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.

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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 2004 edition of the standard has several new features and includes changes resulting from the continuous maintenance proposals from the public. The standard has been completely reformatted for ease of use and clarity. The climate zones have been reduced from 26 to 8 and the Lighting LPDs have been reduced as well. 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, Submittal of 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 list server for this standard to receive notice of all public reviews and approved and published addenda and errata.

Changes from the previous 2001 edition of the standard are not marked in the margin, as was the practice with the 1999 edition, because of the extensive reformatting that has taken place in this 2004 edition.

This edition corrects all known typographical errors in the 2001 standard. It includes the content of 31 addenda that were processed by the committee and approved by the ASHRAE and IESNA Boards of Directors. For the publication dates and brief descriptions of the addenda to 90.1-2001, 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, and
   3. new systems and equipment in existing buildings and

(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) 10CFR Part 430.

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 air flow 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 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.

(a) ***electronic ballast:*** a ballast constructed using electronic circuitry.
(b) ***hybrid ballast:*** a ballast constructed using a combination of magnetic core and insulated wire winding and electronic circuitry.
(c) ***magnetic ballast:*** a ballast constructed with magnetic core and a winding of insulated wire.

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

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

below-grade wall: see *wall*.

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

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, turnstiles, 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:

(a) ***building envelope, exterior:*** the elements of a building that separate conditioned spaces from the exterior.
(b) ***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, and 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 (ci): insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, 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 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:

(a) ***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 Fahrenheit 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.

(b) ***heating degree-day base 18°C, HDD18:*** for any one day, when the mean temperature is less than 18°C, there are as many degree-days as degrees Fahrenheit 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.

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:

(a) ***non-swinging:*** roll-up, sliding, and all other doors that are not swinging doors.
(b) ***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.

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 kilowatt hours (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 Btu/h to total rate of electric input in watts under designated operating conditions. (See *coefficient of performance (COP)—cooling*.)

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

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:

(a) ***base envelope performance factor:*** the building envelope performance factor for the base design.
(b) ***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*.

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 system power: the sum of the nominal power demand (nameplate horsepower) of motors 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, glass doors that are more than one-half glass, and glass block walls. (See *building envelope* and *door*.)

(a) ***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.

(b) ***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:

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

(See *building envelope*, *fenestration*, *opaque area*, and *slab-on-grade floo*r).

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 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.

(a) ***gross building envelope floor area:*** the gross floor area of the building envelope, but excluding slab-on-grade floors.
(b) ***gross conditioned floor area:*** the gross floor area of conditioned spaces.
(c) ***gross lighted floor area:*** the gross floor area of lighted spaces.
(d) ***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 heat capacity per unit area of surface ($kJ/m^2·K$) 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.

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 listing by the U.S. Secretary of the Interior.

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

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

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

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.

kilowatt hour (kWh): the basic unit of electric energy, equal to 1000 Wh.

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.

(a) ***compact fluorescent lamp:*** a fluorescent lamp of a small compact shape, with a single base that provides the entire mechanical support function.

(b) ***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.

(c) ***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.

(d) ***high-intensity discharge (HID) lamp:*** an electric discharge lamp in that 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.

(e) ***incandescent lamp:*** a lamp in which light is produced by a filament heated to incandescence by an electric current.

(f) ***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:

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

(b) ***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: 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 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.

non-swinging 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. For vertical fenestration, the two categories are north-oriented and all other. (See *north-oriented*.)

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.

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

purchased energy 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·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 inspections 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 set point to a higher or lower value.

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

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:

(a) ***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.

(b) ***metal building roof:*** a roof that is constructed with:

1. 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 or

(b) insulation between the metal roofing and the steel framing members or

(c) insulated metal roofing panels installed as described in 1 or 2.

(c) ***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).

(d) ***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 for 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 for 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 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 set point) or cooling (by increasing the set point) 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. Shading coefficient, 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-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.

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

(a) ***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 air changes per hour (ACH) (e.g., atria).
(b) ***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.
(c) ***unconditioned space:*** an enclosed space within a building that is not a conditioned space or a semiheated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces.

space-conditioning category:

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

steel-framed wall: see *wall*.

steel-joist floor: see *floor.*

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

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

swinging door: see *door.*

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

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.

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.

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

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

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.

(a) ***dry-type transformer:*** a *transformer* in which the core and coils are in a gaseous or dry compound.
(b) ***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 $W/m^2 \cdot K$.

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° 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:

(a) ***above-grade wall:*** a wall that is not a below-grade wall.
(b) ***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.
(c) ***mass wall:*** a wall with a heat capacity 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.
(d) ***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).
(e) ***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).
(f) ***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
ci	continuous insulation
COP	coefficient of performance

CTI	Cooling Tower 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°F
HID	high-intensity discharge
hp	horsepower
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
lin	linear
LPD	lighting power density
L/s	liter per second
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	non-standard 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	Systeme 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	watthour
Wh	watthour
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.

> **Exception to 4.2.1.2:** 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; and 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 to 4.2.1.3:

(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 U.S 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 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 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,

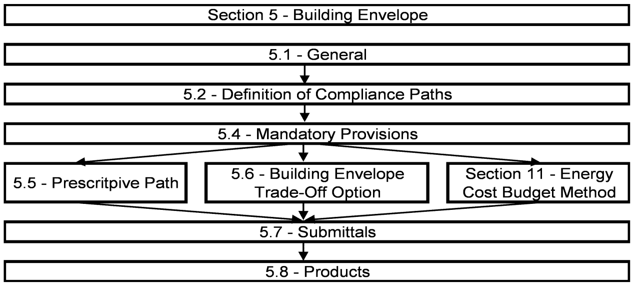
(c) slab/foundation wall after slab/foundation insulation is in place but before concealment,

(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, or (c) *semiheated* space.

5.1.2.2 *Spaces* shall be assumed to be *conditioned space* 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 to 5.1.3: 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; and

(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 United States locations, follow the procedure in 5.1.4.1. For international locations, follow the procedure in 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 to 5.1.4.1: If there are recorded historical climatic data available for a construction site, they may be used to determine compliance if approved by the *building official*.

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 5.1, General; 5.4, Mandatory Provisions; 5.7, Submittals; and 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 50% 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 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 5.5 or 5.6, it shall comply with the requirements found in 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 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 to 5.4.3.2:

(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. A *door* that separates *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 2.1 m when in the closed position.

Exceptions to 5.4.3.4:

(a) *Doors* in buildings in climate zones 1 and 2.
(b) *Doors* in buildings less than four stories above grade.
(c) *Doors* not intended to be used as a *building entrance door*, such as mechanical or electrical equipment rooms.
(d) *Doors* opening directly from a *dwelling unit*.
(e) *Doors* that open directly from a space less than 300 m^2 in area.
(f) *Doors* in building entrances with revolving *doors*.
(g) *Doors* used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

5.5 Prescriptive Building Envelope Option:

5.5.1 For *conditioned space*, the *exterior building envelope* shall comply with either the "nonresidential" or "residential" requirements in Tables 5.5-1 through 5.5-8 (located at the end of this chapter) 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.

Exceptions to 5.5.3(2).

(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 (i) the most restrictive requirement or (ii) an area-weighted average *U-factor, C-factor,* or *F-factor.*

5.5.3.1 Roof Insulation. All *roofs* shall comply with the insulation values specified in Tables 5.5-1 through 5.5-8. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

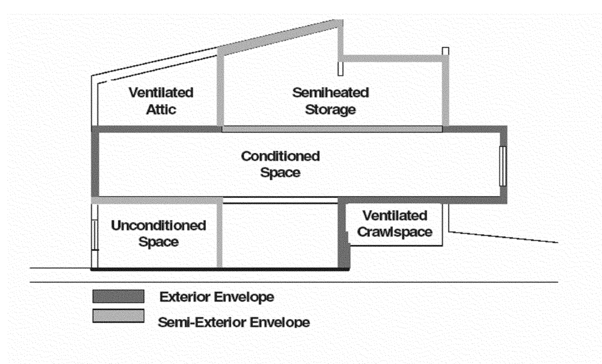


Figure 5-5 Exterior and semi-exterior building envelope.

TABLE 5.5.3.1 Roof U-Factor Multipliers for Exception to 5.5.1.1.

Climate Zone	Roof U-Factor Multiplier
1	0.77
2	0.83
3	0.85
4 through 8	1.00

Exception to 5.5.3.1: For *roofs* where the exterior surface has a minimum total solar reflectance of 0.70 when tested in accordance with one of the solar reflectance test methods listed below and has a minimum thermal emittance of 0.75 when tested in accordance with one of the thermal emittance test methods listed below, other than roofs with ventilated attics or roofs with semi-heated spaces, the U-factor of the proposed roof shall be permitted to be adjusted using Equation 5-1 for demonstrating compliance:

$$U_{roofadj} = U_{roofproposed} \times Factor_{roofmultiplier} \quad (5\text{-}1)$$

where

$U_{roofadj}$ = the adjusted roof U-factor for use in demonstrating compliance,

$U_{roofproposed}$ = the U-factor of the proposed roof, as designed,

$Factor_{roofmultiplier}$ = the roof U-factor multiplier from Table 5.5.3.1

Solar Reflectance Test Methods: ASTM E903, ASTM E1175, or ASTM E1918.

Thermal Emittance Test Methods: ASTM C835, ASTM C1371, or ASTM E408.

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

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

5.5.3.5 Slab-on-Grade Floor Insulation. All *slab-on-grade floors*, including *heated slab-on-grade floors* and *unheated slab-on-grade floors*, shall comply with the insulation values specified in Tables 5.5-1 through 5.5-8.

5.5.3.6 Opaque Doors. All *opaque doors* shall have a *U-factor* not greater than that specified in Tables 5.5-1 through 5.5-8

5.5.4 Fenestration.

5.5.4.1 General. Compliance with *U-factors* and *solar heat gain coefficient (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 to 5.5.4.1: 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 50% of the *gross wall area*.

Exception to 5.5.4.2.1: *Vertical fenestration* complying with Exception (c) to 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*.

Exception to 5.5.4.3: *Vertical fenestration* complying with Exception (c) to 5.5.4.4.1 shall have a *U-factor* not greater than that specified for 40% of the *gross wall area*.

5.5.4.4 Fenestration Solar Heat Gain Coefficient (SHGC).

5.5.4.4.1 SHGC of Vertical Fenestration. *Vertical fenestration* shall have a *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 to 5.5.4.4.1:

(a) In latitudes greater than 10 degrees, the *SHGC* for *north-oriented vertical fenestration* shall be calculated separately and shall not be greater than that specified in Tables 5.5-1 through 5.5-8 for *north-oriented fenestration*. When this exception is used, the *fenestration area* used in selecting the criteria shall be calculated separately for *north-oriented* and all other-oriented *fenestration*.

Note to *adopting authority*: If the project is in the southern hemisphere, change north to south.

(b) For demonstrating compliance for *vertical fenestration* only, the *SHGC* in the proposed building shall be reduced by using the multipliers in Table 5.5.4.4.1 for each *fenestration* product shaded by permanent projections that will last as long as the building itself.

(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 *projection factor* 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.

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 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. *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.

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

Exception to 5.8.1.1: 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 Manufacturer's Requirements. Insulation materials shall be installed in accordance with *manufacturer's* recommendations and in such a manner as to achieve *rated R-value of insulation*.

Exception to 5.8.1.2: 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 *manufacturer's* recommendations for the framing system used. Flexible batt insulation installed in floor cavities shall be supported in a permanent manner by supports no greater than 600 mm on center.

Exception to 5.8.1.5: Insulation materials that rely on air-spaces adjacent to reflective surfaces for their rated performance.

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

(a) the total combined area affected (including necessary clearances) is less than one percent of the opaque area of the assembly, or
(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 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 5.8.1.

5.8.2 Fenestration and Doors.

5.8.2.1 Rating of Fenestration Products. The U-factor, solar heat gain coefficient (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, solar heat gain coefficient (SHGC), and air leakage rate.

Exception to 5.8.2.2: 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 to 5.8.2.3: 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 to 5.8.2.4:

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

(c) U-factors from 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 to 5.8.2.5:

(a) *Shading coefficient* 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*. *Shading coefficient* shall be determined using a spectral data file determined in accordance with NFRC 300. *Shading coefficient* 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 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 A8.2 shall be an acceptable alternative for determining compliance with the *SHGC* criteria for *vertical fenestration*.

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

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 ci	U-0.360	R-2.6 ci	U-7.280	NR
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-3.483	NR
Walls, Above Grade						
Mass	U-3.293	NR	U-0.857[a]	R-1.0 ci[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
Wall, Below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-1.825	NR	U-1.825	NR	U-1.825	NR
Steel Joist	U-1.986	NR	U-1.986	NR	U-1.986	NR
Wood Framed and Other	U-1.599	NR	U-1.599	NR	U-1.599	NR
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Non-Swinging	U-8.233		U-8.233		U-8.233	
Fenestration	**Assembly Max. U (Fixed/Operable)**	**Assembly Max. SHGC (All Orientations/North-Oriented)**	**Assembly Max. U(Fixed/Operable)**	**Assembly Max. SHGC (All Orientations/North-Oriented)**	**Assembly Max. U (Fixed/Operable)**	**Assembly Max. SHGC (All Orientations/North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.44	Uoper-7.21	$SHGC_{north}$-0.44	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-6.93	$SHGC_{all}$-0.19	Ufixed-6.93	$SHGC_{all}$-0.19	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.33	Uoper-7.21	$SHGC_{north}$-0.33	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-11.24	$SHGC_{all}$-0.36	Uall-11.24	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-11.24	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-0.16	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-10.79	$SHGC_{all}$-0.34	Uall-10.79	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-10.79	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-7.72	$SHGC_{all}$-0.36	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR

[a] Exception to A3.1.3.1 applies.

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-0.360	R-2.6 ci	U-0.360	R-2.6 ci	U-1.240	R-0.7 ci
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.948	R-1.1
Attic and Other	U-0.192	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 ci[a]	U-3.293	NR
Metal Building	U-0.642	R-2.3	U-0.642	R-2.3	U-1.045	R-6.0
Steel Framed	U-0.705	R-2.3	U-0.705	R-2.3	U-1.998	NR
Wood Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-1.660	NR
Wall, Below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.780	R-0.7 ci	U-0.606	R-1.1 ci	U-1.825	NR
Steel Joist	U-0.296	R-3.3	U-0.296	R-3.3	U-1.986	NR
Wood Framed and Other	U-0.288	R-3.3	U-0.288	R-3.3	U-1.599	NR
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Non-Swinging	U-8.233		U-8.233		U-8.233	

Fenestration	Assembly Max. U (Fixed/Operable)	Assembly Max. SHGC (All Orientations/North-Oriented)	Assembly Max. U (Fixed/Operable)	Assembly Max. SHGC (All Orientations/North-Oriented)	Assembly Max. U (Fixed/Operable)	Assembly Max. SHGC (All Orientations/North-Oriented)
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-6.93	$SHGC_{all}$-0.17	Ufixed-6.93	$SHGC_{all}$-0.17	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.44	Uoper-7.21	$SHGC_{north}$-0.43	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-11.24	$SHGC_{all}$-0.36	Uall-11.24	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-11.24	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-10.79	$SHGC_{all}$-0.39	Uall-10.79	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-10.79	$SHGC_{all}$-0.34	Uall-10.79	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-7.72	$SHGC_{all}$-0.36	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR

[a] Exception to A3.1.3.1 applies.

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-0.360	R-2.6 ci	U-0.360	R-2.6 ci	U-1.240	R-0.7 ci
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.192	R-5.3	U-0.153	R-6.7	U-0.459	R-2.3
Walls, Above Grade						
Mass	U-0.857[a,b]	R-1.0 ci[a,b]	U-0.701	R-1.3 ci	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-0.479	R-2.3 + R-0.7 ci	U-1.998	NR
Wood Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-0.504	R-2.3
Wall, Below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.606	R-1.1	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-1.599	NR
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.766	R-1.3 for 300 mm	F-1.644	R-1.3 for 600 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Non-Swinging	U-8.233		U-2.839		U-8.233	
FENESTRATION (for Zones 3A and 3B; see next page for Zone 3C)[c]	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-3.24	$SHGC_{all}$-0.25	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-3.24	$SHGC_{all}$-0.25	Ufixed-3.24	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.39	Uoper-3.80	$SHGC_{north}$-0.39	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-3.24	$SHGC_{all}$-0.25	Ufixed-3.24	$SHGC_{all}$-0.25	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.39	Uoper-3.80	$SHGC_{north}$-0.39	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-2.61	$SHGC_{all}$-0.19	Ufixed-2.61	$SHGC_{all}$-0.19	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-0.26	Uoper-2.67	$SHGC_{north}$-0.26	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-6.64	$SHGC_{all}$-0.39	Uall-6.64	$SHGC_{all}$-0.36	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-6.64	$SHGC_{all}$-0.19	Uall-6.64	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-7.38	$SHGC_{all}$-0.65	Uall-7.38	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-7.38	$SHGC_{all}$-0.34	Uall-7.38	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-3.92	$SHGC_{all}$-0.39	Uall-3.92	$SHGC_{all}$-0.36	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.92	$SHGC_{all}$-0.19	Uall-3.92	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR

[a] Exception to A3.1.3.1 applies.
[b] Insulation is not required for non-residential mass walls in Climate Zone 3A located below the “warm-Humid” line, and in Zone 3B.

