
Zone 2A Except	
Broward	1A
Miami-Dade	1A
Monroe	1A
Georgia (GA)	
Zone 3A Except	
Appling	2A
Atkinson	2A
Bacon	2A
Baker	2A
Berrien	2A
Brantley	2A
Brooks	2A
Bryan	2A
Camden	2A
Charlton	2A
Chatham	2A
Clinch	2A
Colquitt	2A
Cook	2A
Decatur	2A
Echols	2A
Effingham	2A
Evans	2A
Glynn	2A
Grady	2A
Jeff Davis	2A
Lanier	2A
Liberty	2A
Long	2A
Lowndes	2A
McIntosh	2A
Miller	2A
Mitchell	2A
Pierce	2A
Seminole	2A
Tattnall	2A
Thomas	2A
Toombs	2A
Ware	2A
Wayne	2A
Banks	4A
Catoosa	4A
Chattooga	4A

TABLE B-1 US Climate Zones *(continued)*

State / County	Zone
(Georgia cont.)	
Dade	4A
Dawson	4A
Fannin	4A
Floyd	4A
Franklin	4A
Gilmer	4A
Gordon	4A
Habersham	4A
Hall	4A
Lumpkin	4A
Murray	4A
Pickens	4A
Rabun	4A
Stephens	4A
Towns	4A
Union	4A
Walker	4A
White	4A
Whitfield	4A
Hawaii (HI)	
Zone 1A	
Idaho (ID)	
Zone 6B Except	
Ada	5B
Benewah	5B
Canyon	5B
Cassia	5B
Clearwater	5B
Elmore	5B
Gem	5B
Gooding	5B
Idaho	5B
Jerome	5B
Kootenai	5B
Latah	5B
Lewis	5B
Lincoln	5B
Minidoka	5B
Nez Perce	5B
Owyhee	5B
(Idaho cont.)	
Payette	5B
Power	5B
Shoshone	5B
Twin Falls	5B
Washington	5B
Illinois (IL)	
Zone 5A Except	
Alexander	4A
Bond	4A
Christian	4A
Clay	4A
Clinton	4A
Crawford	4A
Edwards	4A
Effingham	4A
Fayette	4A
Franklin	4A
Gallatin	4A
Hamilton	4A
Hardin	4A
Jackson	4A
Jasper	4A
Jefferson	4A
Johnson	4A
Lawrence	4A
Macoupin	4A
Madison	4A
Monroe	4A
Montgomery	4A
Perry	4A
Pope	4A
Pulaski	4A
Randolph	4A
Richland	4A
Saline	4A
Shelby	4A
St. Clair	4A
Union	4A
Wabash	4A
Washington	4A
(Illinois cont.)	
Wayne	4A
White	4A
Williamson	4A
Indiana (IN)	
Zone 5A Except	
Brown	4A
Clark	4A
Crawford	4A
Daviess	4A
Dearborn	4A
Dubois	4A
Floyd	4A
Gibson	4A
Greene	4A
Harrison	4A
Jackson	4A
Jefferson	4A
Jennings	4A
Knox	4A
Lawrence	4A
Martin	4A
Monroe	4A
Ohio	4A
Orange	4A
Perry	4A
Pike	4A
Posey	4A
Ripley	4A
Scott	4A
Spencer	4A
Sullivan	4A
Switzerland	4A
Vanderburgh	4A
Warrick	4A
Washington	4A
Iowa (IA)	
Zone 5A Except	
Allamakee	6A
Black Hawk	6A
Bremer	6A
(Iowa cont.)	
Buchanan	6A
Buena Vista	6A
Butler	6A
Calhoun	6A
Cerro Gordo	6A
Cherokee	6A
Chickasaw	6A
Clay	6A
Clayton	6A
Delaware	6A
Dickinson	6A
Emmet	6A
Fayette	6A
Floyd	6A
Franklin	6A
Grundy	6A
Hamilton	6A
Hancock	6A
Hardin	6A
Howard	6A
Humboldt	6A
Ida	6A
Kossuth	6A
Lyon	6A
Mitchell	6A
O'Brien	6A
Osceola	6A
Palo Alto	6A
Plymouth	6A
Pocahontas	6A
Sac	6A
Sioux	6A
Webster	6A
Winnebago	6A
Worth	6A
Wright	6A
Kansas (KS)	
Zone 4A Except	
Cheyenne	5A
Cloud	5A

TABLE B-1 US Climate Zones ***(continued)***

State County	Zone
(Kansas cont.)	
Decatur	5A
Ellis	5A
Gove	5A
Graham	5A
Greeley	5A
Hamilton	5A
Jewell	5A
Lane	5A
Logan	5A
Mitchell	5A
Ness	5A
Norton	5A
Osborne	5A
Phillips	5A
Rawlins	5A
Republic	5A
Rooks	5A
Scott	5A
Sheridan	5A
Sherman	5A
Smith	5A
Thomas	5A
Trego	5A
Wallace	5A
Wichita	5A
Kentucky (KY)	
Zone 4A	
Louisiana (LA)	
Zone 2A Except	
Bienville	3A
Bossier	3A
Caddo	3A
Caldwell	3A
Catahoula	3A
Claiborne	3A
Concordia	3A
De Soto	3A
East Carroll	3A
Franklin	3A
Grant	3A
(Louisiana cont.)	
Jackson	3A
La Salle	3A
Lincoln	3A
Madison	3A
Morehouse	3A
Natchitoches	3A
Ouachita	3A
Red River	3A
Richland	3A
Sabine	3A
Tensas	3A
Union	3A
Vernon	3A
Webster	3A
West Carroll	3A
Winn	3A
Maine (ME)	
Zone 6A Except	
Aroostook	7
Maryland (MD)	
Zone 4A Except	
Garrett	5A
Massachusetts (MA)	
Zone 5	
Michigan (MI)	
Zone 5A Except	
Alcona	6A
Alger	6A
Alpena	6A
Antrim	6A
Arenac	6A
Benzie	6A
Charlevoix	6A
Cheboygan	6A
Clare	6A
Crawford	6A
Delta	6A
Dickinson	6A
Emmet	6A
Gladwin	6A
(Michigan cont.)	
Grand Traverse	6A
Huron	6A
Iosco	6A
Isabella	6A
Kalkaska	6A
Lake	6A
Leelanau	6A
Manistee	6A
Marquette	6A
Mason	6A
Mecosta	6A
Menominee	6A
Missaukee	6A
Montmorency	6A
Newaygo	6A
Oceana	6A
Ogemaw	6A
Osceola	6A
Oscoda	6A
Otsego	6A
Presque Isle	6A
Roscommon	6A
Sanilac	6A
Wexford	6A
Baraga	7
Chippewa	7
Gogebic	7
Houghton	7
Iron	7
Keweenaw	7
Luce	7
Mackinac	7
Ontonagon	7
Schoolcraft	7
Minnesota (MN)	
Zone 6A Except	
Aitkin	7
Becker	7
Beltrami	7
Carlton	7
(Minnesota cont.)	
Cass	7
Clay	7
Clearwater	7
Cook	7
Crow Wing	7
Grant	7
Hubbard	7
Itasca	7
Kanabec	7
Kittson	7
Koochiching	7
Lake	7
Lake of the Woods	7
Mahnomen	7
Marshall	7
Mille Lacs	7
Norman	7
Otter Trail	7
Pennington	7
Pine	7
Polk	7
Red Lake	7
Roseau	7
St. Louis	7
Wadena	7
Wilkin	7
Mississippi (MS)	
Zone 3A Except	
Hancock	2A
Harrison	2A
Jackson	2A
Pearl River	2A
Stone	2A
Missouri (MO)	
Zone 4A Except	
Adair	5A
Andrew	5A
Atchison	5A
Buchanan	5A
Caldwell	5A

TABLE B-1 US Climate Zones *(continued)*

State County	Zone
(Missouri cont.)	
Chariton	5A
Clark	5A
Clinton	5A
Daviess	5A
Gentry	5A
Grundy	5A
Harrison	5A
Holt	5A
Knox	5A
Lewis	5A
Linn	5A
Livingston	5A
Macon	5A
Marion	5A
Mercer	5A
Nodaway	5A
Pike	5A
Putnam	5A
Ralls	5A
Schuyler	5A
Scotland	5A
Shelby	5A
Sullivan	5A
Worth	5A
Montana (MT)	
Zone 6B	
Nebraska (NE)	
Zone 5A	
Nevada (NV)	
Zone 5B Except	
Clark	3B
New Hampshire (NH)	
Zone 6A Except	
Cheshire	5A
Hillsborough	5A
Rockingham	5A
Strafford	5A
New Jersey (NJ)	
Zone 4A Except	
Bergen	5A
(New Jersey cont.)	
Hunterdon	5A
Mercer	5A
Morris	5A
Passaic	5A
Somerset	5A
Sussex	5A
Warren	5A
New Mexico (NM)	
Zone 5B Except	
Chaves	3B
Dona Ana	3B
Eddy	3B
Hidalgo	3B
Lea	3B
Luna	3B
Otero	3B
Bernalillo	4B
Curry	4B
DeBaca	4B
Grant	4B
Guadalupe	4B
Lincoln	4B
Quay	4B
Roosevelt	4B
Sierra	4B
Socorro	4B
Union	4B
Valencia	4B
New York (NY)	
Zone 5A Except	
Bronx	4A
Kings	4A
Nassau	4A
New York	4A
Queens	4A
Richmond	4A
Suffolk	4A
Westchester	4A
Allegany	6A
Broome	6A
(New York cont.)	
Cattaraugus	6A
Chenango	6A
Clinton	6A
Delaware	6A
Essex	6A
Franklin	6A
Fulton	6A
Hamilton	6A
Herkimer	6A
Jefferson	6A
Lewis	6A
Madison	6A
Montgomery	6A
Oneida	6A
Otsego	6A
Schoharie	6A
Schuyler	6A
St. Lawrence	6A
Steuben	6A
Sullivan	6A
Tompkins	6A
Ulster	6A
Warren	6A
Wyoming	6A
North Carolina (NC)	
Zone 4A Except	
Anson	3A
Beaufort	3A
Bladen	3A
Brunswick	3A
Cabarrus	3A
Camden	3A
Carteret	3A
Chowan	3A
Columbus	3A
Craven	3A
Cumberland	3A
Currituck	3A
Dare	3A
Davidson	3A
(North Carolina cont.)	
Duplin	3A
Edgecombe	3A
Gaston	3A
Greene	3A
Hoke	3A
Hyde	3A
Johnston	3A
Jones	3A
Lenoir	3A
Martin	3A
Mecklenberg	3A
Montgomery	3A
Moore	3A
New Hanover	3A
Onslow	3A
Pamlico	3A
Pasquotank	3A
Pender	3A
Perquimans	3A
Pitt	3A
Randolph	3A
Richmond	3A
Robeson	3A
Rowan	3A
Sampson	3A
Scotland	3A
Stanly	3A
Tyrrell	3A
Union	3A
Washington	3A
Wayne	3A
Wilson	3A
Alleghany	5A
Ashe	5A
Avery	5A
Mitchell	5A
Watauga	5A
Yancey	5A
North Dakota (ND)	
Zone 7 Except	

TABLE B-1 US Climate Zones *(continued)*

State County	Zone
(North Dakota cont.)	
Adams	6A
Billings	6A
Bowman	6A
Burleigh	6A
Dickey	6A
Dunn	6A
Emmons	6A
Golden Valley	6A
Grant	6A
Hettinger	6A
LaMoure	6A
Logan	6A
McIntosh	6A
McKenzie	6A
Mercer	6A
Morton	6A
Oliver	6A
Ransom	6A
Richland	6A
Sargent	6A
Sioux	6A
Slope	6A
Stark	6A
Ohio (OH)	
Zone 5A Except	
Adams	4A
Brown	4A
Clermont	4A
Gallia	4A
Hamilton	4A
Lawrence	4A
Pike	4A
Scioto	4A
Washington	4A
Oklahoma (OK)	
Zone 3A Except	
Beaver	4A
Cimarron	4A
Texas	4A
Oregon (OR)	
Zone 4C Except	
Baker	5B
Crook	5B
Deschutes	5B
Gilliam	5B
Grant	5B
Harney	5B
Hood River	5B
Jefferson	5B
Klamath	5B
Lake	5B
Malheur	5B
Morrow	5B
Sherman	5B
Umatilla	5B
Union	5B
Wallowa	5B
Wasco	5B
Wheeler	5B
Pennsylvania (PA)	
Zone 5A Except	
Bucks	4A
Chester	4A
Delaware	4A
Montgomery	4A
Philadelphia	4A
York	4A
Rhode Island (RI)	
Zone 5A	
South Carolina (SC)	
Zone 3A	
South Dakota (SD)	
Zone 6A Except	
Bennett	5A
Bon Homme	5A
Charles Mix	5A
Clay	5A
Douglas	5A
Gregory	5A
Hutchinson	5A
(South Dakota cont.)	
Jackson	5A
Mellette	5A
Todd	5A
Tripp	5A
Union	5A
Yankton	5A
Tennessee (TN)	
Zone 4A Except	
Chester	3A
Crockett	3A
Dyer	3A
Fayette	3A
Hardeman	3A
Hardin	3A
Haywood	3A
Henderson	3A
Lake	3A
Lauderdale	3A
Madison	3A
McNairy	3A
Shelby	3A
Tipton	3A
Texas (TX)	
Zone 3A Except	
Anderson	2A
Angelina	2A
Aransas	2A
Atascosa	2A
Austin	2A
Bandera	2B
Bastrop	2A
Bee	2A
Bell	2A
Bexar	2A
Bosque	2A
Brazoria	2A
Brazos	2A
Brooks	2A
Burleson	2A
Caldwell	2A
(Texas cont.)	
Calhoun	2A
Cameron	2A
Chambers	2A
Cherokee	2A
Colorado	2A
Comal	2A
Coryell	2A
DeWitt	2A
Dimmit	2B
Duval	2A
Edwards	2B
Falls	2A
Fayette	2A
Fort Bend	2A
Freestone	2A
Frio	2B
Galveston	2A
Goliad	2A
Gonzales	2A
Grimes	2A
Guadalupe	2A
Hardin	2A
Harris	2A
Hays	2A
Hidalgo	2A
Hill	2A
Houston	2A
Jackson	2A
Jasper	2A
Jefferson	2A
Jim Hogg	2A
Jim Wells	2A
Karnes	2A
Kenedy	2A
Kinney	2B
Kleberg	2A
La Salle	2B
Lavaca	2A
Lee	2A
Leon	2A

TABLE B-1 US Climate Zones *(continued)*

State County	Zone
(Texas cont.)	
Liberty	2A
Limestone	2A
Live Oak	2A
Madison	2A
Matagorda	2A
Maverick	2B
McLennan	2A
McMullen	2A
Medina	2B
Milam	2A
Montgomery	2A
Newton	2A
Nueces	2A
Orange	2A
Polk	2A
Real	2B
Refugio	2A
Robertson	2A
San Jacinto	2A
San Patricio	2A
Starr	2A
Travis	2A
Trinity	2A
Tyler	2A
Uvalde	2B
Val Verde	2B
Victoria	2A
Walker	2A
Waller	2A
Washington	2A
Webb	2B
Wharton	2A
Willacy	2A
Williamson	2A
Wilson	2A
Zapata	2B
Zavala	2B
Andrews	3B
Baylor	3B
Borden	3B
(Texas cont.)	
Brewster	3B
Callahan	3B
Childress	3B
Coke	3B
Coleman	3B
Concho	3B
Cottle	3B
Crane	3B
Crockett	3B
Crosby	3B
Culberson	3B
Dawson	3B
Dickens	3B
Ector	3B
El Paso	3B
Fisher	3B
Foard	3B
Gaines	3B
Garza	3B
Glasscock	3B
Hackell	3B
Hall	3B
Hardeman	3B
Haskell	3B
Hemphill	3B
Howard	3B
Hudspeth	3B
Irion	3B
Jeff Davis	3B
Jones	3B
Kendall	3B
Kent	3B
Kerr	3B
King	3B
Knox	3B
Lipscomb	3B
Loving	3B
Lubbock	3B
Lynn	3B
Martin	3B
(Texas cont.)	
Mason	3B
McCulloch	3B
Menard	3B
Midland	3B
Mitchell	3B
Motley	3B
Nolan	3B
Pecos	3B
Presidio	3B
Reagan	3B
Reeves	3B
Runnels	3B
Schleicher	3B
Scurry	3B
Shackelford	3B
Sterling	3B
Stonewall	3B
Sutton	3B
Taylor	3B
Terrell	3B
Terry	3B
Throckmorton	3B
Tom Green	3B
Upton	3B
Ward	3B
Wheeler	3B
Wilbarger	3B
Winkler	3B
Armstrong	4B
Bailey	4B
Briscoe	4B
Carson	4B
Castro	4B
Cochran	4B
Dallam	4B
Deaf Smith	4B
Donley	4B
Floyd	4B
Gray	4B
Hale	4B
(Texas cont.)	
Hansford	4B
Hartley	4B
Hockley	4B
Hutchinson	4B
Lamb	4B
Lipscomb	4B
Moore	4B
Ochiltree	4B
Oldham	4B
Parmer	4B
Potter	4B
Randall	4B
Roberts	4B
Sherman	4B
Swisher	4B
Yoakum	4B
Utah (UT)	
Zone 5B Except	
Washington	3B
Box Elder	6B
Cache	6B
Carbon	6B
Daggett	6B
Duchesne	6B
Morgan	6B
Rich	6B
Summit	6B
Uintah	6B
Wasatch	6B
Vermont (VT)	
Zone 6A	
Virginia (VA)	
Zone 4A	
Washington (WA)	
Zone 5B Except	
Clallam	4C
Clark	4C
Cowlitz	4C
Grays Harbor	4C
Jefferson	4C

TABLE B-1 US Climate Zones *(continued)*

State County	Zone	State County	Zone
(Washington cont.)		(West Virginia cont.)	
King	4C	Wayne	4A
Kitsap	4C	Wirt	4A
Lewis	4C	Wood	4A
Mason	4C	Wyoming	4A
Pacific	4C	Wisconsin (WI)	
Pierce	4C	Zone 6A Except	
Skagit	4C	Ashland	7A
Snohomish	4C	Bayfield	7A
Thurston	4C	Burnett	7A
Wahkiakum	4C	Douglas	7A
Whatcom	4C	Florence	7A
Ferry	6B	Forest	7A
Okanogan	6B	Iron	7A
Pend Oreille	6B	Langlade	7A
Stevens	6B	Lincoln	7A
West Virginia (WV)		Oneida	7A
Zone 5A Except		Price	7A
Berkeley	4A	Sawyer	7A
Boone	4A	Taylor	7A
Braxton	4A	Vilas	7A
Cabell	4A	Washburn	7A
Calhoun	4A	Wyoming (WY)	
Clay	4A	Zone 6B Except	
Gilmer	4A	Goshen	5B
Jackson	4A	Platte	5B
Jefferson	4A	Lincoln	7B
Kanawha	4A	Sublette	7B
Lincoln	4A	Teton	7B
Logan	4A	Puerto Rico (PR)	
Mason	4A	Zone 1A Except	
McDowell	4A	Barranquitas 2 SSW	2B
Mercer	4A	Cayey 1 E	2B
Mingo	4A	Pacific Islands (PI)	
Monroe	4A	Zone 1A Except	
Morgan	4A	Midway Sand Island	2B
Pleasants	4A	Virgin Islands (VI)	
Putnam	4A	Zone 1A	
Ritchie	4A		
Roane	4A		
Tyler	4A		

Table B-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 B-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

Table B-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 B-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 B-2 or B-3, use Table B-4 and the Major Climate Type Definitions in Section B2 to determine both the climate zone letter and number.