TABLE 5.5-3 *(continued)* Building Envelope Requirements For Climate Zone 3C

FENESTRATION (for Zone 3C)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-6.93	$SHGC_{all}$-0.61	Ufixed-6.93	$SHGC_{all}$-0.61	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.82	Uoper-7.21	$SHGC_{north}$-0.82	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-6.93	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-0.61	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-6.93	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-6.93	$SHGC_{all}$-0.34	Ufixed-6.93	$SHGC_{all}$-0.34	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-0.61	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-6.93	$SHGC_{all}$-0.20	Ufixed-4.14	$SHGC_{all}$-0.25	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-7.21	$SHGC_{north}$-0.30	Uoper-4.60	$SHGC_{north}$-0.61	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-11.24	$SHGC_{all}$-0.61	Uall-11.24	$SHGC_{all}$-0.39	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-11.24	$SHGC_{all}$-0.39	Uall-11.24	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-10.79	$SHGC_{all}$-0.65	Uall-10.79	$SHGC_{all}$-0.65	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-10.79	$SHGC_{all}$-0.39	Uall-10.79	$SHGC_{all}$-0.34	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-7.72	$SHGC_{all}$-0.61	Uall-7.72	$SHGC_{all}$-0.39	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-7.72	$SHGC_{all}$-0.39	Uall-7.72	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR

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

OPAQUE ELEMENTS	NONRESIDENTIAL Assembly Maximum	NONRESIDENTIAL Insulation Min. R-Value	RESIDENTIAL Assembly Maximum	RESIDENTIAL Insulation Min. R-Value	SEMIHEATED Assembly Maximum	SEMIHEATED Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.360	R-2.6 ci	U-0.360	R-2.6 ci	U-1.240	R-0.7 ci
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.192	R-5.3	U-0.153	R-6.7	U-0.459	R-2.3
Walls, Above Grade						
Mass	U-0.857[a]	R-1.0 ci[a]	U-0.592	R-1.7 ci	U-3.293	NR
Metal Building	U-0.642	R-2.3	U-0.642	R-2.3	U-0.761	R-1.8
Steel Framed	U-0.705	R-2.3	U-0.365	R-2.3 + R-1.3 ci	U-0.705	R-2.3
Wood Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-0.504	R-2.3
Wall, Below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.606	R-1.1	U-0.496	R-1.5	U-1.825	NR
Steel Joist	U-0.296	R-3.3	U-0.214	R-5.3	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-1.644	R-1.3 for 600 mm	F-1.454	R-1.8 for 900 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Non-Swinging	U-8.233		U-2.839		U-8.233	
FENESTRATION	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-2.61	$SHGC_{all}$-0.25	Ufixed-2.61	$SHGC_{all}$-0.25	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-0.36	Uoper-2.67	$SHGC_{north}$-0.36	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-6.64	$SHGC_{all}$-0.49	Uall-5.56	$SHGC_{all}$-0.36	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-6.64	$SHGC_{all}$-0.39	Uall-5.56	$SHGC_{all}$-0.19	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-7.38	$SHGC_{all}$-0.65	Uall-7.38	$SHGC_{all}$-0.62	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-7.38	$SHGC_{all}$-0.34	Uall-7.38	$SHGC_{all}$-0.27	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-3.92	$SHGC_{all}$-0.49	Uall-3.29	$SHGC_{all}$-0.36	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.92	$SHGC_{all}$-0.39	Uall-3.29	$SHGC_{all}$-0.19	Uall-7.72	$SHGC_{all}$-NR

[a] Exception to A3.1.3.1 applies.

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A,B,C)

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	AssemblyMax-imum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.360	R-2.6 ci	U-0.360	R-2.6 ci	U-0.982	R-0.9 ci
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.192	R-5.3	U-0.153	R-6.7	U-0.300	R-3.3
Walls, Above Grade						
Mass	U-0.701	R-1.3 ci	U-0.513	R-2.0 ci	U-3.293	NR
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-0.479	R-2.3 + R-0.7 ci	U-0.365	R-2.3 + R-1.3 ci	U-0.705	R-2.3
Wood Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-0.504	R-2.3
Wall, Below Grade						
Below Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.496	R-1.5	U-0.420	R-1.8	U-1.825	NR
Steel Joist	U-0.296	R-3.3	U-0.214	R-5.3	U-0.390	R-2.3
Wood Framed and Other	U-0.188	R-5.3	U-0.188	R-5.3	U-0.376	R-2.3
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.454	R-1.8 for 900 mm	F-1.454	R-1.8 for 900 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Non-Swinging	U-8.233		U-2.839		U-8.233	
Fenestration	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-2.61	$SHGC_{all}$-0.26	Ufixed-2.61	$SHGC_{all}$-0.26	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-0.36	Uoper-2.67	$SHGC_{north}$-0.49	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-6.64	$SHGC_{all}$-0.49	Uall-6.64	$SHGC_{all}$-0.49	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-6.64	$SHGC_{all}$-0.39	Uall-6.64	$SHGC_{all}$-0.39	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-6.25	$SHGC_{all}$-0.77	Uall-6.25	$SHGC_{all}$-0.77	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-6.25	$SHGC_{all}$-0.62	Uall-6.25	$SHGC_{all}$-0.62	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-3.92	$SHGC_{all}$-0.49	Uall-3.92	$SHGC_{all}$-0.49	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.92	$SHGC_{all}$-0.39	Uall-3.92	$SHGC_{all}$-0.39	Uall-7.72	$SHGC_{all}$-NR

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-0.360	R-2.6 ci	U-0.360	R-2.6 ci	U-0.982	R-0.9 ci
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-0.592	R-1.7 ci	U-0.513	R-2.0 ci	U-3.293	NR
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-0.479	R-2.3 + R-0.7 ci	U-0.365	R-2.3 + R-1.3 ci	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 ci	U-0.504	R-2.3
Wall, Below Grade						
Below Grade Wall	C-6.473	NR	C-0.678	R-1.3 ci	C-6.473	NR
Floors						
Mass	U-0.496	R-1.5	U-0.363	R-2.2 ci	U-1.825	NR
Steel Joist	U-0.214	R-5.3	U-0.214	R-5.3	U-0.390	R-2.3
Wood Framed and Other	U-0.188	R-5.3	U-0.188	R-5.3	U-0.376	R-2.3
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.260	NR	F-1.264	NR
Heated	F-1.454	R-1.8 for 900 mm	F-1.35	R-1.8 for 1200 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-2.839		U-3.975	
Non-Swinging	U-2.839		U-2.839		U-8.233	
FENESTRATION	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-3.24	$SHGC_{all}$-0.39	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-3.80	$SHGC_{north}$-0.49	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-2.61	$SHGC_{all}$-0.26	Ufixed-2.61	$SHGC_{all}$-0.26	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-0.49	Uoper-2.67	$SHGC_{north}$-0.49	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-6.64	$SHGC_{all}$-0.49	Uall-5.56	$SHGC_{all}$-0.46	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-6.64	$SHGC_{all}$-0.49	Uall-5.56	$SHGC_{all}$-0.36	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-4.94	$SHGC_{all}$-0.71	Uall-4.20	$SHGC_{all}$-0.65	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-4.94	$SHGC_{all}$-0.58	Uall-4.20	$SHGC_{all}$-0.55	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-3.92	$SHGC_{all}$-0.49	Uall-3.29	$SHGC_{all}$-0.49	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.92	$SHGC_{all}$-0.49	Uall-3.29	$SHGC_{all}$-0.39	Uall-7.72	$SHGC_{all}$-NR

TABLE 5.5-7 Building Envelope Requirements For Climate Zone 7

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 ci	U-0.360	R-2.6 ci	U-0.982	R-0.9 ci
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 ci	U-0.453	R-2.3 ci	U-3.293	NR
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 ci	U-0.365	R-2.3 + R-1.3 ci	U-0.705	R-2.3
Wood Framed and Other	U-0.504	R-2.3	U-0.291	R-2.3 + R-1.3 ci	U-0.504	R-2.3
Wall, Below Grade						
Below Grade Wall	C-0.678	R-1.3 ci	C-0.678	R-1.3 ci	C-6.473	NR
Floors						
Mass	U-0.496	R-1.5	U-0.363	R-2.2	U-0.780	R-0.7 ci
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-0.376	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-1.454	R-1.8 for 900 mm	F-1.350	R-1.8 for 1200 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-2.839		U-3.975	
Non-Swinging	U-2.839		U-2.839		U-8.233	
Fenestration	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-3.24	$SHGC_{all}$-0.49	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-3.80	$SHGC_{north}$-0.64	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-2.61	$SHGC_{all}$-0.36	Ufixed-2.61	$SHGC_{all}$-0.36	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-0.64	Uoper-2.67	$SHGC_{north}$-0.64	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-6.64	$SHGC_{all}$-0.68	Uall-6.64	$SHGC_{all}$-0.64	Uall-11.24	$SHGC_{all}$-NR
2.1-5.0%	Uall-6.64	$SHGC_{all}$-0.64	Uall-6.64	$SHGC_{all}$-0.64	Uall-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-4.94	$SHGC_{all}$-0.77	Uall-3.46	$SHGC_{all}$-0.77	Uall-10.79	$SHGC_{all}$-NR
2.1-5.0%	Uall-4.94	$SHGC_{all}$-0.71	Uall-3.46	$SHGC_{all}$-0.77	Uall-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-3.92	$SHGC_{all}$-0.68	Uall-3.92	$SHGC_{all}$-0.64	Uall-7.72	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.92	$SHGC_{all}$-0.64	Uall-3.92	$SHGC_{all}$-0.64	Uall-7.72	$SHGC_{all}$-NR

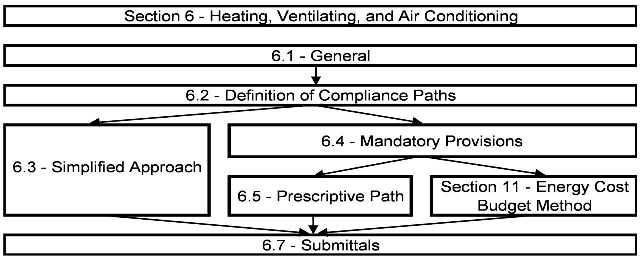
TABLE 5.5-8 Building Envelope Requirements For Cimate Zone 8

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 ci	U-0.273	R-3.5 ci	U-0.527	R-1.8 ci
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-0.153	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 ci	U-0.404	R-2.7 ci	U-0.857[a]	R-1.0 ci[a]
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 ci	U-0.315	R-2.3 + R-1.8 ci	U-0.705	R-2.3
Wood Framed and Other	U-0.291	R-2.3 + R-1.3 ci	U-0.291	R-2.3 + R-1.3 ci	U-0.504	R-2.3
Wall, Below Grade						
Below Grade Wall	C-0.678	R-1.3 ci	C-0.678	R-1.3 ci	C-6.473	NR
Floors						
Mass	U-0.363	R-2.2 ci	U-0.321	R-2.6 ci	U-0.780	R-0.7 ci
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-1.350	R-1.8 for 1200 mm	F-1.350	R-1.8 for 1200 mm	F-1.644	R-1.3 for 600 mm
Opaque Doors						
Swinging	U-2.839		U-2.839		U-3.975	
Non-Swinging	U-2.839		U-2.839		U-8.233	

Fenestration	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)
Vertical Glazing, % of Wall						
0-10.0%	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-NR	Uoper-2.67	$SHGC_{north}$-NR	Uoper-7.21	$SHGC_{north}$-NR
10.1-20.0%	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-NR	Uoper-2.67	$SHGC_{north}$-NR	Uoper-7.21	$SHGC_{north}$-NR
20.1-30.0%	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-NR	Uoper-2.67	$SHGC_{north}$-NR	Uoper-7.21	$SHGC_{north}$-NR
30.1-40.0%	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-2.61	$SHGC_{all}$-NR	Ufixed-6.93	$SHGC_{all}$-NR
	Uoper-2.67	$SHGC_{north}$-NR	Uoper-2.67	$SHGC_{north}$-NR	Uoper-7.21	$SHGC_{north}$-NR
40.1-50.0%	Ufixed-1.99	$SHGC_{all}$-NR	Ufixed-1.99	$SHGC_{all}$-NR	Ufixed-5.54	$SHGC_{all}$-NR
	Uoper-2.21	$SHGC_{north}$-NR	Uoper-2.21	$SHGC_{north}$-NR	Uoper-5.77	$SHGC_{north}$-NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	Uall-5.56	$SHGC_{all}$-NR	Uall-5.56	$SHGC_{all}$-NR	Uall-7.38	$SHGC_{all}$-NR
2.1-5.0%	Uall-5.56	$SHGC_{all}$-NR	Uall-5.56	$SHGC_{all}$-NR	Uall-7.38	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	Uall-3.46	$SHGC_{all}$-NR	Uall-3.46	$SHGC_{all}$-NR	Uall-6.25	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.46	$SHGC_{all}$-NR	Uall-3.46	$SHGC_{all}$-NR	Uall-6.25	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	Uall-3.29	$SHGC_{all}$-NR	Uall-3.29	$SHGC_{all}$-NR	Uall-4.60	$SHGC_{all}$-NR
2.1-5.0%	Uall-3.29	$SHGC_{all}$-NR	Uall-3.29	$SHGC_{all}$-NR	Uall-4.60	$SHGC_{all}$-NR

[a] Exception to A3.1.3.1 applies.

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 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 6.2.

> **Exception to 6.1.1.2:** 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 Building.

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 6.2.

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

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

6.1.1.3.5 New and replacement piping shall comply with 6.4.4.1.

> **Exceptions to 6.1.1.3: 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, or
>
> (b) where a replacement or *alteration* of *equipment* requires extensive revisions to other *systems*, *equipment*, or elements of a *building*, and such replaced or altered equipment is a like-for-like replacement, or
>
> (c) for a refrigerant change of existing *equipment*, or
>
> (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 6.1, General; 6.7, Submittals, 6.8, Minimum Equipment Efficiency; and either

(a) 6.3, Simplified Approach Option for HVAC Systems; or
(b) 6.4, Mandatory Provisions; and 6.5, Prescriptive Path.

6.2.2 Projects using the Energy Cost Budget Method (Section 11 of this standard), must comply with 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 less in height,
(b) *gross floor area* is less than 2300 m^2, and
(c) each HVAC *system* in the building complies with the requirements listed in 6.3.2

6.3.2 Criteria: 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 6.5.6.

TABLE 6.3.2 Eliminate Required Economizer by Increasing Cooling Efficiency

Unitary Systems with Heat Pump Heating						
System Size (kW)	Mandatory Minimum COP_c	Climate Zones				
		5-8	4	3	2	
		Minimum Cooling Efficiency Required (COP_c)[a]				Test Procedure[c]
≥ 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	Climate Zones				
		5-8	4	3	2	
		Minimum Cooling Efficiency Required (COP_c)[a]				Test Procedure[c]
≥ 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 below 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.

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

(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 multi-stage 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 (6.3.2g).

(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 10 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 *manufacturer's* 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 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 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

Condensing 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 less for freeze protection are not covered by this standard.

6.4.1.3 Equipment Not Listed. Equipment not listed in the tables referenced in 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 the Federal Energy Policy Act of 1992 (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 6.4.1.
(f) Products covered in Table 6.8.1G shall have efficiency ratings supported by data furnished by the manufacturer.

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 ASHRAE/IESNA 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 6.4.3.1, a dwelling unit shall be permitted to be considered a single *zone.*

Exceptions to 6.4.3.1.1: Independent perimeter systems that are designed to offset only *building envelope* loads shall be permitted to serve one or more *zones* also served by an interior system provided:

(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 meter 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 to 6.4.3.1.2:

(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, data processing, 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.

(a) **Off-Hour Controls.** HVAC systems shall have the off-hour controls required by Sections 6.4.3.2.1 through 6.4.3.2.4.

Exceptions to 6.4.3.2:

(a) *HVAC systems* serving hotel/motel guest rooms.

(b) *HVAC systems* intended to operate continuously.

(c) *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

6.4.3.2.1 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 10 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 to 6.4.3.2.1: Residential occupancies may use controls that can start and stop the system under two different time schedules per week.

6.4.3.2.2 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 to 6.4.3.2.2: Radiant floor and ceiling heating *systems*.

6.4.3.2.3 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.

6.4.3.2.4 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 6.4.3.2.1 (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 to 6.4.3.2.4: 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.

6.4.3.3 Ventilation System Controls.

6.4.3.3.1 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

6.4.3.3.2 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 to 6.4.3.3.1 and 6.4.3.3.2:

(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*.

6.4.3.3.3 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 to 6.4.3.3.3:

(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.

6.4.3.3.4 Dampers. Where *outdoor air* supply and exhaust air dampers are required by Section 6.4.3.3, they shall have a maximum leakage rate when tested in accordance with AMCA Standard 500 as indicated in Table 6.4.3.3.4.

6.4.3.3.5 Ventilation Fan Controls. Fans with motors greater than ¾ hp (0.5 kW) shall have automatic controls complying with Section 6.4.3.2.1 that are capable of shutting off fans when not required.

Exception to 6.4.3.3.5: *HVAC systems* intended to operate continuously.

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

Exception to 6.4.3.4: 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.

6.4.3.5 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.

6.4.3.6 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 to 6.4.3.6:

(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 computer rooms, museums, and hospitals, and approved by the *authority having jurisdiction*.

TABLE 6.4.3.3.4 Maximum Damper Leakage

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

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

6.4.3.7 Freeze Protection and Snow/Ice Melting Systems. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls capable of shutting off the systems when *outdoor air* temperatures are above 4.4°C or when the conditions of the protected fluid will prevent freezing. Snow- and ice-melting systems shall include automatic controls capable of shutting off the systems when the pavement temperature is above 10°C and no precipitation is falling and an automatic or manual control that will allow shutoff when the outdoor temperature is above 4.4°C so that the potential for snow or ice accumulation is negligible.

6.4.3.8 Ventilation Controls for High-Occupancy Areas. Systems with design *outdoor air* capacities greater than 1400 L/s serving areas having an average design occupancy density exceeding 100 people per 100 m^2 shall include means to automatically reduce *outdoor air* intake below design rates when spaces are partially occupied. Ventilation controls shall be in compliance with ASHRAE Standard 62 and local standards.

Exception to 6.4.3.8: Systems with energy recovery complying with 6.5.6.1.

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 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.

TABLE 6.4.4.2A Minimum Duct Seal Level[a]

Duct Location	Duct Type			
	Supply			
	≤500 Pa[b]	>500 Pa[b]	Exhaust	Return
Outdoor	A	A	C	A
Unconditioned Space	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 and 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.

Exceptions to 6.4.4.1.2:

(a) Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with 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 to 6.4.4.1.3:

(a) Factory-installed piping within HVAC equipment tested and rated in accordance with 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 6.4.4.2.2 and with standard industry practice (see 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 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;

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

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 having a fan shall include either an air or water economizer meeting the requirements of 6.5.1.1 through 6.5.1.4.

Exceptions to 6.5.1: 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

TABLE 6.5.1 Minimum Systems 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

(b) Systems that include gas phase air cleaning in order to meet 6.1.2 of ASHRAE Standard 62.

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

6.5.1.1.3 High-Limit Shutoff. All air economizers shall be capable of 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.

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 Temperature	Fixed Enthalpy
1a, 2a, 3a, 4a	Fixed Dry Bulb Fixed Enthalpy Electronic Enthalpy[a] Differential Enthalpy Dew-Point and Dry-Bulb Temperature	Differential Dry Bulb
All Other Climates	Fixed Dry Bulb Differential Dry Bulb Fixed Enthalpy Electronic Enthalpy[a] Differential Enthalpy Dew-Point and Dry-Bulb Temperature	

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 47 kJ/kg of dry air [a]
Electronic Enthalpy	All	$(T_{OA}, RH_{OA}) > A$	*Outdoor air* temperature/RH exceeds the “A” set point curve [b]
Differential Enthalpy	All	$h_{OA} > h_{RA}$	*Outdoor air* enthalpy exceeds return air enthalpy
Dew Point and Dry-Bulb Temperature	All	$DP_{oa}>13°C$ or $T_{oa}>24°C$	*Outdoor air* dry bulb exceeds 24°C or outside dew point exceeds 13°C

a At altitudes substantially different than sea level, the Fixed Enthalpy limit shall be set to the enthalpy value at 24°C and 50% relative humidity. As an example, at approximately 1830 m elevation the fixed enthalpy limit is approximately 53.5 kJ/kg.

b Set point “A” corresponds to a curve on the psychometric 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.

6.5.1.1.4 Dampers. Both return air and *outdoor air* dampers shall meet the requirements of 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 to 6.5.1.2.1:** 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 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 to 6.5.1.3:

(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, 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 to 6.5.1.4:** Economizers on VAV systems that cause zone level heating to increase due to a reduction in supply air temperature.

6.5.2 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 to 6.5.2.1:

(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 6.1.3 of ASHRAE Standard 62 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,
   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 in accordance with the multiple space requirements defined in ASHRAE Standard 62.

(b) *Zones* where special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates are such that variable air volume 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 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 deadband 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 deadband 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 to 6.5.2.2.3: Where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 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 to 6.5.2.3:

(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 6.1.3 of ASHRAE Standard 62, 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 greater than 2°C dew-point temperature shall use a water economizer if an economizer is required by 6.5.1.

6.5.3 Air System Design and Control. HVAC systems having a total *fan system power* exceeding 4 kW shall meet the provisions of 6.5.3.1 through 6.5.3.2 unless otherwise noted.

6.5.3.1 Fan Power Limitation.

(a) The ratio of the fan system power to the supply fan airflow rate (main fan) of each HVAC system at design conditions shall not exceed the allowable fan system power shown in Table 6.5.3.1.

TABLE 6.5.3.1 Fan Power Limitation

	Allowable Nameplate Motor Power	
Supply Air Volume	Constant Volume	Variable Volume
<9400 L/s	1.9 kW/1000 L/s	2.7 kW/1000 L/s
≥9400 L/s	1.7 kW/1000 L/s	2.4 kW/1000 L/s

Allowable Fan System Power = [Table 6.5.3.1 Fan Power Limitation × (Temperature Ratio) + Pressure Credit + Relief Fan Credit]

where

Table 6.5.3.1 Fan Power Limitation = Table Value × L/Sn/1000

Temperature Ratio = $(T_{t\text{-}stat} - T_S) / 11.1$

Pressure Credit (kW) = Sum of [L/Sn × (SPn – 250) / 486000] + Sum of [L/SHR × SPHR/486000]

Relief Fan Credit (kW) = FR (kW) × [1 – (L/SRF / L/Sn)]

L/Sn = supply air volume of the unit with the filtering system (L/s)

L/SHR = supply air volume of heat recovery coils or direct evaporative humidified/cooler (L/s)

L/SRF = relief fan air volume at normal cooling design operation (L/s)

SPn = air pressure drop of the filtering system when filters are clean (Pa)

SPHR = air pressure drop of heat recovery coils or direct evaporative humidifier/cooler (Pa).

Tt-stat = room thermostat set point

TS= design supply air temperature for the zone in which the thermostat is located

FR= name plate rating of the relief fan in kW

(b) Where air systems require air treatment or filtering systems with pressure drops over 250 Pa when filters are clean, or heat recovery coils or devices, or direct evaporative humidifiers/coolers, or other devices to serve process loads in the airstream, the allowable fan system power may be adjusted using the pressure credit in the allowable fan system equation in Table 6.5.3.1.

(c) If the temperature difference between design room temperature and supply air temperature at cooling design conditions that is used to calculate design zone supply airflow is larger than 11.1°C, the allowable fan system power may be adjusted using the temperature ratio in the allowable fan system power equation in Table 6.5.3.1.

6.5.3.2 Variable Air Volume (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 11 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 *manufacturer's* certified fan data.

6.5.3.2.2 Static Pressure Sensor Location. Static pressure sensors used to control variable air volume 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 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 direct digital control 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 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 to 6.5.4.1:

(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 to 6.5.4.3:

(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 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. Subsection 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 to 6.5.5.1: 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 to 6.5.5.2:

(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 6.5.1.1.

Exceptions to 6.5.6.1:

(a) Laboratory systems meeting 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 air* flow.
(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 to 6.5.6.2:

(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 to 6.5.7.1:

(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) Variable air volume 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 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 to 6.5.8.1: Loading docks equipped with air curtains.

6.5.8.2 Heating Enclosed Spaces. Radiant heating systems that are used as primary or supplemental 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 variable air volume 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 to 6.5.9: Unitary packaged systems with cooling capacities not greater than 26.4 kW.

TABLE 6.5.9 Hot Gas Bypass Limitation

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

6.6 Alternative Compliance Path: (Not Used)

6.7 Submittals

6.7.1 General. *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 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 Appendix E). Construction documents shall require that a written balance report be provided to the 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 to 6.7.2.3.3: Impellers need not be trimmed nor pump speed adjusted:

(a) For pumps with pump motors of 7.5 kW or less.

(b) When throttling results in no greater than 5% of the nameplate horsepower 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 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 Air Conditioners and Condensing Units

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[b]	Test Procedure[a]
Air Conditioners, Air Cooled	<19 kW[c]	All	Split System	2.93 SCOP (before 1/23/2006) 3.52 SCOP (as of 1/23/2006)	ARI 210/240
			Single Package	2.84 SCOP (before 1/23/2006) 3.52 SCOP (as of 1/23/2006)	
	≥19 kW and <40 kW	Electric Resistance (or None)	Split System and Single Package	3.02 COP	ARI 340/360
		All other	Split System and Single Package	2.96 COP	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split System and Single Package	2.84 COP	
		All other	Split System and Single Package	2.78 COP	
	≥70 kW and <223 kW	Electric Resistance (or None)	Split System and Single Package	2.78 COP2.84 IPLV	
		All other	Split System and Single Package	2.72 COP2.78 IPLV	
	≥223 kW	Electric Resistance (or None)	Split System and Single Package	2.70 COP2.75 IPLV	
		All other	Split System and Single Package	2.64 COP2.69 IPLV	
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)	ARI 210/240
			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)	
Small-Duct High-Velocity, Air Cooled	< 19 kW[c]	All	Split System	2.93 SCOP	
Air Conditioners, Water and Evaporatively Cooled	<19 kW	All	Split System and Single Package	3.35 COP	
	≥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 COP3.02 IPLV	
		All other	Split System and Single Package	2.64 COP2.96 IPLV	

TABLE 6.8.1A *(continued)* Air Conditioners and Condensing Units

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[b]	Test Procedure[a]
Condensing Units, Air Cooled	≥40 kW	–		2.96 COP3.28 IPLV	ARI 365
Condensing Units, Water or Evaporatively Cooled	≥40 kW	–		3.84 COP3.84 IPLV	

[a] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] IPLVs are only applicable to equipment with capacity modulation.
[c] Single-phase, air-cooled air-conditioners < 19 kW are regulated by NAECA. SCOP values are those set by NAECA.

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

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[b]	Test Procedure[a]
Air Cooled (Cooling Mode)	<19 kW[c]	All	Split System	2.93 $SCOP_c$ (before 1/23/2006) 3.52 $SCOP_c$ (as of 1/23/2006)	ARI 210/240
			Single Package	2.84 $SCOP_c$ (before 1/23/2006) 3.52 $SCOP_c$ (as of 1/23/2006)	
	≥19 kW and <40 kW	Electric Resistance (or None)	Split System and Single Package	2.96 COP_C	ARI 340/360
		All other	Split System and Single Package	2.90 COP_C	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split System and Single Package	2.72 COP_C	
		All other	Split System and Single Package	2.66 COP_C	
	≥70 kW	Electric Resistance (or None)	Split System and Single Package	2.78 COP_C 2.70 IPLV	
		All other	Split System and Single Package	2.72 COP_C 2.64 IPLV	
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)	ARI 210/240
			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)	
Small-Duct High-Velocity (Air Cooled, Cooling Mode)	< 19 kW[c]	All	Split System	2.93 $SCOP_C$	
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

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

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[b]	Test Procedure[a]
Ground Source (Cooling Mode)	<40 kW	All	25°C Entering Water	3.93 COP_C	ISO-13256-1
Air Cooled (Heating Mode)	<19 KW[c] (Cooling Capacity)	–	Split System	1.99 $SCOP_H$ (before 1/23/2006) 2.17 $SCOP_H$ (as of 1/23/2006)	ARI 210/240
			Single Package	1.93 $SCOP_H$ (before 1/23/2006) 2.17 $SCOP_H$ (as of 1/23/2006)	
	≥19 kWand <40 kW (Cooling Capacity)	–	8.3°C db/6.1°C $_{wb}$ Outdoor air	3.2 COP_H	ARI 340/360
			-8.3°C db/-9.4°C $_{wb}$ Outdoor air	2.2 COP_H	
	≥40 kW (Cooling Capacity)	–	8.3°C db/6.1°C $_{wb}$ Outdoor air	3.1 COP_H	
			-8.3°C db/-9.4°C $_{wb}$ Outdoor air	2.0 COP_H	
Through-the-Wall, (Air Cooled, Heating Mode)	≤38.8 kW[c] (cooling capacity)	All	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)	ARI 210/240
			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)	
Small-Duct High-Velocity (Air Cooled, Heating Mode)	< 19 kW[c] (cooling capacity)	-	Split System	1.99 $SCOP_H$	
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] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] IPLVs and Part load rating conditions are only applicable to equipment with capacity modulation.
[c] Single-phase, air-cooled heat pumps < 19 kW are regulated by NAECA. SCOP and HSPF values are those set by NAECA

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°C db 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)	All Capacities	35.0°C db/ 23.9°Cwb Outdoor air	2.52 COP	ARI 390
SPVHP (Cooling Mode)	All Capacities	35.0°C db/23.9°C wb Outdoor air	2.52 COP	
SPVHP (Heating Mode)	All Capacities	8.3°C db/ 6.1°C wb Outdoor air	2.7 COP	
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 Btu/h. 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		78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥66 kW	Maximum Capacity[e]	80% E_c[c]	ANSI Z21.47
Warm Air Furnace, Oil-Fired	<66 kW		78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or UL 727
	≥66 kW	Maximum Capacity[e]	81% E_t[f]	UL 727
Warm Air Duct Furnaces, Gas- Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	ANSI Z83.9
Warm Air Unit Heaters, Gas-Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	ANSI Z83.8
Warm Air Unit Heaters, Oil-Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	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] E_c = combustion efficiency. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
[d] Combination units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 19 kW) may comply with either rating.
[e] Minimum and maximum ratings as provided for and allowed by the unit's controls.
[f] 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.
[g] E_c = combustion efficiency (100% less flue losses). See test procedure for detailed discussion

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

Equipment Type[d]	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Boilers, Gas-Fired	< 88 kW	Hot Water	80% AFUE	DOE 10 CFR Part 430
		Steam	75% AFUE	
	≥88 kW and ≤ 733 kW	Maximum Capacity[c]	75% E_t[a]	H.I. Htg Boiler Std.
	>733 kW [d]	Hot Water	80% E_c	
	>733 kW [d]	Steam	80% E_c	
Boilers, Oil-Fired	<88 kW		80% AFUE	DOE 10 CFR Part 430
	≥88 kW and ≤733 kW	Maximum Capacity[c]	78% E_t[a]	H.I. Htg Boiler Std.
	>733 kW [d]	Hot Water	83% E_c	
	>733 kW[d]	Steam	83% E_c	
Oil-Fired (Residual)	≥88 kW and ≤733 kW	Maximum Capacity[c]	78% E_t[a]	H.I. Htg Boiler Std.
	>733 kW[d]	Hot Water	83% E_c	
	>733 kW[d]	Steam	83% E_c	

a E_t = thermal efficiency. See reference document for detailed information.
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 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

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
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
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

aFor purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower divided by the nameplate rated motor power.
bFor purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the 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 < 528 kW

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	5.15	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	7.01	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 DT[b]			7.80		6.24		5.20		3.90		3.12		2.60	

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature
[b] Condenser DT = 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 DT + LIFT
$COP_{adj} = K_{adj} * COP_{std}$

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	5.8	6.38	6.14	6.55	6.36	6.79	6.51	6.95	6.62	7.06
5.0	26.7	21.7	5.35	5.58	5.64	5.91	5.80	6.10	6.00	6.31	6.12	6.44	6.20	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	5.8	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 DT[b]			7.80		6.24		5.20		3.90		3.12		2.60	