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; and

T = annual mean temperature, °C.

Moist (A) definition—Locations that are not marine and not dry.

TABLE B-2 Canadian Climatic Zones

Province / **City**	**Zone**	**Province** / **City**	**Zone**	**Province** / **City**	**Zone**	**Province** / **City**	**Zone**
Alberta (AB)		(Manitoba cont.)		Ontario (ON)		(Québec cont.)	
Calgary International A	7	Winnipeg International A	7	Belleville	6	Granby	6
Edmonton International A	7	New Brunswick (NB)		Cornwall	6	Montreal Dorval International A	6
Grande Prairie A	7	Chatham A	7	Hamilton RBG	5	Québec City A	7
Jasper	7	Fredericton A	6	Kapuskasing A	7	Rimouski	7
Lethbridge A	6	Moncton A	6	Kenora A	7	Septles A	7
Medicine Hat A	6	Saint John A	6	Kingston A	6	Shawinigan	7
Red Deer A	7	Newfoundland (NF)		London A	6	Sherbrooke A	7
British Columbia (BC)		Corner Brook	6	North Bay A	7	St Jean de Cherbourg	7
Dawson Creek A	7	Gander International A	7	Oshawa WPCP	6	St Jerome	7
Ft Nelson A	8	Goose A	7	Ottawa International A	6	Thetford Mines	7
Kamloops	5	St John’s A	6	Owen Sound MOE	6	Trois Rivieres	7
Nanaimo A	5	Stephenville A	6	Peterborough	6	Val d’Or A	7
New Westminster BC Pen	5	Northwest Territories (NW)		St Catharines	5	Valleyfield	6
Penticton A	5	Ft Smith A	8	Sudbury A	7	Saskatchewan (SK)	
Prince George	7	Inuvik A	8	Thunder Bay A	7	Estevan A	7
Prince Rupert A	6	Yellowknife A	8	Timmins A	7	Moose Jaw A	7
Vancouver International A	5	Nova Scotia (NS)		Toronto Downsview A	6	North Battleford A	7
Victoria Gonzales Hts	5	Halifax International A	6	Windsor A	5	Prince Albert A	7
Manitoba (MB)		Kentville CDA	6	Prince Edward Island (PE)		Regina A	7
Brandon CDA	7	Sydney A	6	Charlottetown A	6	Saskatoon A	7
Churchill A	8	Truro	6	Summerside A	6	Swift Current A	7
Dauphin A	7	Yarmouth A	6	Québec (PQ)		Yorkton A	7
Flin Flon	7	Nunavut		Bagotville A	7	Yukon Territory (YT)	
Portage La Prairie A	7	Resolute A	8	Drummondville	6	Whitehorse A	8
The Pas A	7						

TABLE B-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 B-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 SUBSECTION 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*, shall be specified.

C1.2 At the Exterior Surface Level. The classification, gross area, orientation, *U-factor*, and exterior conditions shall be specified. For *mass walls* only: *HC* and insulation position. Each surface is associated with a *space-conditioning category* as defined in Section C1.1.

C1.3 For Fenestration. The classification, area, *U-factor*, *SHGC*, VLT, overhang *PF* for *vertical fenestration*, and width, depth, and height for *skylight wells* shall be specified. (See Figure C1.3 for definition of width, depth, and height for *skylight wells*.) Each *fenestration* element is associated with a surface (defined in Section C1.2) and has the orientation of that surface.

C1.4 For Opaque Doors. The classification, area, *U-factor*, *HC*, and insulation position shall be specified. Each *opaque door* is associated with a surface (defined in Section C1.2) and has the orientation of that surface.

C1.5 For Below-Grade Walls. The area, average depth to the bottom of the wall, and *C-factor* shall be specified. Each *below-grade wall* is associated with a *space-conditioning category* as defined in C1.1.

C1.6 For Slab-On-Grade Floor. The perimeter length and F-factor shall be specified. Each slab-on-grade floor is associated with a space-conditioning category as defined in Section C1.1.

C2. OUTPUT REQUIREMENTS

Output reports shall contain the following information.

C2.1 Tables summarizing the minimum information described in Section C1.

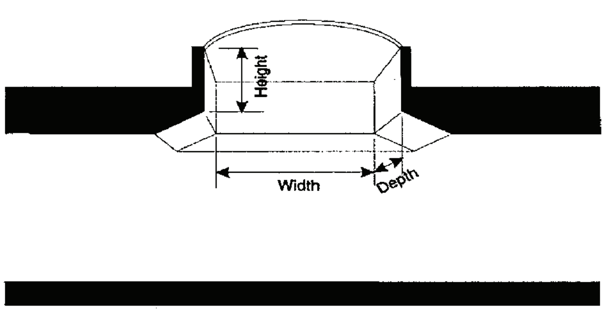


Figure C1.3 Skylight well dimensions.

C2.2 The *envelope performance factor* differential broken down by envelope component. The differential is the difference between the *envelope performance factor* of the proposed building and the *envelope performance factor* of the base envelope design. Envelope components include the *opaque roof*, *skylights*, *opaque above-grade walls* including *vertical fenestration* and *opaque doors*, *below-grade walls*, *floors*, and *slab-on-grade floors.*

C3. BASE ENVELOPE DESIGN SPECIFICATION

C3.1 The base envelope design shall have the same building floor area, *building envelope floor area*, *slab-on-grade floor* perimeter, below-grade floor area, gross *wall area*, *opaque door area*, and *gross roof area* as the proposed design. The distribution of these areas among *space-conditioning categories* shall be the same as the proposed design.

C3.2 The *U-factor* of each *opaque* element of the base envelope design shall be equal to the criteria from Tables 5.5-1 through 5.5-8 for the appropriate climate for each construction classification. *The HC* of *mass wall* elements in the base envelope design shall be identical to the proposed design. *Mass walls* in the base envelope design shall have interior insulation, when required.

C3.3 The *vertical fenestration area* of each *space-conditioning category* in the base envelope design shall be the same as the proposed building or 40% of the *gross wall area*, whichever is less. The distribution of *vertical fenestration* among *space-conditioning categories* and surface orientations shall be the same as the proposed design. If the *vertical fenestration area* of any *space-conditioning category* is greater than 40% of the *gross wall area* of that *space-conditioning category*, then the area of each *fenestration* element shall be reduced in the base envelope design by the same percentage so that the total *vertical fenestration area* is exactly equal to 40% of the *gross wall area*.

C3.4 The *skylight area* of each space category in the base envelope design shall be the same as the proposed building or 5% of the *gross roof area*, whichever is less. This distribution of *skylights* among *space-conditioning categories* shall be the same as the proposed design. If the *skylight area* of any space category is greater than 5% of the *gross roof area* of that *space-conditioning category*, then the area of each *skylight* shall be reduced in the base envelope design by the same percentage so that the total *skylight area* is exactly equal to 5% of the *gross roof area*.

C3.5 The *U-factor* for *fenestration* in the base envelope design shall be equal to the criteria from Tables 5.5-1 through 5.5-8 for the appropriate climate. The *SHGC* for *fenestration* in the base envelope design shall be equal to the criteria from Tables 5.5-1 through 5.5-8. For portions of those tables where there are no requirements, the *SHGC* shall be equal to 0.46 for all *vertical fenestration*, 0.77 for plastic *skylights* on a curb, and 0.72 for all other *skylights* with a curb and without. The VLT for *fenestration* in the base envelope design shall be the VLT factor from Table C3.5 times the *SHGC* criteria as determined in this subsection.

TABLE C3.5 VLT Factor for the Base Envelope Design

Climate Bin	Vertical Fenestration	Glass Skylights	Plastic Skylights
1(A, B)	1.00	1.27	1.20
2(A, B)	1.00	1.27	1.20
3(C)	1.00	1.27	1.20
3(A, B)	1.27	1.27	1.20
4(A, B, C)	1.27	1.27	1.20
5(A, B, C)	1.27	1.27	1.20
6(A, B)	1.27	1.27	1.20
7	1.00	1.00	1.20
8	1.00	1.00	1.20

C4. ZONING AND BUILDING GEOMETRY

No information about thermal zones needs to be entered to perform the calculations, but when the calculations are performed the building shall be divided into thermal zones according to the following procedure.

C4.1 Determine the ratio (*Rc*) of the *gross floor area* to the *gross wall area* for each *space-conditioning category*. The index "c" refers to the *space-conditioning category*, either *nonresidential conditioned*, *residential conditioned*, or *semiheated*.

C4.2 Create a perimeter zone for each unique combination of *space-conditioning category* and *wall* orientation. The *floor area* of each perimeter zone shall be the *gross wall area* of the zone times *Rc* or 1.25, whichever is smaller.

C4.3 For *space-conditioning categories* where *Rc* is greater than 1.25, interior zones shall be created and used in the trade-off procedure. The *floor area* of the interior zone shall be the total floor area for the *space-conditioning category* less the floor area of the perimeter zones created in Section C4.2 for that *space-conditioning category*.

C4.4 *Roof area*, *floor area*, *below-grade wall area*, and *slab-on-grade floor* perimeter associated with each *space-conditioning category* shall be prorated among the zones according to *floor area*.

C4.5 *Skylights* shall be assigned to the interior zone of the *space-conditioning category*. If the *skylight area* is larger than the *roof area* of the interior zone, then the *skylight area* in the interior zone shall be equal to the *roof area* in the interior zone and the remaining *skylight area* shall be prorated among the perimeter zones based on *floor area*.

C5. MODELING ASSUMPTIONS

The following are modeling assumptions for the purposes of this appendix only and are not requirements for building operation.

C5.1 The *residential conditioned* and *nonresidential conditioned space-conditioning categories* shall be modeled with both heating and cooling systems for both the base envelope design and the proposed design. The thermostat setpoints for *residential* and *nonresidential spaces* shall be 21°C for heating and 24°C for cooling, with night setback temperatures of 12°C for heating and 37°C for cooling.

C5.2 The *semiheated* space categories shall be modeled with heating-only systems for both the base envelope design and the proposed design. The thermostat setpoint shall be 10°C for all hours.

C5.3 Both the base envelope design and the proposed design shall be modeled with the same heating, ventilating, and air-conditioning (HVAC) systems. The system shall consist of a packaged rooftop system serving each thermal zone. Cooling shall be provided by a direct expansion air conditioner (EER = 9.5, $COP_{cooling}$ = 2.78). Heating shall be provided by a gas furnace (AFUE = 0.78).

C5.4 The electrical systems shall be the same for both the base envelope design and the proposed design. The *LPD* shall be 12 W/m^2 for *nonresidential conditioned spaces*, 10 W/m^2 for *residential conditioned spaces*, and 5 W/m^2 for *semiheated spaces*. The equipment power density shall be 7.5 W/m^2 for *nonresidential conditioned spaces*, 2.5 W/m^2 for *residential conditioned spaces*, and 2.5 W/m^2 for *semi-heated spaces*. Continuous daylight dimming shall be assumed in all spaces and be activated at 300 lux for *nonresidential conditioned spaces* and *residential conditioned spaces* and 30 fc for *semiheated spaces*.

C5.5 Surface reflectances for daylighting calculations shall be 80% for ceilings, 50% for walls, and 20% for floors.

C5.6 *Envelope performance factor (EPF)* is defined in the following equation.

$$\text{Envelope Performance Factor} = \frac{\text{MBtu} \times 6600 + \text{kWh} \times 80}{\text{Total Building Floor Area}} \quad \text{(C-1)}$$

C5.7 The *U-factor* entered for surfaces adjacent to crawlspaces, attics, and parking garages with mechanical or natural ventilation shall be adjusted by adding R-0.35 to the *thermal resistance* to account for the buffering effect.

C5.8 Heat transfer for *below-grade walls* shall be based on the temperature difference between indoor and outdoor temperature conditions and a heat transfer path at the average wall depth below grade.

C6. EQUATIONS FOR ENVELOPE TRADE-OFF CALCULATIONS

The procedure defined in this subsection shall be used in all building envelope trade-off calculations.

C6.1 Inputs. Building descriptions shall be converted to equation variables using Table C6.1.

C6.2 Envelope Performance Factor. The *EPF* of a building shall be calculated using Equation C-2.

$$EPF = FAF \times [\Sigma HVAC_{surface} + \Sigma Lighting_{zone}] \quad \text{(C-2)}$$

where

FAF = floor area factor for the entire building

TABLE C6.1 Input Variables

Variable	Description	SI Units
$Area_{surface}$	Area of surface	$m^2 \times 10.8$
$Area_{zone}$	Gross floor area of zone as defined in Section C.5	$m^2 \times 10.8$
C-factor	C-factor for below-grade walls	$W/m^2K \times 0.176$
CDD50	CDDs	Base 10°C days × 1.8
CDD65	CDDs	Base 18°C days × 1.8
CDH80	Cooling degree-hours	Base 27°C days × 1.8
CFA	Conditioned floor area	m^2
Depth	Depth of bottom of below-grade wall	m × 3.28
DI	Artificial lighting design illuminance from Section C.5.4	lux × 0.929
DR	Daily range (average outdoor maximum-minimum in hottest month)	°C × 1.8
EPD	Miscellaneous equipment power density from Section C.5.4	$W/m^2 \times 10.8$
F-factor	F-factor for slab-on-grade floors	W/m·K × 0.578
FAF	Building floor area factor	10764/CFA, m^2
HC	Wall heat capacity	$kJ/m^2 \cdot K \times 0.0489$
HDD50	HDDs	Base 10°C days × 1.8
HDD65	HDDs	Base 18°C days × 1.8
Length	Length of slab-on-grade floor perimeter	m × 3.28
LPD	*LPD* from Section C.5.4	$W/m^2 \times 10.8$
R-Value	Effective R-value of soil for below-grade walls	$m^2k/W \times 5.678$
U-factor	U-factor	$W/m^2 \cdot K \times 0.176$
VS	Annual average daily incident solar radiation on vertical surface	$kJ/m^2 \cdot day \times 0.088$

$\Sigma HVAC_{surface}$ = sum of HVAC for each surface calculated using Equation C-3

$\Sigma Lighting_{zone}$ = sum of lighting for each zone calculated using Equation C-4

C6.3 HVAC. The HVAC term for each *exterior* or *semi-exterior* surface in the building shall be calculated using Equation C-3.

$$HVAC_{surface} = COOL + HEAT \qquad (C\text{-}3)$$

where

COOL = cooling factor for the surface calculated according to the appropriate equation in C-14, C-19, or C-22

HEAT = heating factor for the surface calculated according to the appropriate equation in C-16, C-18, or C-23

C6.4 Lighting. The lighting term for each zone in the building as defined in Section C4 shall be calculated using Equation C-4.

$$Lighting_{zone} = LPDadj_{zone} \times AREA_{zone} \times 216 \qquad (C\text{-}4)$$

where

$LPDadj_{zone}$ = lighting power density for the zone adjusted for daylighting potential using Equation C-9

C6.5 Solar and Visible Aperture

C6.5.1 Solar and Visible Aperture of Vertical Fenestration. The visible aperture (VA), solar aperture for cooling (SA_c), and solar aperture for heating (SA_h) of each *vertical fenestration* shall be calculated using Equations C-5, C-6, and C-7.

$$VA = Area_{vf} \times VLT_{vf} \times (1 + PCC1 \times PF + PCC2 \times PF^2) \qquad (C\text{-}5)$$

$$SA_c = Area_{vf} \times 1.163 \times SHGC \times (1 - PCC1 \times PF + PCC2 \times PF^2) \qquad (C\text{-}6)$$

$$SA_h = Area_{vf} \times 1.163 \times SHGC \times (1 + PCH1 \times PF + PCH2 \times PF^2) \qquad (C\text{-}7)$$

where

$Area_{vf}$ = *glazing area* of the *vertical fenestration*

SHGC = the *solar heat gain coefficient* of the *vertical fenestration* assembly

VLT_{vf} = the visible light transmittance of the *vertical fenestration* assembly

PF = the *projection factor* for the overhang shade on the *vertical fenestration*

PCH1, PCH2, PCC1, and PCC2 = overhang projection coefficients for the *vertical fenestration orientation* from Table C6.5.1

TABLE C6.5.1 Overhang Projection Coefficients

Orientation	PCC1	PCC2	PCH1	PCH2
North	–0.5	0.22	0	0
East, South, West	–0.97	0.38	0	0

C6.5.2 Visible Aperture of Skylights. The VA of a *skylight* shall be calculated using Equation C-8.

$$VA = Area_{sky} \times VLT_{sky} \times 10^{(-0.250 \times (5 \times D \times (W + L) / (W \times L))} \qquad \text{(C-8)}$$

where

$Area_{sky}$	=	*fenestration area* of the *skylight* assembly
VLT_{sky}	=	the visible light transmittance of the *skylight* assembly
D	=	average depth of skylight well from *fenestration* to ceiling
W	=	width of skylight well
L	=	length of skylight well

C6.6 Adjusted Lighting Power (*LPD*adj). The adjusted lighting power for each zone shall be calculated using Equation C-9.

$$LPDadj_{zone} = LPD \times (1 - Kd_{zone}) \qquad \text{(C-9)}$$

where Kd_{zone} = daylight potential fraction calculated using Equation C-10.