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature
[b] Condenser DT = 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 DT + LIFT
$COP_{adj} = K_{adj} * COP_{std}$

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	5.65	6.55	5.90	6.83	6.05	7.01	6.26	7.26	6.40	7.42	6.51	7.54
4.4	26.7	22.2	5.10	5.91	5.44	6.30	5.62	6.52	5.83	6.76	5.95	6.89	6.03	6.98
4.4	29.4	25.0	4.24	4.91	4.77	5.53	5.06	5.86	5.35	6.20	5.50	6.37	5.59	6.48
5.0	23.9	18.9	5.74	6.65	5.8	6.93	6.14	7.12	6.36	7.37	6.51	7.55	6.62	7.67
5.0	26.7	21.7	5.23	6.06	5.54	6.42	5.71	6.62	5.91	6.85	6.03	6.99	6.11	7.08
5.0	29.4	24.4	4.45	5.15	4.93	5.71	5.19	6.01	5.46	6.33	5.60	6.49	5.69	6.59
5.6	23.9	18.3	5.83	6.75	6.07	7.03	6.23	7.22	6.47	7.49	6.63	7.68	6.75	7.82
5.6	26.7	21.1	5.35	6.20	5.64	6.53	5.80	6.72	6.00	6.95	6.12	7.09	6.20	7.19
5.6	29.4	23.9	4.63	5.37	5.08	5.88	5.31	6.16	5.56	6.44	5.69	6.59	5.77	6.69
6.1	23.9	17.8	5.91	6.85	6.15	7.13	6.33	7.33	6.58	7.63	6.76	7.83	6.89	7.98
6.1	26.7	20.6	5.46	6.32	5.73	6.63	5.89	6.82	6.08	7.05	6.21	7.19	6.30	7.30
6.1	29.4	23.3	4.81	5.57	5.21	6.03	5.42	6.28	5.66	6.55	5.78	6.70	5.86	6.79
6.7	23.9	17.2	6.00	6.95	6.24	7.23	6.43	7.45	6.71	7.77	6.90	8.00	7.05	8.16
6.7	26.7	20.0	5.56	6.44	5.81	6.73	5.97	6.92	6.17	7.15	6.30	7.30	6.40	7.41
6.7	29.4	22.8	4.96	5.75	5.33	6.17	5.55	6.40	5.74	6.66	5.86	6.79	5.94	6.89
7.2	23.9	16.7	6.08	7.05	6.34	7.35	6.54	7.58	6.84	7.93	7.06	8.18	7.22	8.36
7.2	26.7	19.4	5.65	6.55	5.90	6.83	6.05	7.01	6.26	7.26	6.40	7.42	6.51	7.54
7.2	29.4	22.2	5.10	5.91	5.44	6.30	5.62	6.52	5.83	6.76	5.95	6.89	6.03	6.98
7.8	23.9	16.1	6.17	7.15	6.44	7.47	6.66	7.72	6.99	8.10	7.23	8.37	7.40	8.58
7.8	26.7	18.9	5.74	6.65	5.8	6.93	6.14	7.12	6.36	7.37	6.51	7.55	6.62	7.67
7.8	29.4	21.7	5.23	6.06	5.54	6.42	5.71	6.62	5.91	6.85	6.03	6.99	6.11	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	7.37	7.74	7.65	8.04	8.09	8.50	8.40	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 DT[b]			7.80		6.24		5.20		3.90		3.12		2.60	

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature
[b] Condenser DT = 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 DT + LIFT
$COP_{adj} = K_{adj} * COP_{std}$

6.8.2 Duct Insulation Tables

TABLE 6.8.2A Minimum Duct Insulation R-Value, 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	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Heating Ducts Only							
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-1.41	R-1.41	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 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 crawl spaces, 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 w/ 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

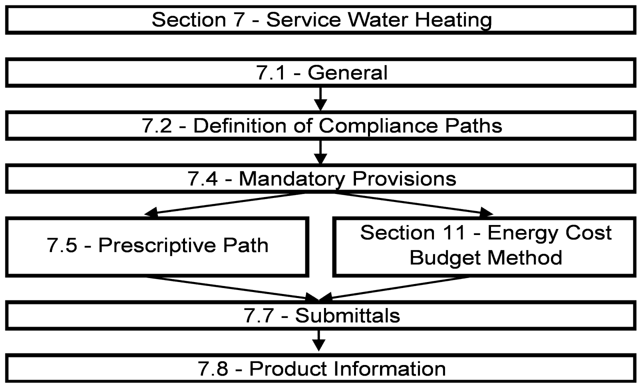
[a] Insulation R-values, measured in $(m^2 \cdot K)/W$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of 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 crawl spaces, both ventilated and non-ventilated.
[c] Includes return air plenums with or without exposed roofs above.

TABLE 6.8.3 Minimum Pipe Insulation Thickness

Fluid Design Operating Temp. Range (°C)	Insulation Conductivity		Nominal Pipe or Tube Size (mm)				
	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	7.60
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	1.3	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 to 7.1.1.2:** When the service water heating to an *addition* is provided by existing service water heating systems and equipment, such systems and equipment shall not be required to comply with this standard. However, any new systems or equipment installed must comply with specific requirements applicable to those systems and equipment.

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

> **Exception to 7.1.1.3:** Compliance shall not be required where there is insufficient space or access to meet these requirements.

7.2 Compliance Path(s)

7.2.1 Compliance shall be achieved by meeting the requirements of 7.1, General; 7.4, Mandatory Provisions; 7.5, Prescriptive Path; 7.7, Submittals; and 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 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 to 7.4.2:** 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, and
> (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 to 7.4.4.1:** When the *manufacturer's* 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 to 7.4.5.2: 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 to 7.4.5.3:

(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 Btu/h 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. *Authority having jurisdiction* may require submittal of compliance documentation and supplemental information, in accord with Section 4.2.2 of this standard.

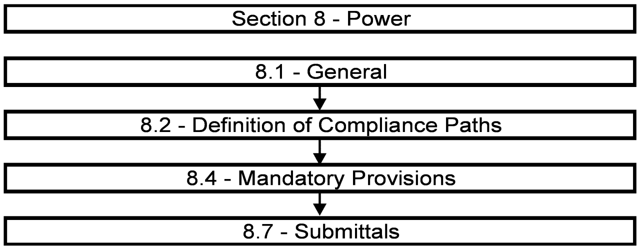
7.8 Product Information

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[c]	≥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 (Et) 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 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 8.1, General; 8.4, Mandatory Provisions; and 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.

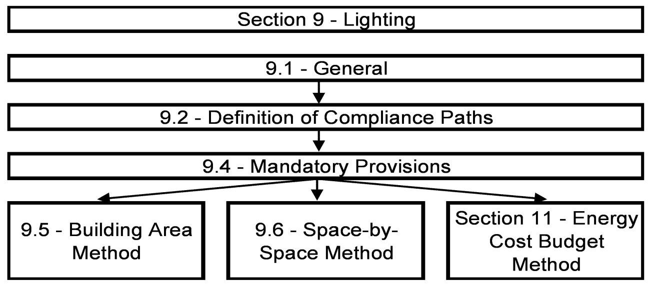
8.7.2 Manuals. Construction documents shall require that an operating manual and maintenance manual be provided to the building owner. The manuals shall include, at a minimum, the following:

(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; and
(c) exterior building grounds lighting provided through the *building's* electrical *service*.

Exceptions to 9.1.1:

(a) emergency lighting that is automatically off during normal *building* operation,
(b) lighting within living 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 lighting power density requirements of Section 9 applicable to that space. New lighting *systems* shall comply with the applicable lighting power density requirements of Section 9. Any new *control devices* as a direct replacement of existing *control devices* shall comply with the specific requirements of 9.4.1.2(b).

Exception to 9.1.2: *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*, current regulators, and *control devices* except as specifically exempted in 9.2.2.3.

Exception to 9.1.3: If two or more independently operating lighting systems in a space are capable of being controlled to prevent simultaneous user operation, the installed interior lighting power 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 *manufacturer's* literature or recognized testing laboratories.
(c) The wattage of line-voltage lighting track and plug-in busway that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the specified wattage of the luminaires included in the system with a minimum of 98 W/lin m.
(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 9.1, General; 9.4, Mandatory Provisions; and the prescriptive requirements of either:

(a) 9.5, Building Area Method, or
(b) 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 9.5, is a simplified approach for demonstrating compliance.

9.2.2.2 The Space-by-Space Method, described in 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 9.5 or the Space-by-Space Method described in 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 9.1.3 shall not exceed the *interior lighting power allowance* developed in accordance with 9.5 or 9.6.

Exceptions to 9.2.2.3: The following *lighting equipment* and applications shall not be considered when determining the *interior lighting power allowance* developed in accordance with 9.5 or 9.6, nor shall the wattage for such lighting be included in the *installed interior lighting power* identified in accordance with 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 the visually impaired.
(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.

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 to 9.4.1.1: 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) 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,
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 to 9.4.1.2: 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 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 an astronomical time switch. Lighting designated for dusk-to-dawn operation shall be controlled by an astronomical time switch or photosensor. Astronomical time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least 10 hours.

Exception to 9.4.1.3: 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 to 9.4.2:

(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 watts per face

9.4.4 Exterior Building Grounds Lighting. All exterior building grounds luminaires that operate at greater than 100 watts 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 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 to 9.4.5: 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.
(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 lighting power density (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 meter) of the building area type.
(c) Multiply the gross lighted floor areas of the building area type(s) times the *lighting power density.*
(d) The *interior lighting power allowance* for the building is the sum of the *lighting power allowances* of all building area types. Trade-offs among building area types are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

9.6 Alternative Compliance Path: Space-by-Space Method

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

(a) 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 *lighting power density* 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, shall be used only for the specified *luminaires,* and shall not be used for any other purpose or in any other space.

9.6.3 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 spaces in which lighting is specified to be installed to meet the requirements of visual display terminals as the primary viewing task, provided that the additional lighting power shall not exceed 3.8 W/m^2 of such spaces and that the specified luminaire meets requirements for use in such spaces. Maximum average luminance measured from the vertical in candelas per square foot of not more than 850 cd/m^2 at 65 degrees, 350 cd/m^2 at 75 degrees, and 175 cd/m^2 at 85 to 90 degrees.
(c) For lighting equipment installed in retail spaces that is specifically designed and directed to highlight merchandise, provided that the additional lighting power shall not exceed (1) 17 W/m^2 times the area of specific display or (2) 42 W/m^2 times the area of specific display for valuable merchandise, such as jewelry, fine apparel and accessories, china and silver, art, and similar items, where detailed display and examination of merchandise are important.

9.7 Submittals (Not Used)

9.8 Product Information (Not Used)

TABLE 9.4.5 Lighting Power Densities for Building Exteriors

Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.)	**Uncovered Parking Areas**	
	Parking Lots and drives	**1.6** W/m^2
	Building Grounds	
	Walkways less than 3 meters wide	**3.3** W/linear meter
	Walkways 3 meters 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
Non-Tradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “tradable Surfaces” section of this table.)	**Building 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-up windows at fast food restaurants	**400** W per drive-through
	Parking near 24-hour retail entrances	**800** W per main entry

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	Lighting Power Density (W/m^2)
Automotive Facility	10
Convention Center	13
Court House	13
Dining: Bar Lounge/Leisure	14
Dining: Cafeteria/Fast Food	15
Dining: Family	17
Dormitory	11
Exercise Center	11
Gymnasium	12
Healthcare-Clinic	11
Hospital	13
Hotel	11
Library	14
Manufacturing Facility	14
Motel	11
Motion Picture Theater	13
Multi-Family	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 general building area type and a specific building area type are listed, the specific building area type shall apply.

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

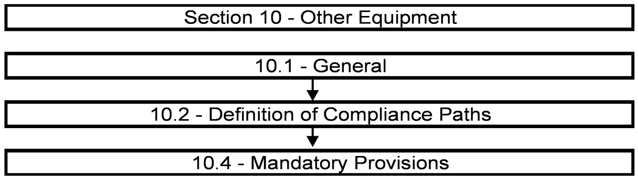
Common Space Types[a]	LPD (W/m^2)	Building Specific Space Types (Continued)	LPD (W/m^2)
Office-enclosed	12	Fire Stations	
Office-open plan	12	Fire Station Engine room	9
Conference/ Meeting/ Multipurpose	14	Sleeping Quarters	3
Classroom/ Lecture/ Training	15	Post Office - Sorting Area	13
For Penitentiary	14	Convention Center - Exhibit Space	14
Lobby	14	Library	
For Hotel	12	Card File & Cataloguing	12
For Performing Arts Theater	36	Stacks	18
For Motion Picture Theatre	12	Reading Area	13
Audience/ Seating Area	10	Hospital	
For Gymnasium	4	Emergency	29
For Exercise Center	3	Recovery	9
For Convention Center	8	Nurse station	11
For Penitentiary	8	Exam/Treatment	16
For Religious Buildings	18	Pharmacy	13
For Sports Arena	4	Patient Room	8
For Performing Arts Theatre	28	Operating Room	24
For Motion Picture theatre	13	Nursery	6
For Transportation	5	Medical Supply	15
Atrium-first three floors	6	Physical Therapy	10
Atrium-each additional floor	2	Radiology	4
Lounge/Recreation	13	Laundry-Washing	6
For Hospital	9	Automotive - Service/Repair	8
Dining area	10	Manufacturing	
For Penitentiary	14	Low Bay (<7.6 m Floor to Ceiling Height)	13
For Hotel	14	High Bay (≥7.6 m Floor to Ceiling Height)	18
For Motel	13	Detailed Manufacturing	23
For Bar Lounge/Leisure Dining	15	Equipment room	13
For Family Dining	23	Control room	5
Food Preparation	13	Hotel/ Motel Guest Rooms	12
Laboratory	15	Dormitory - Living Quarters	12
Restrooms	10	Museum	
Dressing/Locker/Fitting Room	6	General Exhibition	11
Corridor/Transition	5	Restoration	18
For Hospital	11	Bank/Office - Banking Activity Area	16
For Manufacturing Facility	5	Religious Buildings	
Stairs – active	6	Worship-pulpit, choir	26
Active Storage	9	Fellowship Hall	10
For Hospital	10	Retail [For accent lighting see 9.3.1.2.1.(c)]	
Inactive storage	3	Sales area	18
For Museum	9	Mall Concourse	18

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

Common Space Types[a]	LPD (W/m^2)	Building Specific Space Types (Continued)	LPD (W/m^2)
Electrical/ mechanical	16	Sports Arena	
Workshop	20	Ring Sports Area	29
		Court Sports Area	25
Building Specific Space Types		Indoor Playing Field Area	15
Gymnasium/ Exercise Center		Warehouse	
Playing Area	15	Fine Material Storage	15
Exercise Area	10	Medium/Bulky Material Storage	10
Courthouse/ Police Station/ Penitentiary		Parking Garage - Garage Area	2
Courtroom	20	Transportation	
Confinement Cells	10	Airport - Concourse	6
Judges Chambers	14	Air/Train/Bus - Baggage Area	11
		Terminal - Ticket counter	16

[a] In cases where both a common space type and a building specific space 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 to 10.1.1.3: 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 10.1, General; 10.4, Mandatory Provisions; and 10.8, Product Information.

10.2.2 Projects using the Energy Cost Budget Method (Section 11 of this standard), must comply with 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 Pupose 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 Horsepower						
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 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 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met; and
(b) the *design energy cost*, as calculated in 11.3 does not exceed the *energy cost budget*, as calculated by the simulation program described in 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: *The SSPC 90.1 recommends that a compliance shell implementing the rules of the compliance supplement that controls inputs to, and from, output formats 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; and
(h) the *budget building design* characteristics specified in 11.5.

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 6.4.2 for both the *proposed design* and *budget building design*.

11.2.1.4 The simulation program shall be tested according to ASHRAE 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 to 11.2.3:** 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 by 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.

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 design.*

> **Exception to 11.3.2a:** Where there are specific requirements in 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 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*. Heat recovery shall be modeled for the *budget building design* in accordance with 6.5.6.1.

(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 6.5.1. The high-limit shutoff shall be in accordance with Table 11.3.2D.

(f) If the *proposed design* system has a preheat coil, the *budget building design's* system shall be modeled with a preheat coil controlled in the same manner.

(g) 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 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* (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 design* or up to the limit prescribed in 6.5.3.1, whichever is smaller. If this limit is reached, each fan shall be proportionally reduced in brake horsepower until the limit is met. Fan electrical power shall then be determined by adjusting the calculated fan HP by the minimum motor *efficiency* prescribed by 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 design* based on sizing runs; i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the *proposed design* and *budget building design*. Unmet load hours for the *proposed design* shall not differ from unmet load hours for the *budget building design* by more than 50 hours.

(j) Each *HVAC system* in a *proposed design* is mapped on a one-to-one correspondence with one of eleven *HVAC systems* in the *budget building design*. To determine the budget building system:

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 design* shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and area; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls. (b) All conditioned spaces in the *proposed design* shall be simulated as being both heated and cooled even if no cooling or heating system is being installed. (c) When the *energy cost budget* method is applied to buildings in which energy-related features have not yet been designed (e.g., a lighting system), those yet-to-be-designed features shall be described in the *proposed design* so that they minimally comply with applicable mandatory and prescriptive requirements from Sections 5 through 10. Where the space classification for a building is not known, the building shall be categorized as an office building.	The *budget building design* shall be developed by modifying the *proposed design* as described in this table. Except as specifically instructed in this table, all building systems and equipment shall be modeled identically in the *budget building design* and *proposed design*.
2. Additions and Alterations		
	It is acceptable to demonstrate compliance using building models that exclude parts of the *existing building* provided all of the following conditions are met: (a) Work to be performed under the current permit application in excluded parts of the building shall meet the requirements of Sections 5 through 10. (b) Excluded parts of the building are served by HVAC systems that are entirely separate from those serving parts of the building that are included in the building model. (c) Design space temperature and HVAC system operating 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.	Same as Proposed Design
3. Space Use Classification		
	The building type or space type classifications shall be chosen in accordance with 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 in a building if it is a mixed-use facility.	Same as Proposed Design
4. Schedules		
	The schedule types listed in 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 design* and *budget building design*.	Same as Proposed Design

Table 11.3.1 *(continued)* 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)
5. Building Envelope		
	All components of the building envelope in the *proposed 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 5.5.3.1. All other roof surfaces shall be modeled with a reflectance of 0.3. Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices such as fins, overhangs, and light shelves shall be modeled. (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 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 design* but with the minimum U-factor required in 5.5 for new buildings or *additions* and 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 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in 5.5.4.2 is met. Fenestration U-factor shall be the minimum required for the climate, and the solar heat gain coefficient 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 solar heat gain coefficient as described in 5.1.3. *Exception:* When trade-offs are made between an *addition* and an *existing building* as described in Exception to 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.
6. Lighting		
	Lighting power in the *proposed design* shall be determined as follows: (a) Where a complete lighting system exists, the actual lighting power shall be used in the model. (b) Where a lighting system has been designed, lighting power shall be determined in accordance with either 9.5 or 9.6. (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 design* with lighting power set equal to the maximum allowed for the corresponding method and category in either 9.5 or 9.6. Power for fixtures not included in the lighting power density calculation shall be modeled identically in the *proposed 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 Design

Table 11.3.1 *(continued)* 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)
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 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
10. HVAC Systems		
	The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed design* shall be determined as follows: (a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. (b) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in 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 11.3.2 a-j.

Table 11.3.1 *(continued)* 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)
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 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 design* except where 7.5 applies. In this case the boiler shall be split into a separate space heating boiler and hot water heater with *efficiency* requirements set to the least efficient allowed.
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 design.* 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 design.* 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.
13.	**Modeling Exceptions**	
	All elements of the *proposed design* envelope, HVAC, service water heating, lighting, and electrical systems shall be modeled in the *proposed design* in accordance with the requirements of Sections 1 through 12 of Table 11.3.1. *Exception:* Components and systems in the *proposed 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 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 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 design* and *budget building design* models.	Same as Proposed Design

Condenser Cooling Source	Heating System Classification	Single Zone Residential System	Single Zone Non-Residential System	All Other
Water/Ground	Electric Res.	System 5	System 5	System 1
	Heat Pump	System 6	System 6	System 6
	Fossil Fuel	System 7	System 7	System 2
Air/None	Electric Res.	System 8	System 9	System 3
	Heat Pump	System 8	System 9	System3
	Fossil Fuel	System 10	System 11	System 4

(Budget System Type: Heating System Classification, Single Zone Residential System, Single Zone Non-Residential System, All Other)

Figure 11.3.2 HVAC systems map.

1. Enter Figure 11.3.2 at “Water” if the *proposed 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 design* does not require heat rejection, the system shall be treated as if the condenser water type were “Air.” For proposed designs with ground-source or groundwater-source heat pumps, the budget system shall be water-source heat pump (System 6).

2. Select the path that corresponds to the *proposed design* heat source: electric resistance, heat pump (including air-source and water-source), or fuel-fired. Systems utilizing district heating (steam or hot water) shall be treated as if the heating system type were “Fossil Fuel.” Systems with no heating capability shall be treated as if the heating system type were “Fossil Fuel.” For systems with mixed fuel heating sources, the system or systems that use the secondary heating source type (the one with the smallest total installed output capacity for the spaces served by the system) shall be modeled identically in the *budget building design* and the primary heating source type shall be used in Figure 11.3.2 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 11.3.2A Budget System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1	Variable air volume with parallel fan-powered boxes (1)	VAV (4)	Chilled Water (5)	Electric Resistance
2	Variable air volume with reheat (2)	VAV (4)	Chilled Water (5)	Hot Water Fossil Fuel Boiler (6)
3	Packaged variable air volume with parallel fan-powered boxes (1)	VAV (4)	Direct Expansion (3)	Electric Resistance
4	Packaged variable air volume with reheat (2)	VAV (4)	Direct Expansion (3)	Hot Water Fossil Fuel Boiler (6)
5	Two-pipe fan-coil	Constant Volume (9)	Chilled Water (5)	Electric Resistance
6	Water-source heat pump	Constant Volume (9)	Direct Expansion (3)	Electric Heat Pump and Boiler (7)
7	Four-pipe fan coil	Constant Volume (9)	Chilled Water (5)	Hot Water Fossil Fuel Boiler (6)
8	Packaged terminal heat pump	Constant Volume (9)	Direct Expansion (3)	Electric Heat Pump (8)
9	Packaged rooftop heat pump	Constant Volume (9)	Direct Expansion (3)	Electric Heat Pump (8)
10	Packaged terminal air conditioner	Constant Volume (9)	Direct Expansion	Hot Water Fossil Fuel Boiler (6)
11	Packaged rooftop air conditioner	Constant Volume (9)	Direct Expansion	Fossil Fuel Furnace

Notes:

1. **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 6.5.2.1 Exception (a) 1. Supply air temperature setpoint shall be constant at the design condition (see 11.3.2 (h)).
2. **VAV with reheat:** Minimum volume setpoints for VAV reheat boxes shall be 2.15 L/s · m^2 of floor area consistent with 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 air flow rates shall be sized for the reset supply air temperature, i.e., a 5.6°C temperature difference.
3. **Direct Expansion:** The fuel type for the cooling system shall match that of the cooling system in the *proposed design*.
4. **VAV:** Constant volume can be modeled if the system qualifies for Exception (b) to 6.5.2.1. When the *proposed 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 design's* system has a direct digital control system at the zone level, static pressure setpoint reset based on zone requirements in accordance with 6.5.3.2.3 shall be modeled.
5. **Chilled Water:** For systems using purchased chilled water, the chillers are not explicitly modeled and chilled water costs shall be based as determined in 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* 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 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 6.5.4.3. Pump system power for each pumping system shall be the same as the *proposed design*; if the *proposed design* has no chilled water pumps, the *budget building design* pump power shall be 349 kW/1000 L/s (equal to a pump operating against a 23 m head, 65% combined impeller and motor *efficiency*). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in 6.5.4.1. The heat rejection device shall be an axial fan cooling tower with two-speed fans if required in 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 design*; if the *proposed 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.
6. **Fossil Fuel Boiler:** For systems using purchased hot water or steam, the boilers are not explicitly modeled and hot water or steam costs shall be based on actual utility rates. Otherwise, the boiler plant shall use the same fuel as the *proposed design* and shall be natural draft. The *budget building design* boiler plant shall be modeled with a single boiler if the *budget building design* plant load is 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 6.5.4.3. Pump system power for each pumping system shall be the same as the *proposed design*; if the *proposed 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 6.5.4.1.
7. **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 6.5.5.2. Heat addition to the loop shall be provided by a boiler that uses the same fuel as the *proposed design* and shall be natural draft. If no boilers exist in the *proposed design*, the budget building boilers shall be fossil fuel. The *budget building design* boiler plant shall be modeled with a single boiler if the *budget building design* plant load is 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 design*; if the *proposed 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 6.5.4.4. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by 6.5.4.1.
8. **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.
9. **Constant Volume:** Fans shall be controlled in the same manner as in the *proposed design*; i.e., fan operation whenever the space is occupied or fan operation cycled on calls for heating and cooling. 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.

TABLE 11.3.2B Number of Chillers

Total Chiller Plant Capacity	Number of Chillers
≤1055 kW	1
>1055 kW, <2110 kW	2 sized equally
≥2110 kW	2 minimum with chillers added sothat 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 Shut-Off
Air	Table 6.5.1.1.3B
Water (Integrated)	When its operation will no longer Reduce HVAC system energy
Water (Non-Integrated)	When its operation can no longer provide the cooling load

12. NORMATIVE REFERENCES

Reference	Title
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
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 340/360-2000	Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
ARI 365-2002	Commercial and Industrial Unitary Air-Conditioning Condensing Units
ARI 390-2001	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 62-1999	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE Standard 140-2001	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 C90-96	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 C272-91	Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM C518-2002	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus

Reference	Title
ASTM C835-95 (1999)	Standard Test Method for Total Hemispherical Emittance of Surfaces From 20ºC to 1400ºC
ASTM C1363-97	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM C1371-98	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers
ASTM E96-95	Test Methods for Water Vapor Transmission of Materials
ASTM E283-91	Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
ASTM E408-71 (1996)	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 (1996)	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, 530 Wells Fargo, Suite 218, Houston, TX 77090; P.O. Box 73383, Houston, TX 77273	
CTI ATC-105(97)	Acceptance Test Code for Water Cooling Towers
CTI STD-201 (96)	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
ISO, 1, rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland	
ISO 13256-1 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps
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 100-2001	Procedure for Determining Fenestration Product U-Factors (Second Edition) *Published November 2002*

Reference	Title
NFRC 101-2001	Procedure for Determining Thermo-Physical Properties of Materials for Use in NFRC–Approved Software Programs, (First Edition) *Published November 2002*
NFRC 102-2001	Test Procedures for Measuring the Steady-State Thermal Transmittance of Fenestration Systems, (Second Edition) *Published November 2002*
NFRC 200-2001	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence (Second Edition) *Published November 2002*
NFRC 201-2001	Interim Standard Test Method for Measuring the Solar Heat Gain Coefficient of Fenestration Systems Using Calorimetry Hot Box Methods, (Second Edition) *Published November 2002*
NFRC 300-2001	Standard Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems, (Second Edition) *Published November 2002*
NFRC 400-2001	Procedure for Determining Fenestration Product Air Leakage (Second Edition) *Published November 2002*
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

(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 A2 through A8. These values shall be used for all calculations unless otherwise allowed by A1.2. Interpolation between values in a particular table in Appendix A is allowed for *rated R-values of insulation*, including insulated sheathing. Extrapolation beyond values in a table in 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 A2 through A8, the applicant shall determine appropriate values for the assembly using the assumptions in 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 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 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 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 to A2.2.2:** Interruptions for framing and pads for mechanical equipment are permitted with a combined total area not exceeding one percent of the total opaque assembly area.

A2.2.3 U-factor. *U-factors* for *roofs with insulation entirely above deck* shall be taken from Table A2.2. 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 A1.2, the base assembly is a *roof* where the insulation is draped over the steel structure (purlins) and then compressed when the metal spanning members 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 spanning members are attached, or for insulation hung between the purlins, provided there is a minimum 25 mm thermal break between the purlins and the metal spanning members.

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), it is assumed that the insulation boards are installed below the purlins and are 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.

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.

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 Blocks									
Single Layer	None	0	**7.258**	0.919	0.493	0.335	0.255	0.204	1.070
	R-1.1	1.1	**0.947**	0.489	0.330	0.249	0.200	0.167	0.143
	R-1.8	1.8	**0.550**	0.356	0.264	0.209	0.173	0.148	0.129
	R-1.9	1.9	**0.522**	0.344	0.257	0.205	0.170	0.146	0.128
	R-2.3	2.3	**0.471**	0.321	0.244	0.197	0.165	0.142	0.124
	R-2.8	2.8	**0.408**	0.291	0.226	0.185	0.156	0.135	0.119
	R-3.3	3.3	**0.369**	0.270	0.213	0.176	0.150	0.131	0.116
Double Layer	R-1.8 + R-1.8	3.5	**0.357**	0.264	0.209	0.174	0.148	0.129	0.115
	R-1.8 + R-1.9	3.7	**0.346**	0.258	0.205	0.171	0.146	0.128	0.113
	R-1.9 + R-1.9	3.9	**0.340**	0.255	0.203	0.169	0.145	0.127	0.113
	R-1.8 + R-2.3	4.1	**0.329**	0.248	0.199	0.167	0.143	0.125	0.112
	R-1.9 + R-2.3	4.2	**0.323**	0.245	0.197	0.165	0.142	0.124	0.111
	R-2.3 + R-2.3	4.6	**0.312**	0.238	0.193	0.162	0.140	0.123	0.109
	R-1.8 + R-3.3	5.1	**0.295**	0.228	0.186	0.157	0.136	0.120	0.107
	R-1.9 + R-3.3	5.3	**0.289**	0.225	0.184	0.156	0.135	0.119	0.107
	R-2.3 + R-3.3	5.6	**0.278**	0.218	0.179	0.152	0.132	0.117	0.105
	R-2.8 + R-3.3	6.2	**0.266**	0.211	0.175	0.149	0.130	0.115	0.103
	R-3.4 + R-3.3	6.7	**0.261**	0.207	0.172	0.147	0.128	0.114	0.102
(Multiple R-values are listed in order from inside to outside)									
Screw Down Roofs									
	R-1.8	1.8	**0.868**	0.467	0.320	0.243	0.196	0.164	0.141
	R-1.9	1.9	**0.788**	0.443	0.308	0.236	0.192	0.161	0.139
	R-2.3	2.3	**0.737**	0.427	0.300	0.232	0.188	0.159	0.137
Filled Cavity with Thermal Blocks									
	R3.3 + R-1.8	5.1	**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)									

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	3.48
R-1.9	0.52
R-2.3	0.46
R-3.3	0.30
R-5.3	0.19
R-6.7	0.15
R-8.6	0.12
R-10.6	0.10
R-12.5	0.08
R-14.4	0.07
R-16.4	0.06
R-18.3	0.06
R-20.2	0.05
R-22.2	0.05
Wood-framed attic, advanced framing	
None	3.58
R-1.9	0.50
R-2.3	0.44
R-3.3	0.29
R-5.3	0.18
R-6.7	0.15
R-8.6	0.11
R-10.6	0.09
R-12.5	0.08
R-14.4	0.07
R-16.4	0.06
R-18.3	0.05
R-20.2	0.05
R-22.2	0.04
Wood joists, single rafter roof	
None	2.37
R-1.9	0.50
R-2.3	0.44
R-2.6	0.40
R-3.3	0.31
R-3.7	0.29
R-4.4	0.25
R-5.3	0.20
R-6.7	0.16

A2.4 Attic Roofs with Wood Joists

A2.4.1 General. For the purpose of A1.2, the base *attic roof* assembly is a *roof* with a 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-factor* includes 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 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 A2.5.

A2.5 Attic Roofs with Steel Joists.

A2.5.1 General: For the purpose of A1.2, the base assembly is a roof supported by steel joists with insulation between the joists. The assembly represents a *roof* in many ways similar to a *roof with insulation entirely above deck* and a *metal building roof*. It is distinguished from the *metal building roof* category in that there is no metal exposed to the exterior. It is distinguished from the *roof with insulation entirely above deck* in that the insulation is located below the deck and is interrupted by metal trusses that provide thermal bypasses to the insulation. The *U-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. The performance of the insulation/framing layer is calculated using the values in Table A9.2A.

TABLE A2.4.2 Single Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d* (actual)		
	d ≤ 200 mm	200 < *d* ≤ 250 mm	250 < *d* ≤ 300 mm
1-7	R-3.3 U-0.31	R-5.3 U-0.20	R-6.7 U-0.16
8	R-3.7 U-0.29	R-5.3 U-0.20	R-6.7 U-0.16

TABLE A2.5 Assembly U-Factors for Attic Roofs with Steel Joists (1.2 m on center)

Rated R-Value of Insulation Area	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

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.