If a zone has both *skylights* and *vertical fenestration*, the larger of the Kd calculated independently for each shall be used to calculate *LPD*adj.

$$Kd_{zone} = \left(\Phi 1 + \left(\frac{\Phi 2 \times DI \times VA}{Area_{fen}}\right)\right) \times (1 - e^{((\Phi 3 + \Phi 4 \times DI) \times VA)/Area_{surface}}) \qquad \text{(C10)}$$

where

$Area_{fen}$	=	total *fenestration area* of the *vertical fenestration* or *skylight* assemblies in the zone
VA	=	total visible aperture of the *vertical fenestration* or *skylights* in the zone, as calculated in Equation C-5
$Area_{surface}$	=	*gross wall area* of the zone for *vertical fenestration* or *gross roof area* of the zone for *skylights*

and the coefficients 1 through 4 are defined in Table C6.6.

C6.7 Delta Load Factors for Mass Walls in the Exterior Building Envelope. Adjustments to cooling and heating loads for use in Equations C-14 and C-16 due to the mass properties of each *mass wall* component shall be calculated using Equations C-11 and C-12.

$$CMC = 1.43 \times Area_{mw} \times [1 - e^{-CP_1(HC - 1)}] \times \left[CP_2 + CP_3 U - \left(\frac{CP_4}{1 + (CP_5 + CP_6 U)e^{-(CP_7 + CP_8 U^2)(HC - 1)}}\right)\right] \qquad \text{(C-11)}$$

TABLE C6.6 Coefficients for Calculating Kd

Coefficient	Skylight	Vertical Fenestration
Φ1	0.589	0.737
Φ2	5.18E–07	–3.17E-04
Φ3	–220	–24.71
Φ4	2.29	0.234

where

CMC	=	cooling delta load factor
$Area_{mw}$	=	net *opaque area* of this *mass* wall
A_c	=	CDH80/10000 + 2
B	=	DR/10 + 1
HC	=	wall heat capacity
DR	=	average daily temperature range for warmest month
CP_1	=	C_5
CP_2	=	$C_{15}/B^3 + C_{16}/(A_C{}^2B^2) + C_{17}$
CP_3	=	$C_1/A_C{}^3 + C_2B^3 + C_2B^3 + C^3/(A_C{}^2\sqrt{B}) + C_4$
CP_4	=	$C_{12}(A_C{}^2B^2) + C_{13}/B^3 + C_{14}$
U	=	area average of *U-factors* of *mass walls* in the zone
CP_5	=	C_{18}
CP_6	=	$C_6\sqrt{B}\,LN(A_C) + C_7$
LN	=	natural logarithm
CP_7	=	$C_{19}/(A_C{}^2B^2) + C_{20}/(A_CB) + C_{21}A_C{}^2/\sqrt{B} + C_{22}$
CP_8	=	$C_8/(A_C{}^2B^2) + C_9/(A_CB) + C_{10}A_C{}^2/\sqrt{B} + C_{11}$

The coefficients C_1 through C_{22} depend on insulation position in the wall and are taken from Table C6.7A.

$$HMC = 1.43 \times Area_{mw} \times [1 - e^{-HP_1(HC - 1)}] \times \left[HP_2 + HP_3 U - \left(\frac{HP_4}{1 + (HP_5 + HP_6 U)e^{-(HP_7 + HP_8 U^2)(HC - 1)}}\right)\right] \qquad \text{(C-12)}$$

where

HMC	=	heating delta load factor
HC	=	wall heat capacity
$Area_{mw}$	=	net *opaque area* of this *mass* wall
HP_1	=	H_6
A_H	=	HDD65/100 + 2
HP_2	=	$H_{14}LN(A_H) + H_{15}$
LN	=	natural logarithm
HP_3	=	$H_1A_H{}^3 + H_2A_H{}^2 + H_3/\sqrt{A} + H_4\sqrt{A} + H_5$
U	=	area average of *U-factors* of *mass walls* in the zone
HP_4	=	$H_{11}A_H{}^2 + H_{12}/A_H{}^2 + H_{13}$
HP_5	=	H_{16}
HP_6	=	$H_7A_H + H_8$
HP_7	=	$H_{17}/A_H{}^3 + H_{18}$
HP_8	=	$H_9/A_H{}^3 + H_{10}$

The coefficients H_1 through H_{18} depend on the position of the insulation in the wall and are taken from Table C6.7B. If the

TABLE C6.7A Cooling Delta Load Coefficients

	Insulation Position		
Variable	Exterior	Integral	Interior
C_1	220.7245	139.1057	181.6168
C_2	–0.0566	–0.0340	–0.0552
C_3	–118.8354	–10.3267	–34.1590
C_4	–13.6744	–20.8674	–25.5919
C_5	0.2364	0.2839	0.0810
C_6	0.9596	0.3059	1.4190
C_7	–0.2550	0.0226	0.4324
C_8	–905.6780	–307.9438	–1882.9268
C_9	425.1919	80.2096	443.1958
C_{10}	–2.5106	0.0500	0.4302
C_{11}	–43.3880	–5.9895	–28.2851
C_{12}	–259.7234	–11.3961	–63.5623
C_{13}	–33.9755	0.3669	20.8447
C_{14}	20.4882	30.2535	9.8175
C_{15}	–26.2092	8.8337	24.4598
C_{16}	–241.1734	–22.2546	–70.3375
C_{17}	18.8978	29.3297	9.8843
C_{18}	–0.3538	–0.0239	–0.1146
C_{19}	156.3056	63.3228	326.3447
C_{20}	–74.0990	–16.3347	–77.6355
C_{21}	0.4454	–0.0111	–0.0748
C_{22}	7.4967	1.2956	5.2041

U-factor of *mass wall* is greater than 2.3 W/(m^2·K), then the *U-factor* shall be set to 2.3 W/(m^2·K). If the *U-factor* of the *mass wall* is less than 0.28 W/(m^2·K), then the *U-Factor* shall be set to 0.28 W/(m^2·K). If the wall *HC* of the *mass wall* is greater than 409 kJ/(m^2·K), then *HC* = 409 kJ/(m^2·K) shall be used.

C6.8 Walls and Vertical Fenestration in the Exterior Building Envelope. Equations C-14 and C-16 shall be used to calculate COOL and HEAT for *exterior walls* and *vertical fenestration* in the *exterior building envelope* except walls next to crawlspaces, attics, and parking garages with natural or mechanical ventilation. *Walls* next to crawlspaces, attics, and parking garages with natural or mechanical ventilation shall use the equations in Section C6.10 and they shall not be included in calculations in Section C6.8. Zones shall be constructed according to Section C4 and the HEAT and COOL for the combination of all *exterior walls* and *vertical fenestration* in the zone shall be calculated using Equations C-14 and C-16, which include interactive effects. For a zone having a cardinal *orientation* (north, east, south, or west), Equations C-14 and C-15 shall be applied directly. For zones with northeast, northwest, southwest, and southeast *orientation*s, EC shall be determined by finding the average of the values for the two closest cardinal *orientations*; for instance, COOL for a *wall* facing northeast is calculated by taking the average of COOL for a north-facing wall and COOL for an east-facing *wall*.

TABLE C6.7B Heating Delta Load Coefficients

	Insulation Position		
Variable	Exterior	Integral	Interior
H_1	0.0000	0.0000	0.0000
H_2	–0.0015	–0.0018	–0.0015
H_3	13.3886	15.1161	19.8314
H_4	1.9332	2.1056	1.4579
H_5	–11.8967	–13.3053	–15.5620
H_6	0.4643	0.1840	0.0719
H_7	0.0094	0.0255	0.0264
H_8	–0.1000	0.0459	0.7754
H_9	–1223.3962	–622.0801	0.2008
H_{10}	–0.9454	–0.5192	-0.6379
H_{11}	–0.0001	–0.0001	0.0000
H_{12}	3.8585	4.1379	2.4243
H_{13}	7.5829	6.2380	7.9804
H_{14}	–0.7774	–0.7711	–0.1699
H_{15}	9.0147	7.7229	8.5854
H_{16}	0.2007	0.2083	–0.0386
H_{17}	206.6382	105.9849	3.1397
H_{18}	0.2573	0.1983	0.1863

C6.8.1 Effective Internal Gain. The effective internal gain to zone G shall be calculated using Equation C-13.

$$G = \text{EPD} + LPD\text{adj}_{zone} \quad \text{(C-13)}$$

where

$LPD\text{adj}_{zone}$ = lighting power density adjusted for daylighting, from Equation C-9

C6.8.2 Cooling Factor. The cooling factor for the surfaces in the zone shall be calculated using Equation C-14.

$$\text{COOL} = 0.005447 \times [\text{CLU} + \text{CLUO} + \text{CLXUO} + \text{CLM} + \text{CLG} + \text{CLS} + \text{CLC}] \quad \text{(C-14)}$$

where

$$\text{CLU} = \text{Area}_{opaque} \times U_{ow} \times [\text{CU1} \times \text{CDH80} + \text{CU2} \times \text{CDH80}^2 + \text{CU3} \times (\text{VS} \times \text{CDH80})^2 + \text{CU4 x DR}]$$

$$\text{CLUO} = \text{Area}_{grosswall} \times \text{UO} \times [\text{CUO1} \times \text{EA}_C \times \text{VS} \times \text{CDD50} + \text{CUO2} \times \text{G} + \text{CUO3} \times \text{G}^2 \times \text{EA}_C^2 \times \text{VS} \times \text{CDD50} + \text{CUO4} \times \text{G}^2 \times \text{EA}_C^2 \times \text{VS} \times \text{CDD65}]$$

$$\text{CLXUO} = \text{Area}_{grosswall} / \text{UO} \times [\text{CXUO1} \times \text{EA}_C \times \text{VS} \times \text{CDD50} + \text{CXUO2} \times \text{EA}_C \times (\text{VS} \times \text{CDD50})^2 + \text{CXUO3} \times \text{G} \times \text{CDD50} + \text{CXUO4} \times \text{G}^2 \times \text{EA}_C^2 \times \text{VS} \times \text{CDD50} + \text{CXUO5} \times \text{G}^2 \times \text{CDD65}]$$

$$\text{CLM} = \text{Area}_{opaque} \times \text{SCMC} \times [\text{CM1} + \text{CM2} \times \text{EA}_C \times \text{VS} \times \text{CDD50} + \text{CM3} \times \text{EA}_C \times \text{VS} \times \text{CDD65} + \text{CM4} \times \text{EA}_C^2 \times \text{VS} \times \text{CDD50} + \text{CM5} \times \text{G}^2 \times \text{CDD65} + \text{CM6} \times \text{G} \times \text{CDD50} + \text{CM7} \times \text{G} \times \text{CDD65} + \text{CM8} \times \text{G} \times \text{EA}_C \times \text{VS} \times \text{CDD50}]$$

$$CLG = Area_{grosswall} \times \{G \times [CG1 + CG2 \times CDD50 + CG3 \times EA_C \times (VS \times CDD50)^2 + CG4 \times EA_C^2 \times VS \times CDD50 + CG5 \times CDD65 + CG6 \times CDD50^3 + CG7 \times CDD65^3] + G^2 \times [CG8 \times EA_C \times VS \times CDD50 + CG9 \times EA_C^2 \times VS \times CDD50]\}$$

$$CLS = Area_{grosswall} \times \{EA_C \times [CS1 + CS2 \times VS \times CDD50 + CS3 \times (VS \times CDD50)^2 + CS4 \times VS \times CDD65 + CS5 \times (VS \times CDD65)^2] + EA_C^2 \times [CS6 + CS7 \times (VS \times CDD65)^2]\}$$

$$CLC = Area_{grosswall} \times [CC1 \times CDD50 + CC2 \times CDD50^2 + CC3 \times CDH80 + CC4 \times CDH80^2 + CC5 \times CDD65 + CC6 \times (VS \times CDD65)^2 + CC7 \times VS \times CDD50 + CC8 \times (VS \times CDD50)^2 + CC9 \times (VS \times CDH80)^2 + CC10 \times VS + CC11 \times DR + CC12 \times DR^2 + CC13]$$

where

$Area_{grosswall}$ = total gross area of all *walls* and *vertical fenestration* in the zone, including *opaque* and *fenestration areas*

$Area_{opaque}$ = total *opaque area* of all *walls* in the zone

U_{ow} = area average of *U-factors* of *opaque walls* (including those of mass construction) in the zone

VS = annual average daily incident solar energy on surface

DR = average daily temperature range for the warmest month

UO = area average of *U-factor* of *opaque walls* and *vertical fenestration* in the zone

SCMC = sum of the CMC from Equation C-11 for each *mass wall* in the zone

G = effective internal gain to space, from Equation C-13

EA_C = effective solar aperture fraction for zone calculated using Equation C-15

$$EA_C = \frac{\sum SA_C}{Area_{grosswall}} \quad \text{(C-15)}$$

where

ΣSA_c = the sum of SA_c from Equation C-6.6 for all *vertical fenestration* in the zone.

The coefficients used in the above equations depend on the *orientation* of the surface and shall be found in Table C6.8.2.

C6.8.3 Heating Factor. The heating factor for the surfaces in the zone shall be calculated using Equation C-16.

$$HEAT = 0.007669 \times [HLU + HLUO + HLXUO + HLM + HLG + HLS + HLC] \quad \text{(C-16)}$$

where

$$HLU = Area_{opaque} \times U_{ow} \times [HU1 \times HDD50 + HU2 \times (VS \times HDD65)^2]$$

$$HLUO = Area_{grosswall} \times UO \times [HUO1 \times HDD50 + HUO2 \times HDD65 + HUO3 \times EA_H \times VS \times HDD65]$$

$$HLXUO = Area_{grosswall} \times \{(1/UO) \times [HXUO1 \times EA_H \times (VS \times HDD50)^2 + HXUO2 \times EA_H \times (VS \times HDD65)^2] + (1/UO^2) \times [HXUO3 \times EA_H^2 \times VS \times HDD65]\}$$

$$HLM = Area_{opaque} \times SHMC \times [HM1 + HM2 \times G \times UO \times HDD65 + HM3 \times G^2 \times EA_H^2 \times VS \times HDD50 + HM4 \times UO \times EA_H \times VS \times HDD65 + HM5 \times UO \times HDD50 + HM6 \times EA_H \times (VS \times HDD65)^2 + HM7 \times EA_H^2 \times VS \times HDD65/UO]$$

$$HLG = Area_{grosswall} \times \{G \times [HG1 \times HDD65 + HG2 \times UO \times HDD65 + HG3 \times EA_H \times VS \times HDD65 + HG4 \times EA_H^2 \times VS \times HDD50] \times G^2 \times [HG5 \times HDD65 + HG6 \times EA_H^2 \times VS \times HDD65]\}$$

$$HLS = Area_{grosswall} \times \{EA_H \times [HS1 \times VS \times HDD65 + HS2 \times (VS \times HDD50)^2] + EA_H^2 \times [HS3 \times VS \times HDD50 + HS4 \times VS \times HDD65]\}$$

$$HLC = Area_{grosswall} \times [HC1 + HC2 \times HDD65 + HC3 \times HDD65^2 + HC4 \times VS^2 + HC5 \times VS \times HDD50 + HC6 \times VS \times HDD65 + HC7 \times (VS \times HDD50)^2]$$

where

VS = annual average daily incident solar energy on surface

SHMC = sum of the HMC from Equation C-12 for each *mass wall* in the zone

EA_H = effective solar aperture fraction for zone calculated using Equation C-17.

$$EA_H = \frac{\sum SA_H}{Area_{grosswall}} \quad \text{(C-17)}$$

ΣSA_h = the sum of SA_h from Equation C-7 for all *vertical fenestration* in the zone.

The coefficients used in the above equations depend on the *orientation* of the surface and shall be found in Table C6.8.3. Terms not defined for Equation C-16 are found under Equation C-14.

C6.9 Skylights in the Exterior Building Envelope. HEAT and COOL shall be calculated for *skylights* in *nonresidential conditioned* and *residential conditioned* zones using Equations C-18 and C-19.

$$HEAT = Area_{sky} \times HDD65 \times 0.66 \times (H_2 \times U_{sky} + H_3 \times 1.163 \times SHGC) \quad \text{(C-18)}$$

$$COOL = Area_{sky} \times C_2 \times CDD50 \times 0.093 \times SHGC \quad \text{(C-19)}$$

where

$Area_{sky}$ = *fenestration* area of the *skylight* assembly

SHGC = the *solar heat gain coefficient* of the *skylight* assembly

U_{sky} = *U-factor* of *skylight* assembly

The coefficients used in the equations depend on the space type and shall be taken from Table C6.9.