A3 Above-Grade Walls

A3.1 Mass Wall

A3.1.1 General. For the purpose of A1.2, the base assembly is a masonry or concrete *wall*. *Continuous insulation* is installed on the interior, exterior, or within the masonry units, or it is installed on the interior or exterior of the concrete. The *U-factor* includes 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 heat capacity 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. *Heat capacity* for *mass walls* shall be taken from Table A3.1B or A3.1C.

> **Exception to A3.1.3.1:** 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 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.

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)
	R-0	**U-4.20**	**U-3.29**	**U-2.73**
No Framing	**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-0.64	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

TABLE A3.1A *(continued)* 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)
102 mm	R-2.68	U-0.40	U-0.40	U-0.40
102 mm	R-3.52	U-0.34	U-0.33	U-0.33
102 mm	R-3.94	U-0.32	U-0.31	U-0.31
127 mm	R-4.93	U-0.26	U-0.26	U-0.26
152 mm	R-5.92	U-0.22	U-0.22	U-0.22
178 mm	R-6.90	U-0.19	U-0.19	U-0.19
203 mm	R-7.89	U-.17	U-0.16	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-0.12
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 Heat Capacity for Concrete

Density in kg/m³	Properties	Thickness in 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
	Ru	0.81	1.03	1.25	1.47	1.69	1.91	2.13	2.35	2.56	2.78
	Rc	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
	Ru	0.63	0.79	0.95	1.11	1.27	1.43	1.59	1.75	1.91	2.07
	Rc	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
	Ru	0.53	0.65	0.78	0.90	1.03	1.15	1.28	1.40	1.53	1.66
	Rc	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
	Ru	0.46	0.56	0.67	0.77	0.87	0.98	1.08	1.18	1.29	1.39
	Rc	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
	Ru	0.27	0.31	0.35	0.40	0.44	0.48	0.52	0.56	0.60	0.64
	Rc	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
	Ru	0.24	0.27	0.31	0.34	0.37	0.40	0.43	0.46	0.49	0.53
	Rc	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
	Ru	0.22	0.25	0.27	0.30	0.32	0.354	0.37	0.40	0.42	0.45
	Rc	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
	Ru	0.21	0.23	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.39
	Rc	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
	Ru	0.20	0.21	0.23	0.25	0.26	0.28	0.30	0.31	0.33	0.35
	Rc	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

TABLE A3.1B *(continued)* Assembly U-Factors, C-Factors, R_u, R_c, and Heat Capacity for Concrete

Density in kg/m^3	Properties	Thickness in mm									
		75	100	125	150	175	200	225	250	275	300
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
	Ru	0.19	0.20	0.21	0.23	0.24	0.26	0.27	0.28	0.29	0.31
	Rc	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
	Ru	0.18	0.19	0.20	0.22	0.23	0.24	0.25	0.26	0.27	0.28
	Rc	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.13
	HC	147	196	245	94	344	393	442	491	540	589

TABLE A3.1C Assembly U-Factors, C-Factors, R_u, R_c, and Heat Capacity 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
		Ru	0.31	0.38	0.52	0.44	0.90
		Rc	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
		Ru	0.29	0.36	0.48	0.42	0.81
		Rc	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
		Ru	0.29	0.36	0.48	0.42	0.81
		Rc	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
		Ru	0.27	0.33	0.42	0.38	0.67
		Rc	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
		Ru	0.25	0.31	0.39	0.36	0.59
		Rc	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
		Ru	0.24	0.29	0.36	0.33	0.51
		Rc	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
		Ru	0.36	0.43	0.62	0.48	1.17
		Rc	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
		Ru	0.34	0.40	0.57	0.43	5.92
		Rc	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
		Ru	0.32	0.38	0.53	0.43	0.84
		Rc	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
		Ru	0.30	0.36	0.50	0.41	0.84
		Rc	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
		Ru	0.29	0.35	0.46	0.39	0.74
		Rc	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
		Ru	0.27	0.32	0.41	0.36	0.62
		Rc	0.12	0.17	0.26	0.21	0.47
		HC	367	245	253	172	184

TABLE A3.1C *(continued)* Assembly U-Factors, C-Factors, R_u, R_c, and Heat Capacity 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
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
		Ru	0.40	0.46	0.71	0.50	1.39
		Rc	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
		Ru	0.38	0.43	0.66	0.47	1.22
		Rc	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
		Ru	0.36	0.41	0.61	0.45	1.09
		Rc	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
		Ru	0.34	0.39	0.57	0.43	0.97
		Rc	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
		Ru	0.32	0.37	0.52	0.40	0.85
		Rc	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
		Ru	0.30	0.35	0.46	0.37	0.70
		Rc	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
		Ru	0.45	0.49	0.81	0.52	1.66
		Rc	0.30	0.34	0.66	0.37	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
		Ru	0.42	0.46	0.74	0.49	1.47
		Rc	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
		Ru	0.40	0.43	0.69	0.46	1.29
		Rc	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
		Ru	0.38	0.41	0.64	0.44	1.15
		Rc	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
		Ru	0.36	0.39	0.59	0.42	1.00
		Rc	0.21	0.24	0.44	0.27	0.85
		HC	540	40	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
		Ru	0.34	0.37	0.52	0.39	0.82
		Rc	0.19	0.22	0.37	0.24	0.67
		HC	57	357	370	238	259

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	0.75	0.78	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	1.06	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	1.23	1.25	1.27	1.28	1.30	1.31	1.33

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, and 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 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.

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**	na	na	na	na	na	na
	R-1.8 + R-2.3	4.1	**0.35**	na	na	na	na	na	na
	R-2.3 + R-2.3	4.6	**0.32**	na	na	na	na	na	na
	R-3.3 + R-2.3	5.6	**0.27**	na	na	na	na	na	na

A3.3 Steel-Framed Walls.

A3.3.1 General. For the purpose of 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-factor* includes 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-21. 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 89 mm 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 A3.3.1(a).

A3.3.3.3 For *steel-framed walls* with framing from 600 mm to 800 mm on center, use the advanced framing values as described in A3.3.1(b).

A3.3.3.4 For *steel-framed walls* with framing greater than 800 mm on center, use the *metal building wall* values in Table A3.2.

A3.4 Wood-Framed Walls.

A3.4.1 General. For the purpose of 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-factor* includes 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 24 in. on center, use the standard framing values as described in A3.4.1(a).

A3.4.3.3 For *wood-framed walls* with framing from 600 mm to 800 mm on center, use the advanced framing values as described in A3.4.1(b) if the headers are uninsulated or the advanced framing with insulated header values as described in 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 A9.

A4 Below-Grade Walls.

A4.1 General. For the purpose of 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.

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-1.47**	**R-2.65**	**R-3.53**	**R-4.41**	**R-5.29**	**R-6.17**	**R-7.05**
Steel Framing at 400 mm OC																						
(89 mm depth)	None (0.0)	**2.00**	1.48	1.17	0.97	0.83	0.72	0.64	0.58	0.52	0.48	0.44	0.41	0.38	0.36	0.34	0.32	0.25	0.20	0.17	0.15	0.13
	R-1.9 (1.0)	**0.75**	0.66	0.59	0.54	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.21	0.17	0.15	0.13	0.12
	R-2.3 (1.1)	**0.70**	0.63	0.56	0.51	0.47	0.43	0.40	0.38	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.25	0.20	0.17	0.15	0.13	0.12
	R-2.6 (1.1)	**0.67**	0.60	0.54	0.50	0.46	0.42	0.39	0.37	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.20	0.17	0.15	0.13	0.12
(152 mm depth)	R-3.3 (1.3)	**0.62**	0.56	0.51	0.47	0.43	0.40	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.26	0.24	0.23	0.19	0.17	0.14	0.13	0.12
	R-3.7 (1.3)	**0.60**	0.54	0.50	0.46	0.42	0.39	0.37	0.34	0.32	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.19	0.16	0.14	0.13	0.11
Steel Framing at 600 mm OC																						
(89 mm depth)	None (0.0)	**1.92**	1.43	1.14	0.95	0.81	0.71	0.63	0.57	0.52	0.47	0.44	0.41	0.38	0.36	0.33	0.32	0.25	0.20	0.17	0.15	0.13
	R-1.9 (1.2)	**0.66**	0.59	0.53	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.20	0.17	0.15	0.13	0.12
	R-2.3 (1.3)	**0.61**	0.55	0.50	0.46	0.43	0.40	0.37	0.35	0.33	0.31	0.29	0.28	0.27	0.25	0.24	0.23	0.19	0.17	0.14	0.13	0.12
	R-2.6 (1.4)	**0.58**	0.52	0.48	0.44	0.41	0.38	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23	0.19	0.16	0.14	0.13	0.11
(152 mm depth)	R-3.3 (1.5)	**0.53**	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.30	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 OC																						
89 mm depth	None (0.0)	**1.66**	1.26	1.03	0.86	0.75	0.66	0.59	0.53	0.49	0.45	0.41	0.39	0.36	0.34	0.32	0.30	0.24	0.20	0.17	0.15	0.13
	R-1.9 (1.9)	**0.55**	0.49	0.45	0.42	0.39	0.36	0.34	0.32	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.18	0.16	0.14	0.12	0.11
	R-2.3 (2.3)	**0.50**	0.46	0.42	0.39	0.36	0.34	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.22	0.21	0.17	0.15	0.13	0.12	0.11
	R-2.6 (2.6)	**0.47**	0.43	0.39	0.36	0.34	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.21	0.21	0.20	0.17	0.15	0.13	0.12	0.11
140 mm depth	R-3.3 (3.2)	**0.38**	0.35	0.33	0.31	0.29	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.16	0.14	0.12	0.11	0.10
	R-3.7 (3.7)	**0.35**	0.33	0.30	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.18	0.18	0.17	0.15	0.13	0.12	0.11	0.10
+R-1.8 headers	R-3.3 (3.2)	**0.36**	0.34	0.31	0.30	0.28	0.27	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.19	0.18	0.18	0.15	0.14	0.12	0.11	0.10
	R-3.7 (3.7)	**0.33**	0.31	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.17	0.15	0.13	0.12	0.10	0.10
Wood Studs at 600 mm OC																						
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	0.10
	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 (3.7)	**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

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

A4.2.2 It is acceptable to use the *C-factors* in Table 4.2 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, and 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 A6 for *slab-on-grade floors*.

A5.2 Mass Floors

A5.2.1 General. For the purpose of A1.2, the base assembly is *continuous insulation* over or under a solid concrete *floor*. The *U-factor* includes 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 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-factor* includes 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 A1.2, the base assembly is a *floor* attached directly to the top of the wood joist and with insulation located directly below the *floor*, with a ventilated airspace below the insulation. The heat flow path through the joist is calculated to be the same depth as the insulation. The *U-factor* includes 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*

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 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
Concrete Floor with Rigid Foam																						
	None (0.00)	**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	0.09
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 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 Joist Floor with Rigid Foam																						
	None (0.00)	**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 (0.00)	**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

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 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 lineal foot of building perimeter. *F-factors* are provided for unheated slabs and for heated slabs. *Unheated slab-on-grade floors* do not have heating elements, and *heated slab-on-grade floors* do have heating elements within or beneath the slab. *F-factors* are provided for three insulation configurations:

(a) **Horizontal insulation:** *Continuous insulation* is applied directly to the underside of the slab and extends inward horizontally from the perimeter for the distance specified or *continuous insulation* is applied downward from the top of the slab and then extends horizontally to the interior or the exterior from the perimeter for the distance specified.

(b) **Vertical insulation:** *continuous insulation* is applied directly to the slab exterior, extending downward from the top of the slab for the distance specified.

(c) **Fully insulated slab:** *continuous insulation* extends downward from the top of the slab and along the entire perimeter and completely covers the entire area under the slab.

A6.2 Rated R-Value of Insulation for Slab-on-Grade Floors.

A6.2.1 The *rated R-value of insulation* shall be installed around the perimeter of the *slab-on-grade floor* to the distance specified.

Exception to A6.2.1: For a monolithic *slab-on-grade floor*, the insulation shall extend from the top of the slab-on-grade to the bottom of the footing.

A6.2.2 Insulation installed inside the foundation wall shall extend downward from the top of the slab a minimum of the distance specified or to the top of the footing, whichever is less.

A6.2.3 Insulation installed outside the foundation wall shall extend from the top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum of the distance specified. In all climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 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 visible light transmittances 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 visible light transmittances in Table A8.2.

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 A9 only if approved by the *building official* in accordance with A1.2. The procedures required for each class of construction are specified in A9.2. Testing shall be performed in accordance with A9.3. Calculations shall be performed in accordance with A9.4.

A9.2 Required Procedures. Two- or three-dimensional finite difference and finite volume computer models shall be an acceptable alternative method to calculating the thermal performance values for all assemblies and constructions listed below. The following procedures shall also be permitted to determine all alternative *U-factors, F-factors*, and *C-factors*.

(a) **Roofs**.

1. *Roofs with insulation entirely above deck*: testing or series calculation method.
2. *Metal building roofs*: testing.
3. *Attic roofs*, wood joists: testing or parallel path calculation method.

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 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 Joists																						
140 mm depth	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 depth	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 depth	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 depth	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 depth	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

Insulation Description	Rated R-Value of Insulation												
	0.0	0.9	1.3	1.8	2.6	3.5	4.4	5.3	6.2	7.0	7.9	8.8	9.7
Unheated Slabs													
None	1.26												
300 mm horizontal		1.24	1.23	1.23	1.23								
600 mm horizontal		1.21	1.21	1.20	1.19								
900 mm horizontal		1.18	1.17	1.15	1.14								
1200 mm horizontal		1.16	1.13	1.11	1.09								
300 mm vertical		1.05	1.03	1.01	0.99	0.98	0.98	0.98					
600 mm vertical		1.00	0.97	0.93	0.90	0.88	0.87	0.87					
900 mm vertical		0.97	0.93	0.88	0.84	0.82	0.80	0.80					
1200 mm vertical		0.93	0.88	0.83	0.78	0.75	0.73	0.72					
Fully insulated slab		0.80	0.71	0.62	0.52	0.45	0.40	0.37	0.34	0.32	0.30	0.29	0.28
Heated Slabs													
None	2.33												
300 mm horizontal		2.27	2.26	2.26	2.25								
600 mm horizontal		2.21	2.19	2.18	2.16								
900 mm horizontal		2.14	2.10	2.07	2.04								
1200 mm horizontal		2.08	2.02	1.96	1.92								
300 mm vertical		1.84	1.76	1.73	1.70	1.67	1.67	1.66					
600 mm vertical		1.72	1.64	1.57	1.50	1.46	1.44	1.43					
900 mm vertical		1.64	1.54	1.45	1.36	1.32	1.29	1.28					
1200 mm vertical		1.57	1.47	1.35	1.25	1.19	1.16	1.14					
Fully insulated slab		1.28	1.11	0.95	0.76	0.65	0.56	0.51	0.47	0.44	0.41	0.39	0.38

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 the 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 the 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.

TABLE A8.1A Assembly U-Factors for Unlabeled Skylights

Product Type		Sloped Installation						
Frame Type		Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
ID	Glazing 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
	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

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

Product Type		Sloped Installation						
Frame Type		Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
ID	Glazing 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
30	6.4 mm argon spaces	6.17	4.86	4.56	3.43	3.46	2.83	2.51
31	12.7 mm argon spaces	6.07	4.76	4.46	3.33	3.36	2.73	2.41
	Triple Glazing, *e* = 0.20 on surface 2, 3, 4, or 5							
32	6.4 mm airspaces	6.12	4.81	4.51	3.38	3.41	2.78	2.46
33	12.7 mm airspaces	5.96	4.65	4.36	3.22	3.26	2.63	2.32
34	6.4 mm argon spaces	5.81	4.50	4.21	3.07	3.11	2.49	2.17
35	12.7 mm argon spaces	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 airspaces	5.86	4.55	4.26	3.12	3.16	2.53	2.22
37	12.7 mm airspaces	5.75	4.44	4.15	3.02	3.07	2.44	2.12
38	6.4 mm argon spaces	5.60	4.29	4.00	2.86	2.92	2.29	1.97
39	12.7 mm argon spaces	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 airspaces	5.75	4.44	4.15	3.02	3.07	2.44	2.12
41	12.7 mm airspaces	5.65	4.34	4.05	2.91	2.97	2.34	2.02
42	6.4 mm argon spaces	5.44	4.13	3.84	2.71	2.77	2.14	1.82
43	12.7 mm argon spaces	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 airspaces	5.49	4.18	3.90	2.76	2.82	2.19	1.87
45	12.7 mm airspaces	5.33	4.02	3.74	2.60	2.67	2.04	1.73
46	6.4 mm argon spaces	5.28	3.97	3.69	2.55	2.62	1.99	1.68
47	12.7 mm argon spaces	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 Solar Heat Gain Coefficients (SHGC) and Assembly Visible Light Transmittances (VL T) 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 Solar Heat Gain Coefficients (SHGC), and Assembly Visible Light Transmittances (VLT) for Unlabeled Vertical Fenestration

		Unlabeled Vertical Fenestration					
		Clear Glass			Tinted Glass		
Frame Type	Glazing Type	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 frame							
	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 type							
	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

TABLE A9.2A Effective Insulation/Framing Layer A-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 Fac-tor	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 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, or
(c) ASTM C1363

For concrete, the oven-dried conductivity shall be multiplied by 1.2 to reflect the moisture content as typically installed.