TABLE C6.8.2 Cooling Coefficients for the Exterior Wall Equation

Variable	Orientation of Surface			
	North	East	South	West
CU1	0.001539	0.003315	0.003153	0.00321
CU2	–3.0855E-08	–8.9662E-08	–7.1299E-08	–8.1053E-08
CU3	7.99493E-14	3.7928E-14	1.83083E-14	3.3981E-14
CU4	–0.079647	0.163114	0.286458	0.11178
CM1	0.32314	0.515262	0.71477	0.752643
CM2	1.5306E-06	1.38197E-06	1.6163E-06	1.42228E-06
CM3	–2.0432E-06	–1.6024E-06	–2.1106E-06	–1.9794E-06
CM4	–7.5367E-07	–7.6785E-07	–6.6443E-07	–7.4007E-07
CM5	–1.0047E-06	0	8.01057E-06	3.15193E-06
CM6	3.66708E-05	3.56503E-05	4.48106E-05	2.96012E-05
CM7	–6.7305E-05	–6.4094E-05	–0.000119	–7.6672E-05
CM8	–2.3834E-08	–4.7253E-08	–4.9747E-08	0
CUO1	–6.5109E-06	–8.3867E-06	–8.89E-06	–7.5647E-06
CUO2	–1.040207	–1.507235	–1.512625	-1.238545
CUO3	–4.3825E-06	–2.7883E-06	–2.3135E-06	–4.1257E-06
CUO4	0.000012658	8.09874E-06	7.36219E-06	1.06712E-05
CXUO1	1.03744E-06	1.19338E-06	1.18588E-06	1.23251E-06
CXUO2	–1.3218E-13	–1.3466E-13	–1.1625E-13	–1.3E-13
CXUO3	2.75554E-05	2.02621E-05	2.02365E-05	2.36964E-05
CXUO4	9.7409E-08	1.175E-07	9.39207E-08	1.36276E-07
CXUO5	–1.1825E-05	–9.0969E-06	–9.0919E-06	–1.1108E-05
CG1	0.891286	0.583388	0.393756	0.948654
CG2	0.001479	0.001931	0.002081	0.001662
CG3	–5.5204E-13	–2.8214E-13	–2.8477E-13	–4.5572E-13
CG4	2.52311E-06	3.70821E-06	4.30536E-06	5.91511E-06
CG5	–0.001151	–0.001745	–0.001864	–0.00153
CG6	1.95243E-12	0	–2.9606E-12	3.16358E-12
CG7	–8.3581E-12	1.01089E-11	3.30027E-11	0
CG8	1.41022E-06	7.53875E-07	7.133E-07	9.70752E-07
CG9	–2.3889E-06	–1.6496E-06	–1.6393E-06	–1.9736E-06
CS1	46.9871	33.9683	18.32016	29.3089
CS2	3.48091E-05	3.74118E-05	0.000034049	5.02498E-05
CS3	0	0	2.71313E-12	0
CS4	–1.6641E-05	6.94779E-06	–2.8218E-05	–2.7716E-05
CS5	8.42765E-12	0	–3.0468E-12	2.91137E-12
CS6	–56.5446	0	26.9954	14.9771
CS7	–1.3476E-11	–5.881E-12	–6.5009E-12	–7.8922E-12
CC1	0.002747	0	0.010349	0.001865
CC2	0	3.18928E-07	–3.0441E-07	0
CC3	–0.000348	0.000319	0.00024	0.000565
CC4	1.22123E-08	–7.7532E-08	–2.7144E-08	–5.4438E-08
CC5	0.012112	0.011894	0.013248	0.009236
CC6	1.04027E-12	–6.2266E-13	–2.0518E-12	0
CC7	–1.2401E-05	–7.0628E-06	–1.6538E-05	–6.0269E-06
CC8	0	0	8.20869E-13	0
CC9	–3.758E-14	6.06235E-14	1.97598E-14	3.89425E-14
CC10	0.030056	0.023121	0.0265	0.01704
CC11	0	0	–0.271026	–0.244274
CC12	0.002138	0.001103	0.006368	0.007323
CC13	–12.8674	–13.16522	–18.271	–10.1285

TABLE C6.8.3 Heating Coefficients for the Exterior Wall Equation

Variable	Orientation of Surface			
	North	East	South	West
HU1	0.006203	0.007691	0.006044	0.006672
HU2	–1.3587E-12	–5.7162E-13	–2.69E-13	–4.3566E-13
HM1	0.531005	0.545732	0.837901	0.616936
HM2	0.000152	0.000107	0.000208	0.00015
HM3	–5.3183E-07	–1.0619E-07	–6.8253E-07	–2.6457E-07
HM4	–7.7381E-07	–1.4787E-06	2.11938E-06	–4.5783E-07
HM5	–0.000712	–0.000484	–0.001042	–0.000625
HM6	3.34859E-13	4.95762E-14	7.7019E-14	7.37105E-14
HM7	2.39071E-07	2.75045E-07	–3.8989E-07	0
HUO1	0.004943	0.008683	0.009028	0.008566
HUO2	0.013686	0.011055	0.010156	0.01146
HUO3	–1.1018E-05	–8.6896E-06	–7.3232E-06	–8.9867E-06
HXUO1	1.2694E-12	7.85644E-14	–2.8202E-13	3.04904E-14
HXUO2	–7.3058E-13	–8.109E-14	7.45599E-14	–7.4718E-14
HXUO3	1.9709E-07	1.94026E-07	9.87587E-08	1.95776E-07
HG1	–0.001051	–0.000983	–0.000981	–0.000948
HG2	–0.001063	–0.00093	–0.000815	–0.000975
HG3	2.99013E-06	2.62269E-06	2.4188E-06	2.49976E-06
HG4	7.49049E-07	–1.1106E-06	–2.1669E-06	–8.5605E-07
HG5	0.000109	0.000093431	9.75523E-05	8.62389E-05
HG6	–5.5591E-07	–3.158E-07	–2.61E-07	–2.9133E-07
HS1	–2.1825E-05	–2.0922E-05	–2.1089E-05	–2.0205E-05
HS2	3.39179E-12	1.905E-12	1.48388E-12	2.18215E-12
HS3	–6.5325E-06	–2.2341E-05	–1.8473E-05	–2.4049E-05
HS4	2.23087E-05	2.41331E-05	2.45412E-05	2.30538E-05
HC1	–0.106468	–5.19297	–3.66743	–5.29681
HC2	0.00729	0.007684	0.007175	0.007672
HC3	–2.976E-07	–3.0784E-07	–2.6419E-07	–3.0713E-07
HC4	2.01569E-06	6.3035E-06	3.32112E-06	6.43491E-06
HC5	1.29061E-05	4.77552E-06	3.25089E-06	4.83233E-06
HC6	–1.2859E-05	–6.1854E-06	–4.6309E-06	–6.251E-06
HC7	2.75861E-12	8.20051E-13	4.38148E-13	8.09106E-13

C6.10 Calculations for Other Exterior and Semi-Exterior Surfaces. For all *exterior* and *semi-exterior* surfaces not covered in Sections C6.8 and C6.9, the cooling factor, COOL, and heating factor, HEAT, shall be calculated using the procedure in this section.

C6.10.1 U-Factor for Below-Grade Walls. The effective *U-factor* of *below-grade walls* shall be calculated using Equation C-20. R_{soil} shall be selected from Table C6.10.1 based on the average depth of the bottom of the wall below the surface of the ground.

$$\text{U-factor} = 1 / ((1/\text{C-factor}) + 0.85 + R_{soil}) \qquad \text{(C-20)}$$

where

R_{soil} = effective R-value of the soil from Table C6.10.1

C6.10.2 Adjustment for Other Protected Elements of the Exterior Envelope. The adjusted *U-factor* for *exterior envelope* surfaces, which are protected from outdoor conditions by crawlspaces, attics, or parking garages with natural or mechanical ventilation, shall be adjusted using Equation C-21 before calculating HEAT and COOL.

$$U_{adj} = 1 / \left((1 / \text{U-factor}) + 2\right) \qquad \text{(C-21)}$$

C6.10.3 Calculation of COOL and HEAT. COOL and HEAT shall be calculated for each surface using Equations C-22 and C-23 and coefficients from Table C6.10.2, which depend on surface classification and *space-conditioning category.*

$$\text{COOL} = \text{Size} \times \text{Factor} \times 0.08 \times (\text{Ccoef1} \times \text{CDD50} + \text{Ccoef2}) \qquad \text{(C-22)}$$

$$\text{HEAT} = \text{Size} \times \text{Hcoef} \times \text{Factor} \times \text{HDD65} \times 0.66 \qquad \text{(C-23)}$$

where

Size = area of surface or length of exposed *slab-on-grade floor* perimeter in the building

Ccoef1, Ccoef2 = coefficients, from Table C6.10.2

Hcoef = coefficient from Table C6.10.2

Factor = *U-factor* except U_{adj} calculated using Equation C-21 for protected surfaces and for *slab-on-grade floors*, perimeter *F-factor*

TABLE C6.9 Heating and Cooling Coefficients for Skylights

Coefficient	Nonresidential	Residential
C_2	1.09E-02	1.64E-02
H_2	2.12E-04	2.91E-04
H_3	–1.68E-04	–2.96E-04

TABLE C6.10.1 Effective R-Value of Soil for Below-Grade Walls

Depth, m	R_{soil} (m^2k/W)
0.25	0.12
0.50	0.23
0.75	0.33
1.0	0.42
1.25	0.52
1.50	0.59
1.75	0.68
2.00	0.75
2.25	0.83
2.50	0.92
2.75	0.99
3.00	1.06

TABLE C6.10.2 Heating and Cooling Coefficients for Other Exterior and Semi-Exterior Surfaces

Building Envelope Classification	Exterior						Semi-Exterior		
Space-Conditioning Type	Nonresidential			Residential			All		
Surface Type	Ccoef1	Ccoef2	Hcoef	Ccoef1	Ccoef2	Hcoef	Ccoef1	Ccoef2	Hcoef
Roof	0.001153	5.56	2.28E-04	0.001656	9.44	3.37E-04	0	0	8.08E-05
Wall, above-grade, and opaque doors	6.04E-04	0	2.28E-04	1.18E-03	0	3.37E-04	0	0	7.56E-05
Wall, below-grade	2.58E-04	0	2.29E-04	6.80E-04	0	3.35E-04	N/A	0	7.85E-05
Mass floor	6.91E-04	0	2.39E-04	1.01E-03	0	3.60E-04	0	0	7.14E-05
Other floor	7.09E-04	0	2.43E-04	9.54E-04	0	3.66E-04	0	0	7.14E-05
Slab-on-grade floor	0	0	2.28E-04	0	0	3.37E-04	0	0	6.80E-05
Vertical fenestration	N/A	0	N/A	N/A	0	N/A	0	0	7.56E-05
Skylights	N/A	0	N/A	N/A	0	N/A	0	0	8.08E-05

(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 US, Canadian, and international locations. (See Section 5.1.4 for additional information regarding the selection of climatic data.) The following definition applies: N.A. = Not Available.

TABLE D-1 US and US Territory Climatic Data

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
Alabama (AL)									
Alexander City	32.95 N	85.93 W	195	1617	2834	N.A.	N.A.	N.A.	N.A.
Anniston FAA AP	33.58 N	85.85 W	186	1586	2898	–7	34	24	N.A.
Auburn Agronomy Farm	32.60 N	85.50 W	198	1451	3016	N.A.	N.A.	N.A.	N.A.
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	N.A.
Gadsden Steam Plant	34.03 N	86.00 W	172	1843	2669	N.A.	N.A.	N.A.	N.A.
Huntsville WSO AP	34.65 N	86.77 W	190	1846	2697	–9	33	23	N.A.
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	N.A.	N.A.	N.A.	N.A.
Talladega	33.43 N	86.08 W	169	1550	2832	N.A.	N.A.	N.A.	N.A.
Tuscaloosa FAA AP	33.23 N	87.62 W	51	1478	3124	–7	34	25	N.A.
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	N.A.
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.	N.A.	N.A.	N.A.	N.A.
Flagstaff WSO AP	35.13 N	111.67 W	2135	3962	923	–17	28	13	N.A.
Kingman	35.20 N	114.02 W	1078	1784	2800	–6	36	17	N.A.
Nogales	31.42 N	110.95 W	1085	1627	2530	N.A.	N.A.	N.A.	N.A.
Phoenix WSFO AP	33.43 N	112.02 W	338	750	4681	1	42	21	746

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Arizona cont.)									
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	N.A.
Camden	33.60 N	92.82 W	35	1641	2949	N.A.	N.A.	N.A.	N.A.
Fayetteville	36.00 N	94.17 W	381	2244	2473	–14	34	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
Jonesboro	35.88 N	90.70 W	118	1947	2843	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Texarkana FAA AP	33.45 N	94.00 W	110	1275	3418	–7	35	25	N.A.
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	N.A.	N.A.	N.A.	N.A.
Burbank Hollywood	34.20 N	118.37 W	236	669	3250	4	35	21	N.A.
Chico University Farm	39.70 N	121.82 W	56	1641	2474	N.A.	N.A.	N.A.	N.A.
Crescent City	41.77 N	124.20 W	12	2443	904	N.A.	N.A.	N.A.	N.A.
El Centro	32.77 N	115.57 W	–9	642	4518	N.A.	N.A.	N.A.	N.A.
Eureka WSO City	40.80 N	124.17 W	18	2498	849	N.A.	N.A.	N.A.	N.A.
Fairfield/Travis AFB	38.27 N	121.93 W	19	1420	2346	–1	34	19	N.A.
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	N.A.	N.A.	N.A.	N.A.
Livermore	37.67 N	121.77 W	146	1616	2117	N.A.	N.A.	N.A.	N.A.
Lompoc	34.65 N	120.45 W	28	1473	1800	N.A.	N.A.	N.A.	N.A.
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	N.A.
Monterey	36.60 N	121.90 W	117	1736	1430	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(California cont.)									
Napa State Hospital	38.28 N	122.27 W	18	1580	1924	N.A.	N.A.	N.A.	N.A.
Needles FAA Airport	34.77 N	114.62 W	278	727	4803	N.A.	N.A.	N.A.	N.A.
Oakland/Intl	37.73 N	122.20 W	2	1469	1737	N.A.	N.A.	N.A.	1905
Oceanside Marina	33.22 N	117.40 W	3	1117	2261	N.A.	N.A.	N.A.	N.A.
Ontario/Intl	34.05 N	117.62 W	293	827	3235	2	37	21	N.A.
Oxnard	34.20 N	119.18 W	14	1107	2211	4	26	18	N.A.
Palm Springs	33.83 N	116.50 W	129	547	4753	N.A.	N.A.	N.A.	N.A.
Palmdale	34.58 N	118.10 W	791	1638	2702	N.A.	N.A.	N.A.	N.A.
Pasadena	34.15 N	118.15 W	263	807	3042	N.A.	N.A.	N.A.	N.A.
Petaluma Fire Stn 3	38.23 N	122.63 W	8	1694	1771	N.A.	N.A.	N.A.	N.A.
Pomona Cal Poly	34.07 N	117.82 W	225	952	2858	N.A.	N.A.	N.A.	N.A.
Redding WSO	40.50 N	122.30 W	153	1586	2758	N.A.	N.A.	N.A.	N.A.
Redlands	34.05 N	117.18 W	401	1042	3019	N.A.	N.A.	N.A.	N.A.
Richmond	37.93 N	122.35 W	16	1420	1825	N.A.	N.A.	N.A.	N.A.
Riverside/March AFB	33.90 N	117.25 W	468	1034	2942	1	37	20	N.A.
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	N.A.
San Bernardino/Norton	34.10 N	117.23 W	352	1012	3028	1	38	21	N.A.
San Diego WSO AP	32.73 N	117.17 W	3	698	2902	7	27	19	1911
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	N.A.
San Luis Obispo Poly	35.30 N	120.67 W	96	1388	1940	N.A.	N.A.	N.A.	N.A.
Santa Ana Fire Station	33.75 N	117.87 W	41	688	3017	N.A.	N.A.	N.A.	N.A.
Santa Barbara FAA AP	34.43 N	119.83 W	2	1354	1916	1	27	18	N.A.
Santa Cruz	36.98 N	122.02 W	39	1649	1618	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Santa Paula	34.32 N	119.15 W	72	1133	2286	N.A.	N.A.	N.A.	N.A.
Santa Rosa	38.45 N	122.70 W	50	1602	1907	N.A.	N.A.	N.A.	N.A.
Stockton WSO AP	37.90 N	121.25 W	6	1504	2642	–1	36	20	N.A.
Ukiah	39.15 N	123.20 W	189	1641	2149	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(California cont.)									
Visalia	36.33 N	119.30 W	99	1395	2881	N.A.	N.A.	N.A.	N.A.
Yreka	41.72 N	122.63 W	800	2992	1451	N.A.	N.A.	N.A.	N.A.
Colorado (CO)									
Alamosa WSO AP	37.45 N	105.87 W	2296	4861	763	–27	28	13	N.A.
Boulder	40.03 N	105.28 W	1652	3086	1567	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Ft Collins	40.58 N	105.08 W	1525	3538	1339	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
La Junta FAA AP	38.05 N	103.52 W	1277	2925	2108	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Trinidad FAA AP	37.25 N	104.33 W	1751	3046	1653	–19	32	16	N.A.
Connecticut (CT)									
Bridgeport WSO AP	41.17 N	73.13 W	3	3076	1665	–13	29	22	N.A.
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	N.A.	N.A.	N.A.	N.A.
Norwich Pub Util Plt	41.53 N	72.07 W	6	3261	1493	N.A.	N.A.	N.A.	N.A.
Delaware (DE)									
Dover	39.15 N	75.52 W	9	2409	2163	–10	32	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.
Ft Myers FAA AP	26.58 N	81.87 W	4	232	4958	6	34	25	N.A.
Ft Pierce	27.47 N	80.35 W	7	272	4693	N.A.	N.A.	N.A.	N.A.
Gainesville Mun AP	29.68 N	82.27 W	42	704	3894	–1	33	25	N.A.
Jacksonville WSO AP	30.50 N	81.70 W	7	797	3804	–2	34	25	674