A9.3.2 Assembly U-Factors. If assembly *U-factors* are determined by testing, ASTM C1363 test procedures shall be used.

Product samples tested shall be production line material or representative of material as purchased by the consumer or contractor. If the assembly is too large to be tested at one time in its entirety, then either a representative portion shall be tested or different portions shall be tested separately and a weighted average determined. To be representative, the portion tested shall include edges of panels, joints with other panels, typical framing percentages, and thermal bridges.

A9.4 Calculation Procedures and Assumptions. The following procedures and assumptions shall be used for all calculations. R-values for air films, insulation, and *building materials* shall be taken from A9.4.1 through A9.4.3, respectively. In addition, the appropriate assumptions listed in 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 Surface 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
Bldg 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.

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 (mm)		300	240	170	140	155	90	90	90
Nominal Lumber Size (mm)	Actual Depth of Cavity (mm)	Effective Insulation R-Values when Installed in a Confined Cavity							
50 × 300	286	6.5	-	-	-	-	-	-	-
50 × 250	235	5.6	5.3	-	-	-	-	-	-
50 × 200	184	4.8	4.6	3.9	3.7	3.3	-	-	-
50 × 150	140	-	3.7	3.5	3.7	3.2	-	-	-
50 × 100	89	-	-	2.5	-	2.3	2.6	2.3	1.9
	64	-	-	-	-	-	-	1.7	-
	38	-	-	-	-	-	-	1.1	1.0

TABLE A9.4D 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 in kg/m^3	Thermal Conductivity in 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

Exception to A9.4.3: R-values for *building materials* or thermal conductivities determined from testing in accordance with A9.3.

A9.4.4 Building Material Heat Capacities: The *heat capacity* 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.

(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 U.S 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.

Table B-2 shows the climate zone number 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 number 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 in cm and

T = annual mean temperature in °C.

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

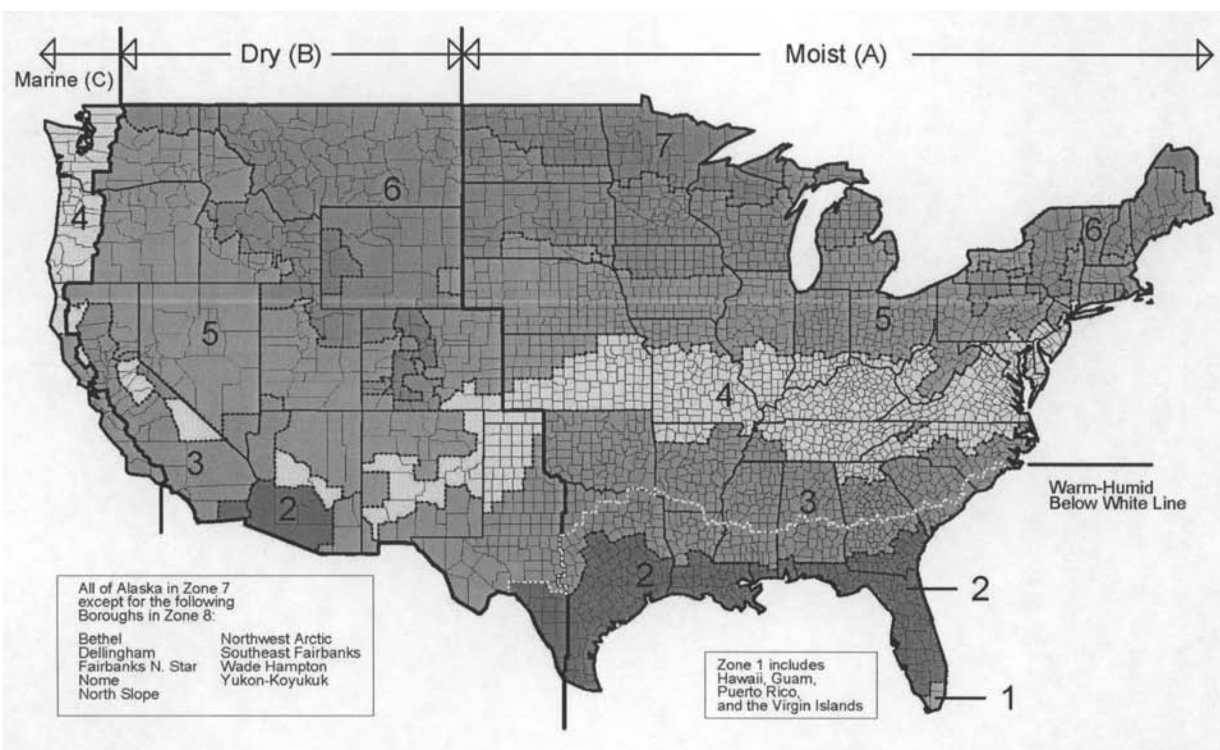


Figure B-1 Climate zones for United States locations.

TABLE B-1 U.S. Climate Zones

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

TABLE B-1 U.S. Climate Zones

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 4 Except	
Cheyenne	5A
Cloud	5A

TABLE B-1 U.S. Climate Zones

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 U.S. Climate Zones

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 U.S. Climate Zones

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 U.S. Climate Zones

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 U.S. Climate Zones

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 Canadian Climatic Zones

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

TABLE 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
(India cont.)	
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
(Mexico cont.)	
Veracruz (Veracruz)	4
Merida (Yucatan)	1
Netherlands	
Amsterdam/Schiphol	5
New Zealand	
Auckland Airport	
Christchurch	
Wellington	
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
RostovNaDonu	5
Vladivostok	6
Volgograd	6
Saudi Arabia	
Dhahran	1
Riyadh	1
Senegal	
Dakar/Yoff	1

TABLE B-3 *(continued)* International Climate Zones

Country / City (Province or Region)	Zone	Country / City (Province or Region)	Zone	Country / City (Province or Region)	Zone	Country / City (Province or Region)	Zone
Singapore		Switzerland		Tunisia		Uruguay	
Singapore/Changi	1	Zurich	5	Tunis/El Aouina	3	Montevideo/Carrasco	3
South Africa		Syria		Turkey		Venezuela	
Cape Town/D F Malan	4	Damascus Airport	3	Adana	3	Caracas/Maiquetia	1
Johannesburg	4	Taiwan		Ankara/Etimesgut	4	Vietnam	
Pretoria	3	Tainan	1	Istanbul/Yesilkoy	4	Hanoi/Gialam	1
Spain		Taipei	2	United Kingdom		Saigon (Ho Chi Minh)	1
Barcelona	4	Tanzania		Birmingham (England)	5		
Madrid	4	Dar es Salaam	1	Edinburgh (Scotland)	5		
Valencia/Manises	3	Thailand		Glasgow Apt (Scotland)	5		
Sweden		Bangkok	1	London/Heathrow (England)	4		
Stockholm/Arlanda	6						

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*.

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

C1.3 For Fenestration: The classification, area, *U-factor, solar heat gain coefficient* (SHGC), visible light transmittance (VLT), overhang *projection factor* for *vertical fenestration,* and width, depth, and height for *skylight wells*. (See Figure C1.3 for definition of width, depth, and height for *skylight wells*.) Each *fenestration* element is associated with a surface (defined in C1.2) and has the orientation of that surface.

C1.4 For Opaque Doors: The classification, area, *U-factor, heat capacity,* and insulation position. Each *opaque door* is associated with a surface (defined in 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.* 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. Each slab-on-grade floor is associated with a space-conditioning category as defined in C1.1.

C2 Output Requirements

Output reports shall contain the following information.

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

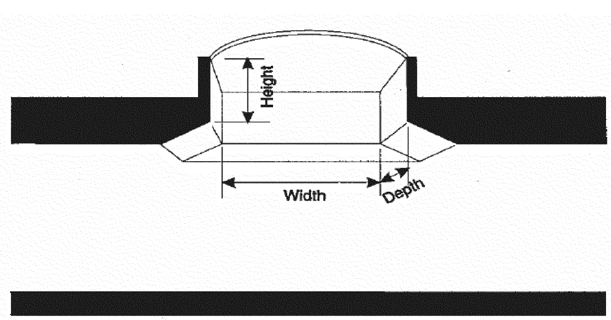


Figure C1.3 Skylight well dimensions.

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 heat capacity* 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 *solar heat gain coefficient (SHGC)* for *fenestration* in the base envelope design shall be equal to the criteria from Tables 5.5-1 through 5.5-7 for Table 5.5-8 shall be equal to 0.64 for *north-oriented* and 0.46 for all other *vertical fenestration,* 0.77 for plastic *skylights* on a curb, and 0.72 for all other *skylights* with a curb and without. The visible light transmittance (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 *semi-heated*.

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 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 lighting power density 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 500 lux for *nonresidential conditioned spaces* and *residential conditioned spaces* and 300 lux 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* is defined in the following equation.

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

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 *envelope performance factor (EPF)* of a building shall be calculated using Equation C-2.

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

where

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 C.5	$m^2 \times 10.8$
C-factor	C-factor for below-grade walls	$W/m^2K \times 0.176$
CDD50	Cooling degree-days	Base 10°C days × 1.8
CDD65	Cooling degree-days	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 C.5.4	lux × 0.929
DR	Daily range (average outdoor max-min in hottest month)	°C × 1.8
EPD	Miscellaneous equipment power density from 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	Heating degree-days	Base 10°C days × 1.8
HDD65	Heating degree-days	Base 18°C days × 1.8
Length	Length of slab-on-grade floor perimeter	m × 3.28
LPD	Lighting power density from 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	$W/m^2K \times 0.176$
VS	Annual average daily incident solar radiation on vertical surface	$kJ/m^2 \cdot day \times 0.088$

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

FAF = floor area factor for the entire building

$\Sigma HVAC_{surface}$ = 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 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

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

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

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 (LPDadj). The adjusted lighting power for each zone shall be calculated using Equation C-9.

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

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 LPDadj.

$$Kd_{zone} = \left(\Phi 1 + \left(\frac{\Phi 2 \times DI \times VA}{Area_{fen}}\right)\right) \times (1 - e^{((\Phi 3 + \Phi 4 \times DI) \times VA) / Area_{surface}}) \quad \text{(C-10)}$$

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 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.

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

where

CMC = cooling delta load factor

$Area_{mw}$ = net *opaque area* of this *mass* wall

A_c = CDH80/10000 + 2

B = DR/10 + 1

TABLE C6.6 Coefficients for Calculating K_d

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

HC = wall heat capacity

DR = average daily temperature range for warmest month

B = DR/10 +1

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.

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

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 *U-factor* of *mass wall* is greater than 2.3 W/(m²·K), then the *U-factor* shall be set to 2.3 W/(m²·K). If the *U-factor* of the *mass wall* is less than 0.28 W/(m²·K), then the *U-Factor* shall be set to 0.28 W/(m²·K). If the wall heat capacity (HC) of the *mass wall* is greater than 409 kJ/(m²·K), then HC = 409 kJ/(m²·K) shall be used.

TABLE C6.7A Cooling Delta Load Coefficients

Variable	Insulation Position 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

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 subsection C6.10 and they shall not be included in calculations in subsection C6.8. Zones shall be constructed according to 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

Variable	Insulation Position 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 the zone G shall be calculated using Equation C-13.

$$G = EPD + LPDadj_{zone} \qquad \text{(C-13)}$$

where

$LPDadj_{zone}$ = 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.

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

where

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

$$CLUO = Area_{grosswall} \times UO \times [CUO1 \times EA_C \times VS \times CDD50 + CUO2 \times G + CUO3 \times G^2 \times EA_C{}^2 \times VS \times CDD50 + CUO4 \times G^2 \times EA_C{}^2 \times VS \times CDD65]$$

$$CLXUO = Area_{grosswall} / UO \times [CXUO1 \times EA_C \times VS \times CDD50 + CXUO2 \times EA_C \times (VS \times CDD50)^2 + CXUO3 \times G \times CDD50 + CXUO4 \times G^2 \times EA_C{}^2 \times VS \times CDD50 + CXUO5 \times G^2 \times CDD65]$$

$$CLM = Area_{opaque} \times SCMC \times [CM1 + CM2 \times EA_C \times VS \times CDD50 + CM3 \times EA_C \times VS \times CDD65 + CM4 \times EA_C^2 \times VS \times CDD50 + CM5 \times G^2 \times CDD65 + CM6 \times G \times CDD50 + CM7 \times G \times CDD65 + CM8 \times G \times EA_C \times VS \times CDD50]$$

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

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

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

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

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

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.

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

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.

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

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.

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

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

where

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

SHGC = the *solar heat gain coefficien*t 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.

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

TABLE C6.8.2 Cooling Coefficients for the Exterior Wall Equation

	Orientation of Surface			
Variable	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

	Orientation of Surface			
Variable	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

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

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

Depth (m)	$R_{soil}(m^2 k/W)$
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	NA	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	NA	0	NA	NA	0	NA	0	0	7.56E-05
Skylights	NA	0	NA	NA	0	NA	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 U.S, Canadian, and international locations. (See 5.1.4 for additional information regarding the selection of climatic data.) Table numbers corresponding to the envelope criteria tables in Normative Appendix B are also included. The following definition applies: N.A. = Not Available.

TABLE D-1
U.S. and U.S. Territory Climatic Data

State / City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
Alabama (AL)											
Alexander City	32.95	N	85.93	W	195	1,617	2,834	N.A.	N.A.	N.A.	N.A.
Anniston FAA AP	33.58	N	85.85	W	186	1,586	2,898	-7	34	24	N.A.
Auburn Agronomy Farm	32.60	N	85.50	W	198	1,451	3,016	N.A.	N.A.	N.A.	N.A.
Birmingham FAA AP	33.57	N	86.75	W	190	1,621	2,892	-8	33	24	760
Dothan	31.32	N	85.45	W	122	946	3,699	-2	34	24	N.A.
Gadsden Steam Plant	34.03	N	86.00	W	172	1,843	2,669	N.A.	N.A.	N.A.	N.A.
Huntsville WSO AP	34.65	N	86.77	W	190	1,846	2,697	-9	33	23	N.A.
Mobile WSO AP	30.68	N	88.25	W	64	946	3,756	-3	33	24	774
Montgomery WSO AP	32.30	N	86.40	W	67	1,236	3,328	-4	34	24	734
Selma	32.42	N	87.00	W	44	1,249	3,378	N.A.	N.A.	N.A.	N.A.
Talladega	33.43	N	86.08	W	169	1,550	2,832	N.A.	N.A.	N.A.	N.A.
Tuscaloosa FAA AP	33.23	N	87.62	W	51	1,478	3,124	-7	34	25	N.A.
Alaska (AK)											
Anchorage WSCMO AP	61.17	N	150.02	W	34	5,872	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	7,744	578	-44	25	15	682
Juneau AP	58.37	N	134.58	W	3	4,943	311	-16	21	14	540
Kodiak WSO AP	57.75	N	152.50	W	33	4,898	251	-14	18	13	384
Nome WSO AP	64.50	N	165.43	W	3	7,849	152	-35	18	13	210
Arizona (AZ)											
Douglas FAA AP	31.47	N	109.60	W	1,537	2,659	N.A.	N.A.	N.A.	N.A.	
Flagstaff WSO AP	35.13	N	111.67	W	2,135	3,962	923	-17	28	13	N.A.
Kingman	35.20	N	114.02	W	1,078	1,784	2,800	-6	36	17	N.A.
Nogales	31.42	N	110.95	W	1,085	1,627	2,530	N.A.	N.A.	N.A.	N.A.
Phoenix WSFO AP	33.43	N	112.02	W	338	750	4,681	1	42	21	746