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Florida cont.)									
Key West WSO AP	24.55 N	81.75 W	1	56	5652	13	32	26	N.A.
Lakeland	28.02 N	81.92 W	44	327	4707	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.
Pensacola FAA AP	30.47 N	87.20 W	34	898	3787	–2	33	26	N.A.
St Augustine WFOY	29.90 N	81.32 W	2	578	4034	N.A.	N.A.	N.A.	N.A.
St Petersburg	27.77 N	82.63 W	2	335	4743	6	34	26	N.A.
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	N.A.
Americus	32.05 N	84.25 W	149	1350	3130	N.A.	N.A.	N.A.	N.A.
Athens WSO AP	33.95 N	83.32 W	244	1607	2822	–7	33	24	N.A.
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	N.A.
Columbus WSO AP	32.52 N	84.95 W	136	1256	3362	–5	34	24	N.A.
Dalton	34.75 N	84.95 W	213	1973	2526	N.A.	N.A.	N.A.	N.A.
Dublin	32.50 N	82.90 W	65	1376	3147	N.A.	N.A.	N.A.	N.A.
Gainesville	34.30 N	83.85 W	356	1944	2394	N.A.	N.A.	N.A.	N.A.
La Grange	33.05 N	85.02 W	217	1482	2898	N.A.	N.A.	N.A.	N.A.
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	N.A.
Valdosta/Moody AFB	30.97 N	83.20 W	71	862	4009	–1	34	25	N.A.
Waycross	31.25 N	82.32 W	44	1125	3429	–2	34	24	N.A.
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	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
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	N.A.
Coeur D'Alene R S	47.68 N	116.75 W	657	3466	1231	N.A.	N.A.	N.A.	N.A.
Idaho Falls FAA AP	43.52 N	112.07 W	1441	4479	1029	–24	32	16	N.A.
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	N.A.	N.A.	N.A.	N.A.
Mountain Home	43.13 N	115.70 W	972	3431	1514	–18	36	17	N.A.
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	N.A.	N.A.	N.A.	N.A.
Illinois (IL)									
Aurora	41.75 N	88.35 W	196	3722	1600	N.A.	N.A.	N.A.	N.A.
Belleville/Scott AFB	38.55 N	89.85 W	138	2710	2304	–16	34	25	N.A.
Carbondale Sewage Plt	37.73 N	89.17 W	118	2703	2186	N.A.	N.A.	N.A.	N.A.
Champaign	40.03 N	88.28 W	230	3160	2054	N.A.	N.A.	N.A.	N.A.
Chicago Midway AP	41.73 N	87.77 W	188	3431	1806	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Danville	40.13 N	87.65 W	170	3117	1928	–20	32	25	N.A.
Decatur	39.83 N	89.02 W	188	3068	2029	–19	33	24	N.A.
Dixon	41.83 N	89.52 W	213	3818	1647	N.A.	N.A.	N.A.	N.A.
Freeport Waste Wtr Plt	42.30 N	89.60 W	228	3983	1522	N.A.	N.A.	N.A.	N.A.
Galesburg	40.95 N	90.38 W	235	3508	1805	N.A.	N.A.	N.A.	N.A.
Joliet Brandon Rd Dam	41.50 N	88.10 W	165	3591	1681	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Peoria WSO AP	40.67 N	89.68 W	198	3416	1855	–21	32	23	N.A.
Quincy FAA AP	39.93 N	91.20 W	232	3202	1986	–20	33	24	N.A.
Rantoul	40.32 N	88.17 W	225	3435	1827	N.A.	N.A.	N.A.	N.A.
Rockford WSO AP	42.20 N	89.10 W	220	3872	1584	–23	31	23	N.A.
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	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
Indiana (IN)									
Anderson Sewage Plant	40.10 N	85.72 W	258	3287	1717	N.A.	N.A.	N.A.	N.A.
Bloomington Indiana U	39.17 N	86.52 W	251	2949	1992	N.A.	N.A.	N.A.	N.A.
Columbus	39.20 N	85.92 W	189	3076	1863	N.A.	N.A.	N.A.	N.A.
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
Goshen College	41.57 N	85.83 W	245	3490	1634	N.A.	N.A.	N.A.	N.A.
Hobart	41.53 N	87.25 W	182	3357	1760	N.A.	N.A.	N.A.	N.A.
Indianapolis WSFO	39.73 N	86.27 W	241	3119	1918	–19	31	23	N.A.
Kokomo	40.42 N	86.05 W	260	3572	1654	N.A.	N.A.	N.A.	N.A.
Lafayette	40.35 N	86.87 W	182	3460	1705	–21	32	24	N.A.
Marion	40.57 N	85.67 W	240	3478	1664	N.A.	N.A.	N.A.	N.A.
Muncie Ball State Univ	40.22 N	85.42 W	286	3348	1776	N.A.	N.A.	N.A.	N.A.
Peru/Grissom AFB	40.65 N	86.15 W	248	3282	1910	–19	32	24	N.A.
Richmond Wtr Wks	39.88 N	84.88 W	309	3213	1669	N.A.	N.A.	N.A.	N.A.
Shelbyville Sewage Plt	39.52 N	85.78 W	228	3213	1828	N.A.	N.A.	N.A.	N.A.
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	N.A.
Valparaiso Waterworks	41.52 N	87.03 W	243	3482	1634	N.A.	N.A.	N.A.	N.A.
Iowa (IA)									
Ames	42.03 N	93.80 W	334	3764	1711	N.A.	N.A.	N.A.	N.A.
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	N.A.
Clinton	41.80 N	90.27 W	178	3513	1828	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Ft Dodge	42.50 N	94.20 W	339	4034	1612	–25	31	23	N.A.
Iowa City	41.65 N	91.53 W	195	3459	1908	N.A.	N.A.	N.A.	N.A.
Keokuk Lock and Dam	40.40 N	91.37 W	160	3316	1926	N.A.	N.A.	N.A.	N.A.
Marshalltown	42.07 N	92.93 W	265	3983	1563	N.A.	N.A.	N.A.	N.A.
Mason City FAA AP	43.17 N	93.33 W	363	4354	1474	–26	31	23	610

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Iowa cont.)									
Newton	41.70 N	93.05 W	285	3768	1739	N.A.	N.A.	N.A.	N.A.
Ottumwa Airport	41.10 N	92.45 W	256	3483	1897	–21	33	24	N.A.
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	N.A.
Kansas (KS)									
Atchison	39.57 N	95.12 W	288	2880	2189	N.A.	N.A.	N.A.	N.A.
Chanute FAA Airport	37.67 N	95.48 W	298	2583	2348	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Garden City FAA AP	37.93 N	100.72 W	878	2898	2187	–19	36	21	N.A.
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	N.A.	N.A.	N.A.	N.A.
Hutchinson	37.93 N	98.03 W	478	2835	2281	N.A.	N.A.	N.A.	N.A.
Liberal	37.05 N	100.92 W	863	2614	2325	N.A.	N.A.	N.A.	N.A.
Manhattan	39.20 N	96.58 W	324	2802	2308	N.A.	N.A.	N.A.	N.A.
Parsons	37.37 N	95.28 W	277	2559	2411	N.A.	N.A.	N.A.	N.A.
Russell FAA AP	38.87 N	98.82 W	568	2966	2188	–20	36	22	N.A.
Salina FAA AP	38.80 N	97.63 W	383	2834	2315	–19	36	23	N.A.
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	N.A.
Kentucky (KY)									
Ashland	38.45 N	82.62 W	169	2903	1822	N.A.	N.A.	N.A.	N.A.
Bowling Green FAA AP	36.97 N	86.42 W	166	2404	2296	–14	33	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Owensboro	37.77 N	87.15 W	123	2408	2346	N.A.	N.A.	N.A.	N.A.
Paducah WSO	37.07 N	88.77 W	124	2377	2398	–14	34	24	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
Louisiana (LA)									
Alexandria	31.32 N	92.47 W	26	1113	3559	–3	34	26	N.A.
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	N.A.	N.A.	N.A.	N.A.
Houma	29.58 N	90.73 W	4	794	3874	N.A.	N.A.	N.A.	N.A.
Lafayette FAA AP	30.20 N	91.98 W	11	882	3821	–2	34	26	N.A.
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	N.A.	N.A.	N.A.	N.A.
Monroe FAA AP	32.52 N	92.05 W	23	1337	3355	–6	34	26	N.A.
Natchitoches	31.77 N	93.08 W	39	1196	3485	N.A.	N.A.	N.A.	N.A.
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	N.A.
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	N.A.	N.A.	N.A.	N.A.
Millinocket	45.65 N	68.70 W	109	4946	949	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Maryland (MD)									
Baltimore WSO AP	39.18 N	76.67 W	59	2615	2061	–12	33	23	N.A.
Cumberland	39.63 N	78.75 W	222	2798	1907	N.A.	N.A.	N.A.	N.A.
Hagerstown	39.65 N	77.73 W	201	2941	1856	N.A.	N.A.	N.A.	N.A.
Salisbury	38.37 N	75.58 W	3	2237	2223	–11	32	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
Framingham	42.28 N	71.42 W	51	3479	1497	N.A.	N.A.	N.A.	N.A.
Lawrence	42.70 N	71.17 W	17	3512	1471	N.A.	N.A.	N.A.	N.A.
Lowell	42.65 N	71.37 W	33	3522	1508	N.A.	N.A.	N.A.	N.A.
New Bedford	41.63 N	70.93 W	36	3014	1652	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Massachusetts cont.)									
Springfield	42.10 N	72.58 W	57	3197	1687	N.A.	N.A.	N.A.	N.A.
Taunton	41.90 N	71.07 W	6	3526	1367	N.A.	N.A.	N.A.	N.A.
Worcester WSO AP	42.27 N	71.87 W	300	3877	1224	–18	28	21	N.A.
Michigan (MI)									
Adrian	41.92 N	84.02 W	231	3743	1437	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Benton Harbor AP	42.13 N	86.43 W	197	3502	1572	N.A.	N.A.	N.A.	N.A.
Detroit City Airport	42.42 N	83.02 W	190	3426	1692	–18	31	22	N.A.
Escanaba	45.75 N	87.03 W	182	4774	924	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Jackson FAA AP	42.27 N	84.45 W	306	3773	1504	–19	30	23	N.A.
Kalamazoo State Hosp	42.28 N	85.60 W	288	3461	1675	N.A.	N.A.	N.A.	N.A.
Lansing WSO AP	42.77 N	84.60 W	256	3945	1361	–19	30	22	N.A.
Marquette	46.55 N	87.38 W	202	4642	961	–25	28	19	N.A.
Mt Pleasant University	43.58 N	84.77 W	242	4131	1288	N.A.	N.A.	N.A.	N.A.
Muskegon WSO AP	43.17 N	86.23 W	191	3847	1312	–16	28	21	N.A.
Pontiac State Hospital	42.65 N	83.30 W	299	3696	1539	N.A.	N.A.	N.A.	N.A.
Port Huron	42.98 N	82.42 W	179	3832	1412	N.A.	N.A.	N.A.	N.A.
Saginaw FAA AP	43.53 N	84.08 W	201	3966	1376	–18	31	22	N.A.
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	N.A.	N.A.	N.A.	N.A.
Minnesota (MN)									
Albert Lea	43.62 N	93.42 W	374	4526	1449	N.A.	N.A.	N.A.	N.A.
Alexandria FAA AP	45.87 N	95.38 W	431	4999	1287	–29	30	21	N.A.
Bemidji Airport	47.50 N	94.93 W	419	5667	989	N.A.	N.A.	N.A.	N.A.
Brainerd	46.37 N	94.20 W	359	5243	1088	–31	29	20	N.A.
Duluth WSO AP	46.83 N	92.18 W	435	5454	853	–29	27	19	650

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Minnesota cont.)									
Faribault	44.30 N	93.27 W	286	4599	1388	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.
Virginia	47.50 N	92.55 W	437	5569	879	N.A.	N.A.	N.A.	N.A.
Willmar State Hospital	45.13 N	95.02 W	343	4798	1369	N.A.	N.A.	N.A.	N.A.
Winona	44.05 N	91.63 W	198	4274	1497	N.A.	N.A.	N.A.	N.A.
Mississippi (MS)									
Biloxi/Keesler AFB	30.42 N	88.92 W	8	826	3859	–1	33	26	N.A.
Clarksdale	34.20 N	90.57 W	52	1771	2976	N.A.	N.A.	N.A.	N.A.
Columbus AFB	33.65 N	88.45 W	67	1538	3092	–7	34	26	N.A.
Greenville	33.38 N	91.02 W	40	1543	3145	N.A.	N.A.	N.A.	N.A.
Greenwood FAA AP	33.50 N	90.08 W	47	1499	3200	–7	34	26	N.A.
Hattiesburg	31.32 N	89.30 W	49	1211	3381	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
McComb FAA AP	31.23 N	90.47 W	125	1175	3347	–5	33	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
Tupelo WSO AP	34.27 N	88.73 W	110	1711	2902	–8	34	24	N.A.
Vicksburg Military Pk	32.35 N	90.85 W	77	1220	3366	N.A.	N.A.	N.A.	N.A.
Missouri (MO)									
Cape Girardeau FAA AP	37.23 N	89.57 W	102	2437	2422	–14	34	25	N.A.
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	N.A.	N.A.	N.A.	N.A.
Hannibal	39.72 N	91.37 W	217	3127	2047	N.A.	N.A.	N.A.	N.A.
Jefferson City Wtr Plt	38.58 N	92.15 W	204	2946	2058	N.A.	N.A.	N.A.	N.A.
Joplin FAA AP	37.17 N	94.50 W	298	2391	2454	–16	34	24	N.A.
Kansas City WSO AP	39.32 N	94.72 W	296	2996	2140	–18	34	24	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Missouri cont.)									
Kirksville Radio KIRX	40.22 N	92.58 W	295	3259	1941	N.A.	N.A.	N.A.	N.A.
Mexico	39.18 N	91.88 W	236	3106	2036	N.A.	N.A.	N.A.	N.A.
Moberly Radio KWIX	39.40 N	92.43 W	256	2891	2193	N.A.	N.A.	N.A.	N.A.
Poplar Bluff R S	36.77 N	90.42 W	115	2404	2427	–13	33	24	N.A.
Rolla	38.13 N	91.77 W	350	2638	2325	N.A.	N.A.	N.A.	N.A.
Rolla Univ of MO	37.95 N	91.77 W	359	2755	2214	N.A.	N.A.	N.A.	N.A.
St Joseph	39.77 N	94.92 W	247	3106	2102	N.A.	N.A.	N.A.	N.A.
St Louis WSCMO AP	38.75 N	90.37 W	163	2643	2379	–17	34	24	N.A.
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	N.A.
Butte FAA AP	45.95 N	112.50 W	1688	5287	640	–30	29	29	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.
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	N.A.
Lewistown FAA AP	47.07 N	109.45 W	1259	4711	878	–28	30	16	673
Livingston FAA AP	45.70 N	110.45 W	1418	4011	1056	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Columbus	41.47 N	97.33 W	441	3635	1858	N.A.	N.A.	N.A.	N.A.
Fremont	41.43 N	96.48 W	359	3411	1901	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Kearney	40.73 N	99.02 W	649	3638	1717	N.A.	N.A.	N.A.	N.A.
Lincoln WSO AP	40.85 N	96.75 W	362	3488	1919	–22	34	23	N.A.
Mc Cook	40.22 N	100.58 W	786	3397	1798	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Nebraska cont.)									
Norfolk WSO AP	41.98 N	97.43 W	472	3818	1707	–24	33	22	N.A.
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	N.A.
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	N.A.
Nevada (NV)									
Carson City	39.15 N	119.77 W	1417	3162	1284	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Portsmouth/Pease AFB	43.08 N	70.82 W	31	3651	1343	–16	29	21	N.A.
New Jersey (NJ)									
Atlantic City WSO AP	39.45 N	74.57 W	42	2872	1777	–13	31	23	N.A.
Long Branch Oakhurst	40.27 N	74.00 W	9	2918	1698	N.A.	N.A.	N.A.	N.A.
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	N.A.
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	N.A.	N.A.	N.A.	N.A.
Carlsbad FAA AP	32.33 N	104.27 W	985	1562	3062	–7	37	19	N.A.
Clovis/Cannon AFB	34.38 N	103.32 W	1309	2213	2321	–12	34	18	N.A.
Farmington	36.73 N	108.23 W	1677	3035	1837	–13	33	16	N.A.
Gallup FAA AP	35.52 N	108.78 W	1971	3469	1308	–18	31	13	N.A.
Grants Airport	35.17 N	107.90 W	1987	3282	1378	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(New Mexico cont.)									
Hobbs	32.70 N	103.13 W	1101	1584	2867	N.A.	N.A.	N.A.	N.A.
Raton Filter Plant	36.92 N	104.43 W	2112	3391	1215	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Batavia	42.98 N	78.18 W	271	3698	1409	N.A.	N.A.	N.A.	N.A.
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
Cortland	42.60 N	76.18 W	344	3982	1236	N.A.	N.A.	N.A.	N.A.
Elmira/Chemung Co	42.17 N	76.90 W	290	3803	1345	–19	31	22	N.A.
Geneva Research Farm	42.88 N	77.03 W	218	3855	1313	N.A.	N.A.	N.A.	N.A.
Glens Falls FAA AP	43.35 N	73.62 W	97	4242	1212	–23	29	22	N.A.
Gloversville	43.05 N	74.35 W	247	4258	1177	N.A.	N.A.	N.A.	N.A.
Ithaca Cornell Univ	42.45 N	76.45 W	292	4004	1176	N.A.	N.A.	N.A.	N.A.
Lockport	43.18 N	78.65 W	158	3724	1379	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	790
NY Kennedy WSO AP	40.65 N	73.78 W	4	2793	1857	–12	31	22	N.A.
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	N.A.	N.A.	N.A.	N.A.
Plattsburgh AFB	44.65 N	73.47 W	50	4354	1208	–23	28	21	N.A.
Poughkeepsie FAA AP	41.63 N	73.88 W	47	3551	1479	–17	31	22	N.A.
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	N.A.
Schenectady	42.83 N	73.92 W	67	3823	1389	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Watertown	43.97 N	75.87 W	151	4189	1274	–24	18	21	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
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	N.A.	N.A.	N.A.	N.A.
Elizabeth City FAA AP	36.27 N	76.18 W	3	1744	2647	N.A.	N.A.	N.A.	N.A.
Fayetteville/Pope AFB	35.17 N	79.02 W	66	1620	2949	–6	34	24	N.A.
Goldsboro	35.33 N	77.97 W	33	1689	2788	–6	34	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
Henderson	36.37 N	78.42 W	146	2243	2223	N.A.	N.A.	N.A.	N.A.
Hickory FAA AP	35.73 N	81.38 W	348	2071	2333	–8	33	22	N.A.
Jacksonville/New River	34.70 N	77.43 W	8	1365	3154	–5	33	26	N.A.
Lumberton	34.70 N	79.07 W	39	1784	2624	N.A.	N.A.	N.A.	N.A.
New Bern FAA AP	35.07 N	77.05 W	5	1523	2923	–6	33	26	N.A.
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	N.A.	N.A.	N.A.	N.A.
Wilmington WSO AP	34.27 N	77.90 W	21	1372	3087	–5	33	26	N.A.
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	N.A.
Dickinson FAA AP	46.78 N	102.80 W	786	4809	1196	N.A.	N.A.	N.A.	N.A.
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	N.A.
Jamestown FAA AP	46.92 N	98.68 W	454	5093	1257	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Bowling Green	41.38 N	83.62 W	205	3601	1598	N.A.	N.A.	N.A.	N.A.
Cambridge	40.02 N	81.58 W	243	3049	1732	N.A.	N.A.	N.A.	N.A.
Cincinnati-Abbe WSO	39.15 N	84.52 W	231	2771	2074	–15	32	24	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Ohio cont.)									
Cleveland WSFO AP	41.42 N	81.87 W	234	3445	1531	–17	30	22	N.A.
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
Defiance	41.28 N	84.38 W	213	3682	1561	N.A.	N.A.	N.A.	N.A.
Findlay FAA AP	41.02 N	83.67 W	242	3501	1615	–19	31	22	N.A.
Fremont	41.33 N	83.12 W	182	3577	1568	N.A.	N.A.	N.A.	N.A.
Lancaster	39.73 N	82.63 W	262	3327	1631	N.A.	N.A.	N.A.	N.A.
Lima Sewage Plant	40.72 N	84.13 W	259	3474	1694	N.A.	N.A.	N.A.	N.A.
Mansfield WSO AP	40.82 N	82.52 W	394	3477	1566	–18	29	22	N.A.
Marion	40.62 N	83.13 W	294	3559	1576	N.A.	N.A.	N.A.	N.A.
Newark Water Works	40.08 N	82.42 W	254	3143	1726	N.A.	N.A.	N.A.	N.A.
Norwalk	41.27 N	82.62 W	204	3574	1508	N.A.	N.A.	N.A.	N.A.
Portsmouth	38.75 N	82.88 W	164	2729	1989	N.A.	N.A.	N.A.	N.A.
Sandusky	41.45 N	82.72 W	178	3406	1659	N.A.	N.A.	N.A.	N.A.
Springfield New Wtr Wk	39.97 N	83.82 W	283	3474	1550	N.A.	N.A.	N.A.	N.A.
Steubenville	40.38 N	80.63 W	302	3167	1697	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Wooster Exp Station	40.78 N	81.92 W	310	3544	1428	N.A.	N.A.	N.A.	N.A.
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	N.A.
Oklahoma (OK)									
Ada	34.78 N	96.68 W	309	1768	2954	N.A.	N.A.	N.A.	N.A.
Altus AFB	34.65 N	99.27 W	420	1750	3171	–11	38	23	N.A.
Ardmore	34.20 N	97.15 W	262	1501	3321	N.A.	N.A.	N.A.	N.A.
Bartlesville	36.75 N	96.00 W	217	2098	2764	N.A.	N.A.	N.A.	N.A.
Chickasha Exp Station	35.05 N	97.92 W	330	1870	2943	N.A.	N.A.	N.A.	N.A.
Enid	36.42 N	97.87 W	379	2104	2844	–15	37	23	N.A.
Lawton	34.62 N	98.45 W	350	1921	2927	–11	36	23	N.A.
McAlester FAA AP	34.88 N	95.78 W	231	1863	2907	–12	36	24	N.A.
Muskogee	35.77 N	95.33 W	177	1896	2881	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Oklahoma cont.)									
Norman	35.18 N	97.45 W	338	1831	2929	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Seminole	35.23 N	96.67 W	263	1721	3084	N.A.	N.A.	N.A.	N.A.
Stillwater	36.12 N	97.10 W	272	2238	2621	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Bend	44.07 N	121.28 W	1115	3848	781	N.A.	N.A.	N.A.	N.A.
Corvallis State Univ	44.63 N	123.20 W	68	2735	1139	N.A.	N.A.	N.A.	N.A.
Eugene WSO AP	44.12 N	123.22 W	110	2526	1308	–6	31	18	N.A.
Grants Pass	42.42 N	123.33 W	292	2344	1659	N.A.	N.A.	N.A.	N.A.
Klamath Falls	42.20 N	121.78 W	1249	3686	1086	–16	31	17	N.A.
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	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.
Chambersburg	39.93 N	77.63 W	195	3097	1700	N.A.	N.A.	N.A.	N.A.
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
Johnstown	40.33 N	78.92 W	370	3138	1682	N.A.	N.A.	N.A.	N.A.
Lancaster	40.05 N	76.28 W	82	3102	1711	N.A.	N.A.	N.A.	N.A.
Meadville	41.63 N	80.17 W	324	3852	1227	N.A.	N.A.	N.A.	N.A.
New Castle	41.02 N	80.37 W	251	3634	1390	N.A.	N.A.	N.A.	N.A.
Philadelphia WSCMO AP	39.88 N	75.23 W	3	2752	2013	–12	32	23	646

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Pennsylvania cont.)									
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	N.A.	N.A.	N.A.	N.A.
State College	40.80 N	77.87 W	356	3536	1461	N.A.	N.A.	N.A.	N.A.
Uniontown	39.92 N	79.72 W	291	3158	1618	N.A.	N.A.	N.A.	N.A.
Warren	41.85 N	79.15 W	368	3828	1297	N.A.	N.A.	N.A.	N.A.
West Chester	39.97 N	75.63 W	137	2935	1827	N.A.	N.A.	N.A.	N.A.
Williamsport WSO AP	41.25 N	76.92 W	159	3382	1553	–17	31	22	N.A.
York Pump Station 22	39.92 N	76.75 W	118	2920	1819	N.A.	N.A.	N.A.	N.A.
Rhode Island (RI)									
Newport	41.52 N	71.32 W	6	3144	1416	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Charleston WSO AP	32.90 N	80.03 W	12	1118	3438	N.A.	N.A.	N.A.	N.A.
Charleston WSO City	32.78 N	79.93 W	3	1037	3502	–4	33	25	N.A.
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	N.A.
Georgetown	33.35 N	79.25 W	3	1156	3304	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Orangeburg	33.50 N	80.87 W	48	1408	3043	N.A.	N.A.	N.A.	N.A.
Spartanburg	34.98 N	81.88 W	256	1604	2803	N.A.	N.A.	N.A.	N.A.
Sumter/Shaw AFB	33.97 N	80.48 W	73	1392	3029	–4	34	24	N.A.
South Dakota (SD)									
Aberdeen WSO AP	45.45 N	98.43 W	395	4692	1387	N.A.	N.A.	N.A.	N.A.
Brookings	44.32 N	96.77 W	500	4807	1238	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(South Dakota, cont.)									
Watertown FAA AP	44.92 N	97.15 W	532	4653	1388	N.A.	N.A.	N.A.	N.A.
Yankton	42.88 N	97.35 W	359	4058	1631	N.A.	N.A.	N.A.	N.A.
Tennessee (TN)									
Athens	35.43 N	84.58 W	286	2252	2244	N.A.	N.A.	N.A.	N.A.
Bristol WSO AP	36.48 N	82.40 W	464	2448	2012	–13	31	22	N.A.
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	N.A.	N.A.	N.A.	N.A.
Columbia	35.63 N	87.08 W	198	2337	2248	N.A.	N.A.	N.A.	N.A.
Dyersburg FAA AP	36.02 N	89.40 W	102	1964	2783	N.A.	N.A.	N.A.	N.A.
Greeneville Exp Stn	36.10 N	82.85 W	402	2440	2061	N.A.	N.A.	N.A.	N.A.
Jackson FAA AP	35.60 N	88.92 W	131	1967	2731	–11	34	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Amarillo WSO AP	35.23 N	101.70 W	1094	2366	2293	–14	34	19	680
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	N.A.	N.A.	N.A.	N.A.
Beaumont Research Ctr	30.07 N	94.28 W	8	932	3724	–2	33	26	N.A.
Beeville	28.45 N	97.70 W	77	762	4107	–2	37	25	N.A.
Big Spring	32.25 N	101.45 W	761	1540	3123	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Dallas FAA AP	32.85 N	96.85 W	134	1255	3659	–8	37	23	N.A.
Del Rio/Laughlin AFB	29.37 N	100.78 W	329	870	4004	–2	37	23	732

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Texas cont.)									
Denton	33.20 N	97.10 W	192	1481	3231	N.A.	N.A.	N.A.	N.A.
Eagle Pass	28.70 N	100.48 W	245	801	4268	N.A.	N.A.	N.A.	N.A.
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	N.A.
Galveston WSO City	29.30 N	94.80 W	2	702	4099	N.A.	N.A.	N.A.	N.A.
Greenville	33.20 N	96.22 W	185	1641	3071	N.A.	N.A.	N.A.	N.A.
Harlingen	26.20 N	97.67 W	11	452	4669	N.A.	N.A.	N.A.	N.A.
Houston /Hobby	29.65 N	95.28 W	15	762	4087	–2	34	25	N.A.
Houston-Bush Intercontinental Airport	29.97 N	95.35 W	29	888	3820	–3	34	25	N.A.
Huntsville	30.72 N	95.55 W	150	1034	3721	N.A.	N.A.	N.A.	N.A.
Killeen/Robert-Gray	31.07 N	97.83 W	309	1182	3598	–7	36	23	N.A.
Lamesa	32.70 N	101.93 W	903	1755	2837	N.A.	N.A.	N.A.	N.A.
Laredo	27.57 N	99.50 W	131	569	4719	0	38	23	598
Longview	32.47 N	94.73 W	100	1352	3289	N.A.	N.A.	N.A.	N.A.
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
McAllen	26.20 N	98.22 W	37	432	4776	1	37	24	N.A.
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	N.A.	N.A.	N.A.	N.A.
Palestine	31.78 N	95.60 W	141	1114	3586	N.A.	N.A.	N.A.	N.A.
Pampa No 2	35.53 N	100.98 W	990	2421	2295	N.A.	N.A.	N.A.	N.A.
Pecos	31.42 N	103.50 W	795	1392	3329	N.A.	N.A.	N.A.	N.A.
Plainview	34.18 N	101.70 W	1027	2065	2479	N.A.	N.A.	N.A.	N.A.
Port Arthur WSO AP	29.95 N	94.02 W	4	833	3886	N.A.	N.A.	N.A.	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	N.A.
Sherman	33.63 N	96.62 W	219	1606	3157	N.A.	N.A.	N.A.	721
Snyder	32.72 N	100.92 W	711	1769	2877	N.A.	N.A.	N.A.	N.A.
Temple	31.08 N	97.37 W	213	1196	3604	N.A.	N.A.	N.A.	N.A.
Tyler	32.35 N	95.40 W	166	1219	3645	N.A.	N.A.	N.A.	N.A.
Vernon	34.08 N	99.30 W	366	1770	3114	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Texas cont.)									
Victoria WSO AP	28.85 N	96.92 W	31	720	4171	–2	34	24	N.A.
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	N.A.	N.A.	N.A.	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	N.A.	N.A.	N.A.	N.A.
Moab	38.60 N	109.60 W	1208	2497	2420	N.A.	N.A.	N.A.	N.A.
Ogden Sugar Factory	41.23 N	112.03 W	1304	3306	1696	N.A.	N.A.	N.A.	N.A.
Richfield Radio KSVC	38.77 N	112.08 W	1606	3537	1278	N.A.	N.A.	N.A.	N.A.
Saint George	37.10 N	113.57 W	841	1786	3013	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Virginia (VA)									
Charlottesville	38.03 N	78.52 W	265	2347	2168	N.A.	N.A.	N.A.	N.A.
Danville-Bridge St	36.58 N	79.38 W	124	2191	2353	N.A.	N.A.	N.A.	N.A.
Fredericksburg Natl Pk	38.32 N	77.45 W	27	2530	2086	N.A.	N.A.	N.A.	N.A.
Lynchburg WSO AP	37.33 N	79.20 W	279	2411	2071	–11	32	23	N.A.
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	N.A.	N.A.	N.A.	N.A.
Winchester	39.18 N	78.12 W	207	2927	1786	N.A.	N.A.	N.A.	N.A.
Washington (WA)									
Aberdeen	46.97 N	123.82 W	3	2936	827	N.A.	N.A.	N.A.	N.A.
Bellingham FAA AP	48.80 N	122.53 W	45	3116	838	–9	24	18	N.A.
Bremerton	47.57 N	122.67 W	49	2844	1022	N.A.	N.A.	N.A.	N.A.
Ellensburg	46.97 N	120.55 W	451	3761	1111	N.A.	N.A.	N.A.	N.A.
Everett	47.98 N	122.18 W	18	2951	922	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., m	HDD18	CDD10	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Washington cont.)									
Kennewick	46.22 N	119.10 W	118	2719	1775	N.A.	N.A.	N.A.	N.A.
Longview	46.15 N	122.92 W	3	2830	1032	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Seattle EMSU WSO	47.65 N	122.30 W	6	2562	1178	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	640
Tacoma/McChord AFB	47.15 N	122.48 W	98	2864	1011	–8	28	17	N.A.
Walla Walla FAA AP	46.10 N	118.28 W	355	2754	1756	–16	35	18	N.A.
Wenatchee	47.42 N	120.32 W	195	3099	1642	–16	33	18	N.A.
Yakima WSO AP	46.57 N	120.53 W	324	3315	1304	–16	33	18	703
West Virginia (WV)									
Beckley WSO AP	37.78 N	81.12 W	763	3088	1494	N.A.	N.A.	N.A.	N.A.
Bluefield FAA AP	37.30 N	81.22 W	874	2906	1615	–15	28	21	N.A.
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	N.A.	N.A.	N.A.	N.A.
Elkins WSO AP	38.88 N	79.85 W	607	3400	1311	–19	28	21	N.A.
Huntington WSO AP	38.37 N	82.55 W	252	2592	2008	–14	32	23	N.A.
Martinsburg FAA AP	39.40 N	77.98 W	161	2884	1871	–13	33	23	N.A.
Morgantown FAA AP	39.65 N	79.92 W	377	2979	1753	–16	31	22	N.A.
Parkersburg	39.27 N	81.57 W	187	2830	1948	–16	31	22	N.A.
Wisconsin (WI)									
Appleton	44.25 N	88.37 W	228	4274	1396	N.A.	N.A.	N.A.	N.A.
Ashland Exp Farm	46.57 N	90.97 W	198	4978	1006	N.A.	N.A.	N.A.	N.A.
Beloit	42.50 N	89.03 W	237	3978	1521	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.

TABLE D-1 US and US 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	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	13 < Tdb < 21
(Wisconsin cont.)									
Marinette	45.10 N	87.63 W	184	4477	1262	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
Sheboygan	43.75 N	87.72 W	197	3937	1328	N.A.	N.A.	N.A.	N.A.
Stevens Point	44.50 N	89.57 W	328	4449	1292	N.A.	N.A.	N.A.	N.A.
Waukesha	43.02 N	88.23 W	262	3954	1477	N.A.	N.A.	N.A.	N.A.
Wausau FAA AP	44.92 N	89.62 W	364	4682	1212	–26	29	21	N.A.
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
Cody	44.52 N	109.07 W	1539	4128	1143	–26	31	14	N.A.
Evanston	41.27 N	110.95 W	2075	4914	714	N.A.	N.A.	N.A.	N.A.
Lander WSO AP	42.82 N	108.73 W	1636	4383	1213	–26	31	14	N.A.
Laramie FAA AP	41.32 N	105.68 W	2214	5004	687	N.A.	N.A.	N.A.	N.A.
Newcastle	43.85 N	104.22 W	1344	4037	1399	N.A.	N.A.	N.A.	N.A.
Rawlins FAA AP	41.80 N	107.20 W	2053	4708	892	N.A.	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.	N.A.
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	N.A.
Pacific Islands (PI)									
Guam (GU) - Andersen AFB	13.58 N	144.93 E	185	0	5939	23	31	26	N.A.
Marshall Island (MH) - Kwajalein Atoll	8.73 N	167.73 E	8	0	6483	24	31	26	N.A.
Midway Island (MH) - Midway Island NAF	28.22 N	177.37 W	4	74	4624	15	30	24	N.A.
Samoa (WS) - Pago Pago WSO Airport	14.33 S	170.72 W	3	0	6121	22	31	27	N.A.
Wake Island - Wake Island WSO Airport	19.28 N	166.65 E	4	0	6165	22	31	26	N.A.
Philippines									
Philippines (PH) - Angeles, Clark AFB	15.18 N	120.55 E	145	0	6267	21	35	25	N.A.

TABLE D-2 Canadian Climatic Data

Province City	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%
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
New Westminster BC Pen	49.22 N	122.90 W	17	3067	939	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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
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	N.A.	N.A.	N.A.

TABLE D-2 Canadian Climatic Data *(continued)*

Province City	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%
(Newfoundland cont.)								
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Cornwall	45.02 N	74.75 W	63	4479	1215	N.A.	N.A.	N.A.
Hamilton RBG	43.28 N	79.88 W	101	3818	1361	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Peterborough	44.28 N	78.32 W	193	4465	1097	N.A.	N.A.	N.A.
St Catharines	43.20 N	79.25 W	90	3722	1424	N.A.	N.A.	N.A.
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

TABLE D-2 Canadian Climatic Data *(continued)*

Province City	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%
(Ontario cont.)								
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	N.A.	N.A.	N.A.
Granby	45.38 N	72.70 W	167	4648	1102	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
St Jerome	45.80 N	74.05 W	169	5095	984	N.A.	N.A.	N.A.
Thetford Mines	46.10 N	71.35 W	380	5382	792	N.A.	N.A.	N.A.
Trois Rivieres	46.37 N	72.60 W	52	5069	981	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	Cooling Design Temperature 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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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
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

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%
(Chile cont.)											
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
Cangzhou	Municipalities	38.33	N	116.83	E	11	2716	2502	–10	33	23
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
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

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.)											
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
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

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.)											
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
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
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

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.)											
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
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

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.)											
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
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

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.)											
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
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	Cooling Design Temperature 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
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

TABLE D-3 International Climatic Data *(continued)*

Country City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)											
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
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

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.)											
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
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

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.)											
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
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

TABLE D-3 International Climatic Data *(continued)*

Country City	Province or Region	Latitude		Longitude		Elev., m	HDD18	CDD10	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)											
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
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

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.)									
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
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	N.A.	N.A.	N.A.
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

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%
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
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Kupang Penfui	Sunda Island	10.17 S	123.67 E	108	1	6492	N.A.	N.A.	N.A.
Makassar	Celebes	5.07 S	119.55 E	17	2	6378	N.A.	N.A.	N.A.

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%
(Indonesia cont.)											
Medan	Sumatra	3.57	N	98.68	E	26	0	6384	N.A.	N.A.	N.A.
Palembang	Sumatra	2.90	S	104.70	E	10	0	6425	N.A.	N.A.	N.A.
Surabaja Perak	Java	7.22	S	112.72	E	3	0	6716	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Mexico											
Mexico City	Distrito Federal	19.40	N	99.20	W	2308	668	2646	4	28	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	Cooling Design Temperature Wet-Bulb
									99.6%	1.0%	1.0%
(Mexico cont.)											
Guadalajara	Jalisco	20.67	N	103.38	W	1589	389	3401	N.A.	N.A.	N.A.
Monterrey	Nuevo Laredo	25.87	N	100.20	W	450	469	4626	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Papua New Guinea											
Port Moresby		9.43	S	147.22	E	28	1	6262	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Talara		4.57	S	81.25	W	86	2	4985	16	31	24
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

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%
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	N.A.	N.A.	N.A.
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
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	N.A.	N.A.	N.A.
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

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.)									
Chilung		25.13 N	121.75 E	3	262	4752	10	33	26
Chinmen		24.43 N	118.43 E	12	541	4122	N.A.	N.A.	N.A.
Dawu		22.35 N	120.90 E	9	13	5753	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Hwalien		24.02 N	121.62 E	15	123	5024	N.A.	N.A.	N.A.
Joyutang		23.88 N	120.85 E	1015	324	3964	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Kungshan		22.78 N	120.25 E	10	88	5292	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Penkaiyu		25.63 N	122.07 E	102	295	4533	N.A.	N.A.	N.A.
Sing Jo		24.80 N	120.97 E	33	297	4711	N.A.	N.A.	N.A.
Sinkung		23.10 N	121.37 E	37	49	5334	N.A.	N.A.	N.A.
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	N.A.	N.A.	N.A.
Taitung/Fongyentsun		22.80 N	121.18 E	37	40	5426	N.A.	N.A.	N.A.
Taoyuan (AB)		25.07 N	121.23 E	50	348	4620	9	33	28

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%**
(Taiwan cont.)									
Tung Shih		23.27 N	119.67 E	45	106	5120	N.A.	N.A.	N.A.
Wu-Chi		24.25 N	120.52 E	5	225	4828	10	32	27
Yilan		24.77 N	121.75 E	7	229	4676	N.A.	N.A.	N.A.
Tanzania									
Dar es Salaam		6.88 S	39.20 E	55	2	5975	N.A.	N.A.	N.A.
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
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	N.A.	N.A.	N.A.
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 90.1-2007 and to acknowledge source documents when appropriate. Some documents are also included in Section 12, "Normative References," because there are other citations of those documents within the standard that are normative.

Address/Contact Information

AABC
Associated Air Balance Council
1518 K Street Northwest, Suite 503
Washington, DC 20005
aabchg@aol.com

BLAST
Building Systems Laboratory
University of Illinois
1206 West Green Street
Urbana, IL 61801
www.bso.uiuc.edu/BLAST/index.html

CRRC
Cool Roof Rating Council
1738 Excelsior Avenue
Oakland, CA 94602
(T) 866-465-2523
(T) 510-482-4420
(F) 510-482-4421
www.coolroofs.org

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

NEBB
National Environmental Balancing Bureau
8575 Grovemont Circle
Gaithersburg, MD 20877
www.nebb.org

SMACNA
Sheet Metal & Air Conditioning Contractors' National Association
4201 Lafayette Center Drive
Chantilly, VA 20151
info@smacna.org
www.smacna.org

TMY2 Data
National Renewable Energy Laboratory
NREL/RReDC
Attn: Pamela Gray-Hann
1617 Cole Blvd., MS-1612
Golden, Colorado, USA 80401
http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

WYEC2 Data
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASHRAE Bookstore
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
(T) 404-636-8400
(F) 404-321-5478
www.ashrae.org/bookstore

IWEC Data
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASHRAE Bookstore
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
(T) 404-636-8400
(F) 404-321-5478
www.ashrae.org/bookstore

Subsection No.	Reference	Title/Source
Exception to 5.5.3.1	CRRC-1-2002	Cool Roof Rating Council Product Rating Program
6.4.2	*2001 ASHRAE Handbook—Fundamentals*	ASHRAE
6.4.4.1.1	MICA Insulation Standards—1999	National Commercial and Industrial Insulation Standards
6.4.4.2.1	SMACNA Duct Construction Standards—1995	HVAC Duct Construction Standards, Metal and Flexible
6.4.4.2.2	SMACNA Duct Leakage Test Procedures—1985	*HVAC Air Duct Leakage Test Manual*
6.7.2.3.1	NEBB Procedural Standards—1999	Procedural Standards for Building Systems Commissioning
6.7.2.3.1	AABC 2002	Associated Air Balance Council Test and Balance Procedures
6.7.2.3.1	ASHRAE Standard 111-1988	*Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems*
6.7.2.2	ASHRAE Guideline 4-1993	*Preparation of Operating and Maintenance Documentation for Building Systems*
6.7.2.4	ASHRAE Guideline 1-1996	*The HVAC Commissioning Process*
7.4.1 and 7.5	*2003 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

(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

ASHRAE/IESNA Standard 90.1-2007 incorporates ANSI/ASHRAE/IESNA Standard 90.1-2004 and Addenda a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, x, y, aa, ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ap, aq, ar, and av to ANSI/ASHRAE/IESNA Standard 90.1-2004. Table F-1 lists each addendum and describes the way in which the text is affected by the change and states the ASHRAE and ANSI approval dates.

TABLE F-1 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2004, Changes Identified

Addenda to 90.1-2004	Section(s) Affected	Description of Changes[a]	ASHRAE Standards Committee Approval Date	ASHRAE Board of Directors Approval Date	IESNA Approval Date	ANSI Approval Date
90.1a	Informative Appendix G	This addendum clarifies how windows should be distributed in the baseline simulation model and how uninsulated assemblies should be treated in the baseline simulation model, increases the size range for the use of packaged VAV systems in the baseline model, and provides more detail on how service hot-water systems should be modeled. Many of these changes may affect the ultimate performance rating of buildings using Appendix G. In addition, a reference was added to ASHRAE Standard 140 for the method of testing simulation programs.	1/21/06	1/26/06	1/18/06	4/10/06
90.1b	6. Heating, Ventilating, and Air Conditioning	Revises Table 6.8.1D and adds a definition for *single-package vertical air-conditioner* and *single-package vertical heat pump*.	6/25/05	6/30/05	8/3/05	8/3/05
90.1c	5. Building Envelope	This addendum revises the definition of *building entrance* to include vestibules and clarifies the requirements and exceptions for vestibules in Section 5.4.3.4.	6/25/05	6/30/05	8/3/05	8/3/05
90.1d	12. Normative References	This addendum updates the references applicable to the building envelope and deletes references that are not cited in the standard.	6/25/05	6/30/05	8/3/05	8/3/05
90.1e	9. Lighting	This addendum recognizes that track and busway type lighting systems can be limited by circuit breakers and permanently installed current limiters in Section 9.1.4.	6/25/05	6/30/05	8/3/05	8/3/05
90.1f	6. Heating, Ventilating, and Air Conditioning	This addendum modifies Tables 6.8.1A and 6.8.1B by raising the minimum efficiency for three-phase air-cooled central conditioners and heat pumps to be consistent with federal minimum standards.	1/21/06	1/26/06	1/18/06	4/10/06
90.1g	6. Heating, Ventilating, and Air Conditioning	This addendum amends the minimum efficiency levels of air-cooled air conditioners and heat pumps in Tables 6.8.1 A and 6.8.1B to be consistent with federal minimum standards.	1/21/06	1/26/06	1/18/06	4/10/06
90.1h	6. Heating, Ventilating, and Air Conditioning	This addendum revises the exceptions to Sections 6.4.3.1.2 and 6.4.3.6 by removing data processing centers from having specific exceptions on temperature and humidification dead bands.	1/21/06	1/26/06	1/18/06	4/10/06
90.1i	9. Lighting	This addendum adds language to Section 9.1.4(b) that allows additional flexibility in assigning wattage to luminaires with multi-level ballasts where other luminaire components would restrict lamp size.	1/21/06	1/26/06	1/18/06	4/10/06
90.1j	9. Lighting	This addendum to Section 9.4.1.3 allows additional flexibility in complying with the controls requirements by allowing additional combinations of commonly available control equipment.	1/21/06	1/26/06	1/18/06	4/10/06
90.1k	Informative Appendix A	This addendum revises Table A2.3 to add U-factors for screw-down roofs with R-19 insulation.	1/21/06	1/26/06	1/18/06	4/10/06
90.1l	12. Normative References	This addendum updates the reference to ASHRAE Standard 140.	1/21/06	1/26/06	1/18/06	4/10/06

TABLE F-1 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2004, Changes Identified *(continued)*

Addenda to 90.1-2004	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval Date	ASHRAE Board of Directors Approval Date	IESNA Approval Date	ANSI Approval Date
90.1m	9. Lighting	This addendum revises the exception to Section 9.2.2.3 to provide an option for compliance that exempts the commonly used furniture mounted track lighting if it incorporates automatic shutoff.	1/21/06	1/26/06	1/18/06	4/10/06
90.1n	5. Building Envelope	This addendum revises Section 5.5.4.4.1 to provide an exception to allow a user to take credit for overhangs towards compliance with the maximum SHGC requirements.	1/21/06	1/26/06	1/18/06	4/10/06
90.1o	Normative Appendix D	This addendum increases the amount of international climatic data in Appendix D.	1/21/06	1/26/06	1/18/06	4/10/06
90.1p	9. Lighting	This addendum modifies Exception (g) to Section 9.2.2.3 to allow for increased lighting for medical- and age-related issues in addition to visual impairment.	1/21/06	1/26/06	1/18/06	4/10/06
90.1q	6. Heating, Ventilating, and Air Conditioning	This addendum removes Exception (a) to Section 6.4.3.2 for HVAC systems serving hotel/motel rooms and guest rooms.	1/21/06	1/26/06	1/18/06	4/10/06
90.1r	12. Normative References	This addendum updates the reference to ARI 340/260 from the 2000 edition to the 2004 edition.	1/21/06	1/26/06	1/18/06	4/10/06
90.1s	6. Heating, Ventilating, and Air Conditioning and 12. Normative References	This addendum updates language in the standard based on differences between Standard 62-1999 and 62.1-2004. The reference has also been updated.	1/21/06	1/26/06	1/18/06	4/10/06
90.1t	6. Heating, Ventilating, and Air Conditioning and 12. Normative References	This addendum changes Table 6.8.1F to add an additional requirement of combustion efficiency to the current requirement of thermal efficiency for boilers, which will increase minimum efficiency. The reference in Section 12 has also been changed to reflect the change in the table.	1/21/06	1/26/06	1/18/06	4/10/06
90.1u	Informative Appendix G	This addendum provides guidance for complying with the intent of the baseline building design for HVAC systems 5, 6, 7, and 8, which shall be modeled as floor-by-floor HVAC systems.	1/21/06	1/26/06	1/18/06	4/10/06
90.1v	6. Heating, Ventilating, and Air Conditioning	This addendum modifies the provisions of Section 6.4.3.8 to allow for demand control ventilation.	1/21/06	1/26/06	1/18/06	5/10/06
90.1x	12. Normative References and Informative Appendix G	This addendum updates the normative references in Section 12 and Informative Appendix G for ATM-02 to ATM-04.	1/21/06	1/26/06	1/18/06	4/10/06
90.1y	5. Envelope, 12. Normative References, and Informative Appendix G	This addendum adds a reference and method of test for deriving SRI (ASTM Test Method E, 1980) for high albedo roofs. The changes in the standard were in both Section 5 and Informative Appendix G.	6/24/06	6/29/06	6/18/06	3/3/07
90.1aa	9. Lighting	This addendum modifies Section 9.1 to clarify some lighting requirements.	6/24/06	6/29/06	6/18/06	3/3/07
90.1ab	11. Energy Cost Budget Method and Informative Appendix G	This addendum corrects the referenced section in Tables 11.3.1 and G3.1; Heating, Ventilating, and Air Conditioning to Sections 9.1.3, 9.1.4, and 9.2.	6/24/06	6/29/06	6/18/06	3/3/07
90.1ac	3. Definitions and 6. Heating, Ventilating, and Air Conditioning	This addendum modifies the fan power limitation requirements in Section 6.5.3.	1/27/07	3/2/07	1/18/07	3/27/07
90.1ad	5. Building Envelope	This addendum changes the exception to Section 5.3.1.1 to add a requirement that the values for solar reflectance and thermal emittance be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the Cool Roof Rating Council.	2/5/05	2/10/05	2/3/05	3/14/05
90.1ae	9. Lighting	Change to Section 9.2.1.1, “Space Control.”	1/27/07	3/2/07	1/18/07	3/27/07

TABLE F-1 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2004, Changes Identified *(continued)*

Addenda to 90.1-2004	Sections Affected	Description of Changes*	ASHRAE Standards Committee Approval Date	ASHRAE Board of Directors Approval Date	IESNA Approval Date	ANSI Approval Date
90.1ag	Informative Appendix G	This addendum clarifies that only HVAC fans that provide outdoor air for ventilation need to be modeled as running continuously.	6/24/06	6/29/06	6/18/06	3/3/07
90.1ah	11. Energy Cost Budget Method	This addendum modifies the requirements in Table 11.3.1 for condenser heat recovery.	6/24/06	6/29/06	6/18/06	3/3/07
90.1ai	9. Lighting	This addendum modifies the interior lighting power requirements for retail display lighting in Section 9.6.2.	1/27/07	3/2/07	1/18/07	3/27/07
90.1 aj	5. Building Envelope	This addendum modifies the exception to Section 5.5.3.1 by adding the ASTM Test Method E 1980—Standard Practice for Calculating Solar Reflectance Index (SRI) of Horizontal and Low Sloped Opaque Surfaces.	6/24/06	6/29/06	6/18/06	3/3/07
90.1ak	Table 6.2.1G, Performance Requirements for Heat Rejection Equipment, and Section 6.2.1	This addendum changes Table 6.2.1G to add requirements for cooling towers to be tested to CTI test procedures and to update the corresponding references in Section 6.2.1.	6/24/06	6/29/06	6/18/06	3/3/07
90.1al	Normative Appendix A	This addendum corrects the terminology used in Section A2.3 for metal building roofs.	6/24/06	6/29/06	6/18/06	3/3/07
90.1am	11. Energy Cost Budget Method and Informative Appendix G	This addendum modifies the VAV turndown requirements in Section 11 and Informative Appendix G in accordance to the requirements in Section 6.5.2.1.	6/24/06	6/29/06	6/18/06	3/3/07
90.1an	6. Heating, Ventilating, and Air Conditioning	This addendum modifies the equipment efficiency requirements for commercial boilers in Table 6.8.1F.	1/27/07	3/2/07	1/18/07	3/27/07
90.1ao	6. Heating, Ventilating, and Air Conditioning	This addendum adds a footnote for increasing unit heater efficiency requirements (requiring intermittent ignition devices, power venting, or flue dampers) to comply with federal law.	1/27/07	3/2/07	1/18/07	3/27/07
90.1ap	9. Lighting	This addendum clarifies the intent of a "sales area" space in Table 9.6.1.	1/27/07	3/2/07	1/18/07	3/3/07
90.1aq	12. Normative References	This addendum updates the references to CTI documents.	1/27/07	3/2/07	1/18/07	3/3/07
90.1ar	6. Mechanical	This addendum lowers the part-load fan power limitation from 15 HP to 10 HP in Section 6.5.3.2.1.	1/27/07	3/2/07	1/18/07	3/3/07
90.1as	5. Building Envelope	This addendum modifies the opaque assembly requirements in Tables 5.5-1 through 5.5-8.	5/18/07	6/4/07	6/4/07	12/18/07
90.1at	5. Building Envelope	This addendum modifies the fenestration requirements in Tables 5.5-1 through 5.5-8.	5/18/07	6/4/07	6/4/07	12/18/07
90.1av	5. Building Envelope	This addendum adds an exception to Section 5.5.4.4.1 to allow credit for overhangs toward compliance with the maximum SHGC requirements.	1/27/07	3/2/07	1/18/07	3/3/07

[a] These descriptions may not be complete and are provided for information only.

NOTE

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

(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 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 may be useful for evaluating the performance of all *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:

$$\text{Percentage improvement} = 100 \times (\textit{Baseline building performance} - \textit{Proposed building performance}) / \textit{Baseline building performance}$$

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 submitted shall include the following:

a. Calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.
b. 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.
c. 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 time any loads are not met by the HVAC system for both the *proposed design* and *baseline building design*.
d. An explanation of any error messages noted in the *simulation program* output.

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 may 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, 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 Energy Rates. Annual energy costs 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.

Note: The above provision allows users to gain credit for features that yield load management benefits. Where such features are not present, users can simply use state average unit prices from EIA, which are updated annually and readily available on EIA's Web site (www.eia.doe.gov).

Exception: On-site renewable energy sources or site-recovered energy shall not be considered to be purchased energy and shall not be included in the *proposed building performance*. Where on-site renewable or site-recovered sources are used, the *baseline building performance* shall be based on the energy source used as the backup energy source or on the use of electricity if no backup energy source has been specified.

G2.5 Exceptional Calculation Methods. Where no simulation program is available that adequately models a design, material, or device, the *rating authority* may approve an exceptional calculation method to demonstrate above-standard performance using this method. Applications for approval of an exceptional method shall include documentation of the calculations performed and theoretical and/or empirical information supporting the accuracy of the 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 heating source as specified in Table G3.1.1A and shall conform with the system descriptions in Table G3.1.1B. For systems 1, 2, 3, and 4, 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:

a. 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.
b. If the baseline HVAC system type is 5, 6, 7, or 8, use separate single-zone systems conforming with the requirements of System 3 or System 4 (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, computer server rooms, natatoriums, and continually occupied security areas.
c. If the baseline HVAC system type is 5, 6, 7, or 8, use separate single-zone systems conforming with the requirements of System 3 or System 4 (depending on building heat source) for any zones having special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates.
d. For laboratory spaces with a minimum of 2400 L/sof exhaust, use system type 5 or 7 that reduce the exhaust and makeup air volume to 50% of design values during unoccupied periods. For all-electric buildings, the heating shall be electric resistance.

G3.1.1.1 Purchased Heat. For systems using purchased hot water or steam, hot water or steam costs shall be based on actual utility rates, and on-site boilers shall not be modeled in the *baseline building design*.

G3.1.2 General *Baseline* HVAC System Requirements. HVAC systems in the *baseline building design* shall conform with the general provisions in this section.

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, and temperature and humidity control setpoints and schedules shall be the same for *proposed* and *baseline building designs*. 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 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 Design
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*. **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:** a. 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. b. HVAC fans shall remain on during occupied and unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.	Same as Proposed Design **Exception:** 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, lighting controls, natural ventilation, demand control ventilation, and measures that reduce service water heating loads.

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">5. Building Envelope</td><td></td></tr>
<tr><td colspan="2">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.
a. 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:
1. Separate model of each of these assemblies within the energy simulation model.
2. 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.
b. 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.
c. For exterior roofs, the roof surface may be modeled with a reflectance of 0.45 if the reflectance of the proposed design roof is greater than 0.70 and its emittance is greater than 0.75 or has a minimum SRI of 82. Reflectance values shall be based on testing in accordance with ASTM C1549, ASTM E903, or ASTM E1918, and emittance values shall be based on testing in accordance with ASTM C1371 or ASTM E408, and SRI shall be based on ASTM E1980 calculated at medium wind speed. All other roof surfaces shall be modeled with a reflectance of 0.30.
d. Manual fenestration shading devices such as blinds or shades shall not be modeled. Automatically controlled fenestration shades or blinds may be modeled. Permanent shading devices such as fins, overhangs, and light shelves may be modeled.</td><td>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.
b. Opaque Assemblies. Opaque assemblies used for new 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.
Opaque assemblies used for alterations shall conform with Section 5.1.3.
c. Vertical Fenestration. Vertical fenestration areas for new buildings and additions shall equal that in the proposed design or 40% of gross above-grade wall area, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the proposed design. Fenestration U-factors shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. Fenestration SHGC shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. All vertical glazing 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 shall not be modeled. The fenestration areas for envelope alterations shall reflect the limitations on area, U-factor, and SHGC as described in Section 5.1.3.
d. Skylights and Glazed Smoke Vents. Skylight area shall be equal to that in the proposed building design or 5% of the gross roof area that is part of the building envelope, whichever is smaller. If the skylight area of the proposed building design is greater than 5% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 5% skylight-to-roof ratio. 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 Tables 5.5-1 through 5.5-8.
e. Roof albedo. All roof surfaces shall be modeled with a reflectivity of 0.30.
f. Existing Buildings. For existing building envelopes, the baseline building design shall reflect existing conditions prior to any revisions that are part of the scope of work being evaluated.</td></tr>
</table>

TABLE G3.1 Modeling Requirements for Calculating Proposed and Baseline Building Performance *(continued)*

No. Proposed Building Performance	Baseline Building Performance
6. Lighting	
Lighting power in the *proposed design* shall be determined as follows: a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model. b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where lighting neither exists nor is 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. Credit may be taken for the use of automatic controls for daylight utilization but only if their operation is either modeled directly in the building simulation or modeled in the building simulation through schedule adjustments determined by a separate daylighting analysis approved by the *rating authority*. g. For automatic lighting controls in addition to those required for minimum code compliance under Section 9.4.1, credit may be taken for automatically controlled systems by reducing the connected lighting power by the applicable percentages listed in Table G3.2. Alternatively, credit may be taken for these devices by modifying the lighting schedules used for the *proposed design*, provided that credible technical documentation for the modifications are provided to the *rating authority*.	Lighting power in the *baseline building design* shall be determined using the same categorization procedure (building area or space function) 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. No automatic lighting controls (e.g., programmable controls or automatic controls for daylight utilization) shall be modeled in the *baseline building design*, as the lighting schedules used are understood to reflect the mandatory control requirements in this standard.
7. Thermal Blocks—HVAC Zones Designed	
Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate *thermal block*. **Exception:** Different HVAC zones may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied, provided that all of the following conditions are met: a. The space use classification is the same throughout the *thermal block*. b. 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. c. All of the zones are served by the same HVAC system or by the same kind of HVAC system.	Same as Proposed Design.
8. Thermal Blocks—HVAC Zones Not Designed	
Where the HVAC zones and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following 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 Design.
9. Thermal Blocks—Multifamily Residential Buildings	
Residential spaces shall be modeled using at least one *thermal block* per *dwelling unit*, except that those units facing the same orientations may be combined into one *thermal block*. Corner units and units with roof or floor loads shall only be combined with units sharing these features.	Same as Proposed Design.

TABLE G3.1 Modeling Requirements for Calculating Proposed and Baseline Building Performance *(continued)*

No. Proposed Building Performance	Baseline Building Performance
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. c. Where no heating system exists or no heating system has been specified, the heating system classification shall be assumed to be electric, and 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*.	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).
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.	The service hot-water system in the *baseline building design* shall use the same energy source as the corresponding system in the *proposed design* and shall conform with the following conditions: a. Where the complete service hot-water system exists, the *baseline building design* shall reflect the actual system type using the actual component capacities and efficiencies. b. Where a new service hot-water system has been specified, 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. Where the energy source is electricity, the heating method shall be electrical resistance. 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 electrical-resistance heat 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. 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.

TABLE G3.1 Modeling Requirements for Calculating Proposed and Baseline Building Performance *(continued)*

No. Proposed Building Performance	Baseline Building Performance
	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.
12. Receptacle and Other Loads	
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*.	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 in Section 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* may 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 may not be changed.
13. Modeling Limitations to the Simulation Program	
If the simulation program cannot model a component or system included in the *proposed design* explicitly, substitute a thermodynamically similar component model that can approximate the expected performance of the component that cannot be modeled explicitly.	Same as Proposed Design.

TABLE G3.1.1A Baseline HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less 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 Less 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

Notes:
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.
Where no heating system is to be provided or no heating energy source is specified, use the "Electric and Other" heating source classification.
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.
For laboratory spaces with a minimum of 5000 cfm of exhaust, use system type 5 or 7 and reduce the exhaust and makeup air volume to 50% of design values during unoccupied periods. For all-electric buildings, the heating shall be electric resistance.

TABLE G3.1.1B 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 reheat	VAV	Direct expansion	Electric resistance
7. VAV with Reheat	Packaged rooftop VAV with reheat	VAV	Chilled water	Hot-water fossil fuel boiler
8. VAV with PFP Boxes	VAV with reheat	VAV	Chilled water	Electric resistance

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.Where *efficiency* ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.

G3.1.2.2 Equipment Capacities. The equipment 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. Unmet load hours for the *proposed design* or *baseline building designs* shall not exceed 300 (of the 8760 hours simulated), and unmet load hours for the *proposed design* shall not exceed the number of unmet load hours for the *baseline building design* by more than 50. If unmet load hours in the *proposed design* exceed the unmet load hours in the *baseline building* by more than 50, simulated capacities in the *baseline building* shall be decreased incrementally and the building resimulated until the unmet load hours are within 50 of the unmet load hours of the *proposed design*. If unmet load hours for the *proposed design* or *baseline building design* exceed 300, simulated capacities shall be increased incrementally, and the building with unmet loads resimulated until unmet load hours are reduced to 300 or less. 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.

G3.1.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine *baseline* equipment capacities may 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 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*.

G3.1.2.4 Fan System Operation. Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. 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.

G3.1.2.5 Ventilation. Minimum *outdoor air* ventilation rates shall be the same for the *proposed* and *baseline building designs*.

Exception: When modeling demand-control ventilation in the *proposed design* when its use is not required by Section 6.4.3.8.

G3.1.2.6 Economizers. Outdoor air economizers shall not be included in *baseline* HVAC Systems 1 and 2. *Outdoor air* economizers shall be included in *baseline* HVAC Systems 3 through 8 based on climate as specified in Table G3.1.2.6A.

Exceptions: Economizers shall not be included for systems meeting one or more of the exceptions listed below.

a. 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*.
b. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework systems. This exception shall only be used if the system in the *proposed design* does not use an economizer. If the exception is used, an economizer shall not be included in the *baseline building design.*

G3.1.2.7 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb switch with setpoint temperatures in accordance with the values in Table G3.1.2.6B.

G3.1.2.8 Design Airflow Rates. 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 required ventilation air or makeup air, 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.

G3.1.2.9 System Fan Power. System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-

TABLE G3.1.2.6A Climate Conditions under which Economizers are Included for Baseline Systems 3 through 8

Climate Zone	Conditions
1a, 1b, 2a, 3a, 4a	N.R.
Others	Economizer Included

N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G3.1.2.6B Economizer High-Limit Shutoff

Climate Zone	High-Limit Shutoff
1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	24°C
5a, 6a, 7a	21°C
Others	18°C

powered VAV boxes) shall be calculated using the following formulas:

For Systems 1 and 2,

$$P_{fan} = CFM_S \cdot 0.3 .$$

For systems 3 through 8,

$$P_{fan} = \text{Watts} \times 746 / \text{Fan Motor Efficiency} .$$

where

P_{fan}	=	electric power to fan motor (watts) and
input kW	=	input kW of *baseline* fan motor from Table G3.1.2.9
Fan Motor Efficiency	=	the efficiency from Table 10.8 for the next motor size greater than the input kW using the enclosed motor at 1800 rpm.
CFM_S	=	the baseline system maximum design supply fan airflow rate in L/s

G3.1.2.10 Exhaust Air Energy Recovery. Individual fan systems that have both a design supply air capacity of 2400 L/s or greater and have a minimum outdoor air supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% 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 at design conditions. Provision shall be made to bypass or control the heat-recovery system to permit air economizer operation, where applicable.

Exceptions: If any of these exceptions apply, exhaust air energy recovery shall not be included in the *baseline building design*:

a. Systems serving spaces that are not cooled and that are heated to less than 16°C.
b. Systems exhausting toxic, flammable, or corrosive fumes or paint or dust. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.
c. Commercial kitchen hoods (grease) classified as Type 1 by NFPA 96. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.
d. Heating systems in climate zones 1 through 3.
e. Cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8.
f. Where the largest exhaust source is less than 75% of the design outdoor airflow. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.
g. Systems requiring dehumidification that employ energy recovery in series with the cooling coil. This exception shall only be used if exhaust air energy recovery and series-style energy recovery coils are not used in the *proposed design.*
h. Systems serving laboratories with exhaust rates of 2400 L/s or greater.

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, and 7). 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, and 7). 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 (Systems 1, 5, and 7). 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 serving 11,148 m^2 or more shall be modeled with variable-speed drives, and systems serving less than 11,148 m^2 shall be modeled as riding the pump curve.

TABLE G3.1.2.9 Baseline Fan Power

Baseline Fan Motor Power	
Constant Volume Systems 3–4	**Variable Volume Systems 5–8**
$L_S \cdot 0.0015 + A$	$L_S \cdot 0.0021 + A$

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. Do not include pressure drop adjustments for evaporative coolers or heat recovery devices that are not required in the baseline building system by Section G3.1.2.10.

G3.1.3.6 Piping Losses (Systems 1, 5, 7, and 8). 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 and 8). Electric chillers shall be used in the *baseline building design* regardless of the cooling energy source, e.g., direct-fired absorption, absorption from purchased steam, or purchased chilled water. 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.

G3.1.3.8 Chilled-Water Design Supply Temperature (Systems 7 and 8). 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 and 8). 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.

G3.1.3.10 Chilled-Water Pumps (Systems 7 and 8). 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.

G3.1.3.11 Heat Rejection (Systems 7 and 8). The heat rejection device shall be an axial fan cooling tower with two-speed fans. Condenser water design supply temperature shall be 29°C or 5.6°C approaching design wet-bulb temperature, whichever is lower, with a design temperature rise of 5.6°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. Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller.

TABLE G3.1.3.7 Type and Number of Chillers

Building Peak Cooling Load	Number and Type of Chiller(s)
≤11,148 m^2	1 water-cooled screw chiller
>11,148 m^2, <22,296 m^2	2 water-cooled screw chillers sized equally
≥22,296 m^2	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 2813 kW, all sized equally

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 2.15 L/s·m^2 of floor area served or the minimum ventilation rate, whichever is larger.

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 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 flow 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). VAV system supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table G3.1.3.15.

TABLE G3.1.3.15 Part-Load Performance for VAV Fan Systems

Method 1—Part-Load Fan Power Data

Fan Part-Load Ratio	Fraction of Full-Load Power
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00

Method 2—Part-Load Fan Power Equation

$$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$$

where

P_{fan} = fraction of full-load fan power and

PLR_{fan} = fan part-load ratio (current cfm/design cfm).

TABLE G3.2 Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Device(s)	Non-24-h and ≤ 460 m^2	All Other
1. Programmable timing control	10%	0%
2. Occupancy sensor	15%	10%
3. Occupancy sensor and programmable timing control	15%	10%

Note: The 460 m^2 condition pertains to the total conditioned floor area of the building.

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.

ASHRAE will accept the following as equivalent to the signature required on the change submittal form to convey non-exclusive copyright:

Files attached to an e-mail:	Electronic signature on change submittal form (as a picture; *.tif, or *.wpg).
Files on a CD:	Electronic signature on change submittal form (as a picture; *.tif, or *.wpg) or a letter with submitter’s signature accompanying the CD or sent by facsimile (single letter may cover all of proponent’s proposed changes).

Submit an e-mail or a CD containing the change proposal files to:
Manager of Standards
ASHRAE
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
E-mail: change.proposal@ashrae.org
(Alternatively, mail paper versions to ASHRAE address or fax to 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, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305.
Phone: 404-636-8400. Fax: 404-321-5478. E-mail: standards.section@ashrae.org.

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), submitted on a CD, 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:

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I hereby grant the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (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.

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All electronic submittals must have the following statement completed:

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2. Number and year of standard:

3. Page number and clause (section), subclause, or paragraph number:

4. I propose to: [ ] Change to read as follows [ ] Delete and substitute as follows
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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: _______

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POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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