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Arizona cont.)											
Prescott	34.57	N	112.43	W	1,586	2,775	1,597	-9	33	16	725
Tucson WSO AP	32.13	N	110.93	W	787	932	3,845	-1	39	18	716
Winslow WSO AP	35.02	N	110.73	W	1,490	2,653	2,045	-12	34	16	634
Yuma WSO AP	32.67	N	114.60	W	62	515	4,943	4	43	22	697
Arkansas (AR)											
Blytheville AFB	35.97	N	89.95	W	78	2,031	2,852	-11	35	25	N.A.
Camden	33.60	N	92.82	W	35	1,641	2,949	N.A.	N.A.	N.A.	N.A.
Fayetteville	36.00	N	94.17	W	381	2,244	2,473	-14	34	24	N.A.
Ft Smith WSO AP	35.33	N	94.37	W	136	1,932	2,821	-11	36	24	547
Hot Springs	34.52	N	93.05	W	207	1,767	2,913	N.A.	N.A.	N.A.	N.A.
Jonesboro	35.88	N	90.70	W	118	1,947	2,843	N.A.	N.A.	N.A.	N.A.
Little Rock FAA AP	34.73	N	92.23	W	78	1,753	2,944	-9	35	25	626
Pine Bluff	34.22	N	92.02	W	65	1,676	3,037	N.A.	N.A.	N.A.	N.A.
Texarkana FAA AP	33.45	N	94.00	W	110	1,275	3,418	-7	35	25	N.A.
California (CA)											
Bakersfield WSO AP	35.42	N	119.05	W	150	1,212	3,361	0	38	21	848
Blythe FAA Airport	33.62	N	114.72	W	118	636	4,883	N.A.	N.A.	N.A.	N.A.
Burbank Hollywood	34.20	N	118.37	W	236	669	3,250	4	35	21	N.A.
Chico University Farm	39.70	N	121.82	W	56	1,641	2,474	N.A.	N.A.	N.A.	N.A.
Crescent City	41.77	N	124.20	W	12	2,443	904	N.A.	N.A.	N.A.	N.A.
El Centro	32.77	N	115.57	W	-9	642	4,518	N.A.	N.A.	N.A.	N.A.
Eureka WSO City	40.80	N	124.17	W	18	2,498	849	N.A.	N.A.	N.A.	N.A.
Fairfield/Travis AFB	38.27	N	121.93	W	19	1,420	2,346	-1	34	19	N.A.
Fresno WSO AP	36.77	N	119.72	W	99	1,420	2,972	-1	38	21	785
Laguna Beach	33.55	N	117.78	W	10	1,198	2,156	N.A.	N.A.	N.A.	N.A.
Livermore	37.67	N	121.77	W	146	1,616	2,117	N.A.	N.A.	N.A.	N.A.
Lompoc	34.65	N	120.45	W	28	1,473	1,800	N.A.	N.A.	N.A.	N.A.
Long Beach WSO AP	33.82	N	118.15	W	10	794	2,934	4	31	19	1502
Los Angeles WSO AP	33.93	N	118.38	W	30	810	2,654	6	27	18	1849
Merced/Castle AFB	37.37	N	120.57	W	57	1,493	2,608	-1	36	21	N.A.
Monterey	36.60	N	121.90	W	117	1,736	1,430	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(California cont.)											
Napa State Hospital	38.28	N	122.27	W	18	1,580	1,924	N.A.	N.A.	N.A.	N.A.
Needles FAA Airport	34.77	N	114.62	W	278	727	4,803	N.A.	N.A.	N.A.	N.A.
Oakland/Intl	37.73	N	122.20	W	2	1,469	1,737	N.A.	N.A.	N.A.	1905
Oceanside Marina	33.22	N	117.40	W	3	1,117	2,261	N.A.	N.A.	N.A.	N.A.
Ontario/Intl	34.05	N	117.62	W	293	827	3,235	2	37	21	N.A.
Oxnard	34.20	N	119.18	W	14	1,107	2,211	4	26	18	N.A.
Palm Springs	33.83	N	116.50	W	129	547	4,753	N.A.	N.A.	N.A.	N.A.
Palmdale	34.58	N	118.10	W	791	1,638	2,702	N.A.	N.A.	N.A.	N.A.
Pasadena	34.15	N	118.15	W	263	807	3,042	N.A.	N.A.	N.A.	N.A.
Petaluma Fire Stn 3	38.23	N	122.63	W	8	1,694	1,771	N.A.	N.A.	N.A.	N.A.
Pomona Cal Poly	34.07	N	117.82	W	225	952	2,858	N.A.	N.A.	N.A.	N.A.
Redding WSO	40.50	N	122.30	W	153	1,586	2,758	N.A.	N.A.	N.A.	N.A.
Redlands	34.05	N	117.18	W	401	1,042	3,019	N.A.	N.A.	N.A.	N.A.
Richmond	37.93	N	122.35	W	16	1,430	1,825	N.A.	N.A.	N.A.	N.A.
Riverside/March AFB	33.90	N	117.25	W	468	1,034	2,942	1	37	20	N.A.
Sacramento FAA AP	38.52	N	121.50	W	5	1,527	2,486	-1	36	20	990
Salinas FAA AP	36.67	N	121.60	W	21	1,647	1,639	1	26	17	N.A.
San Bernardino/Norton	34.10	N	117.23	W	352	1,012	3,028	1	38	21	N.A.
San Diego WSO AP	32.73	N	117.17	W	3	698	2,902	7	27	19	1911
San Francisco WSO AP	37.62	N	122.38	W	2	1,676	1,602	3	26	17	1796
San Jose	37.35	N	121.90	W	20	1,326	2,186	2	32	19	N.A.
San Luis Obispo Poly	35.30	N	120.67	W	96	1,388	1,940	N.A.	N.A.	N.A.	N.A.
Santa Ana Fire Station	33.75	N	117.87	W	41	688	3,017	N.A.	N.A.	N.A.	N.A.
Santa Barbara FAA AP	34.43	N	119.83	W	2	1,354	1,916	1	27	18	N.A.
Santa Cruz	36.98	N	122.02	W	39	1,649	1,618	N.A.	N.A.	N.A.	N.A.
Santa Maria WSO AP	34.90	N	120.45	W	77	1,658	1,621	0	28	17	2016
Santa Monica Pier	34.00	N	118.50	W	4	1,011	2,303	N.A.	N.A.	N.A.	N.A.
Santa Paula	34.32	N	119.15	W	72	1,133	2,286	N.A.	N.A.	N.A.	N.A.
Santa Rosa	38.45	N	122.70	W	50	1,602	1,907	N.A.	N.A.	N.A.	N.A.
Stockton WSO AP	37.90	N	121.25	W	6	1,504	2,642	-1	36	20	N.A.
Ukiah	39.15	N	123.20	W	189	1,641	2,149	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(California cont.)											
Visalia	36.33	N	119.30	W	99	1,395	2,881	N.A.	N.A.	N.A.	N.A.
Yreka	41.72	N	122.63	W	800	2,992	1,451	N.A.	N.A.	N.A.	N.A.
Colorado (CO)											
Alamosa WSO AP	37.45	N	105.87	W	2,296	4,861	763	-27	28	13	N.A.
Boulder	40.03	N	105.28	W	1,652	3,086	1,567	N.A.	N.A.	N.A.	N.A.
Colorado Sprgs WSO AP	38.82	N	104.72	W	1,856	3,564	1,284	-19	31	14	725
Denver WSFO AP	39.77	N	104.87	W	1,611	3,344	1,518	-19	32	15	739
Durango	37.28	N	107.88	W	2,011	3,839	1,079	N.A.	N.A.	N.A.	N.A.
Ft Collins	40.58	N	105.08	W	1,525	3,538	1,339	N.A.	N.A.	N.A.	N.A.
Grand Junction WSO AP	39.10	N	108.55	W	1,477	3,082	2,018	-17	34	16	518
Greeley UNC	40.42	N	104.70	W	1,437	3,503	1,499	N.A.	N.A.	N.A.	N.A.
La Junta FAA AP	38.05	N	103.52	W	1,277	2,925	2,108	N.A.	N.A.	N.A.	N.A.
Pueblo WSO AP	38.28	N	104.52	W	1,414	3,007	1,866	-18	34	17	720
Sterling	40.62	N	103.22	W	1,200	3,634	1,561	N.A.	N.A.	N.A.	N.A.
Trinidad FAA AP	37.25	N	104.33	W	1,751	3,046	1,653	-19	32	16	N.A.
Connecticut (CT)											
Bridgeport WSO AP	41.17	N	73.13	W	3	3,076	1,665	-13	29	22	N.A.
Hartford-Brainard Fld	41.73	N	72.65	W	4	3,419	1,538	-17	31	22	598
Norwalk Gas Plant	41.12	N	73.42	W	11	3,258	1,538	N.A.	N.A.	N.A.	N.A.
Norwich Pub Util Plt	41.53	N	72.07	W	6	3,261	1,493	N.A.	N.A.	N.A.	N.A.
Delaware (DE)											
Dover	39.15	N	75.52	W	9	2,409	2,163	-10	32	24	N.A.
Wilmington WSO AP	39.67	N	75.60	W	724	2,743	1,976	-12	32	23	617
Florida (FL)											
Belle Glade Exp Stn	26.67	N	80.63	W	4	251	4,603	N.A.	N.A.	N.A.	N.A.
Daytona Beach WSO AP	29.18	N	81.05	W	8	505	4,204	1	32	25	641
Ft Lauderdale	26.07	N	80.15	W	3	95	5,408	8	32	26	N.A.
Ft Myers FAA AP	26.58	N	81.87	W	4	232	4,958	6	34	25	N.A.
Ft Pierce	27.47	N	80.35	W	7	272	4,693	N.A.	N.A.	N.A.	N.A.
Gainesville Mun AP	29.68	N	82.27	W	42	704	3,894	-1	33	25	N.A.
Jacksonville WSO AP	30.50	N	81.70	W	7	797	3,804	-2	34	25	674

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Florida cont.)											
Key West WSO AP	24.55	N	81.75	W	1	56	5,652	13	32	26	N.A.
Lakeland	28.02	N	81.92	W	44	327	4,707	N.A.	N.A.	N.A.	N.A.
Miami WSCMO AP	25.80	N	80.30	W	3	111	5,263	8	32	25	259
Ocala	29.20	N	82.08	W	22	517	4,276	N.A.	N.A.	N.A.	N.A.
Orlando WSO Mc Coy	28.43	N	81.33	W	27	381	4,571	3	34	24	571
Panama City/Tyndall	30.07	N	85.58	W	5	675	3,902	1	32	26	N.A.
Pensacola FAA AP	30.47	N	87.20	W	34	898	3,787	-2	33	26	N.A.
St Augustine WFOY	29.90	N	81.32	W	2	578	4,034	N.A.	N.A.	N.A.	N.A.
St Petersburg	27.77	N	82.63	W	2	335	4,743	6	34	26	N.A.
Tallahassee WSO AP	30.38	N	84.37	W	16	947	3,688	-4	34	24	747
Tampa WSCMO AP	27.97	N	82.53	W	5	403	4,577	2	33	25	592
West Palm Beach WSO AP	26.68	N	80.12	W	5	179	5,027	6	32	26	308
Georgia (GA)											
Albany	31.53	N	84.13	W	54	1,225	3,344	-3	35	24	N.A.
Americus	32.05	N	84.25	W	149	1,350	3,130	N.A.	N.A.	N.A.	N.A.
Athens WSO AP	33.95	N	83.32	W	244	1,607	2,822	-7	33	24	N.A.
Atlanta WSO AP	33.65	N	84.43	W	307	1,662	2,799	-8	33	23	749
Augusta WSO AP	33.37	N	81.97	W	45	1,425	3,066	-6	34	24	774
Brunswick	31.17	N	81.50	W	3	877	3,738	-1	33	26	N.A.
Columbus WSO AP	32.52	N	84.95	W	136	1,256	3,362	-5	34	24	N.A.
Dalton	34.75	N	84.95	W	213	1,973	2,526	N.A.	N.A.	N.A.	N.A.
Dublin	32.50	N	82.90	W	65	1,376	3,147	N.A.	N.A.	N.A.	N.A.
Gainesville	34.30	N	83.85	W	356	1,944	2,394	N.A.	N.A.	N.A.	N.A.
La Grange	33.05	N	85.02	W	217	1,482	2,898	N.A.	N.A.	N.A.	N.A.
Macon WSO AP	32.70	N	83.65	W	107	1,297	3,237	-5	34	24	787
Savannah WSO AP	32.13	N	81.20	W	14	1,026	3,549	-3	34	24	N.A.
Valdosta/Moody AFB	30.97	N	83.20	W	71	862	4,009	-1	34	25	N.A.
Waycross	31.25	N	82.32	W	44	1,125	3,429	-2	34	24	N.A.
Hawaii (HI)											
Hilo (Hawaii)	19.72	N	155.07	W	10	0	4,866	16	29	23	153
Honolulu WSFO AP (Oahu)	21.33	N	157.92	W	2	0	5,527	16	31	23	69
Kaneohe Mauka (Oahu)	21.42	N	157.82	W	0	57	4,975	19	29	23	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. 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
Idaho (ID)											
Boise WSFO AP	43.57	N	116.22	W	865	3,256	1,559	-17	34	17	647
Burley FAA AP	42.53	N	113.77	W	1,267	3,747	1,208	-21	32	17	N.A.
Coeur D'Alene R S	47.68	N	116.75	W	657	3,466	1,231	N.A.	N.A.	N.A.	N.A.
Idaho Falls FAA AP	43.52	N	112.07	W	1,441	4,479	1,029	-24	32	16	N.A.
Lewiston WSO AP	46.38	N	117.02	W	437	2,928	1,647	-14	34	18	748
Moscow-Univ of Idaho	46.73	N	116.97	W	810	3,768	994	N.A.	N.A.	N.A.	N.A.
Mountain Home	43.13	N	115.70	W	972	3,431	1,514	-18	36	17	N.A.
Pocatello WSO AP	42.92	N	112.60	W	1,357	3,989	1,190	-22	32	16	546
Twin Falls WSO	42.55	N	114.35	W	1,207	3,761	1,108	N.A.	N.A.	N.A.	N.A.
Illinois (IL)											
Aurora	41.75	N	88.35	W	196	3,722	1,600	N.A.	N.A.	N.A.	N.A.
Belleville/Scott AFB	38.55	N	89.85	W	138	2,710	2,304	-16	34	25	N.A.
Carbondale Sewage Plt	37.73	N	89.17	W	118	2,703	2,186	N.A.	N.A.	N.A.	N.A.
Champaign	40.03	N	88.28	W	230	3,160	2,054	N.A.	N.A.	N.A.	N.A.
Chicago Midway AP	41.73	N	87.77	W	188	3,431	1,806	N.A.	N.A.	N.A.	N.A.
Chicago O'Hare WSO AP	41.98	N	87.90	W	205	3,631	1,634	-21	31	23	613
Chicago University	41.78	N	87.60	W	181	3,196	1,884	N.A.	N.A.	N.A.	N.A.
Danville	40.13	N	87.65	W	170	3,117	1,928	-20	32	25	N.A.
Decatur	39.83	N	89.02	W	188	3,068	2,029	-19	33	24	N.A.
Dixon	41.83	N	89.52	W	213	3,818	1,647	N.A.	N.A.	N.A.	N.A.
Freeport Waste Wtr Plt	42.30	N	89.60	W	228	3,983	1,522	N.A.	N.A.	N.A.	N.A.
Galesburg	40.95	N	90.38	W	235	3,508	1,805	N.A.	N.A.	N.A.	N.A.
Joliet Brandon Rd Dam	41.50	N	88.10	W	165	3,591	1,681	N.A.	N.A.	N.A.	N.A.
Moline WSO AP	41.45	N	90.50	W	177	3,597	1,782	-22	32	23	640
Mt Vernon	38.35	N	88.87	W	149	2,883	2,121	N.A.	N.A.	N.A.	N.A.
Peoria WSO AP	40.67	N	89.68	W	198	3,416	1,855	-21	32	23	N.A.
Quincy FAA AP	39.93	N	91.20	W	232	3,202	1,986	-20	33	24	N.A.
Rantoul	40.32	N	88.17	W	225	3,435	1,827	N.A.	N.A.	N.A.	N.A.
Rockford WSO AP	42.20	N	89.10	W	220	3,872	1,584	-23	31	23	N.A.
Springfield WSO AP	39.85	N	89.68	W	181	3,160	2,019	-20	33	24	600
Waukegan	42.35	N	87.88	W	213	3,964	1,397	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
Indiana (IN)											
Anderson Sewage Plant	40.10	N	85.72	W	258	3,287	1,717	N.A.	N.A.	N.A.	N.A.
Bloomington Indiana U	39.17	N	86.52	W	251	2,949	1,992	N.A.	N.A.	N.A.	N.A.
Columbus	39.20	N	85.92	W	189	3,076	1,863	N.A.	N.A.	N.A.	N.A.
Evansville WSO AP	38.05	N	87.53	W	115	2,616	2,263	-16	33	24	611
Ft Wayne WSO AP	41.00	N	85.20	W	242	3,485	1,709	-20	31	23	601
Goshen College	41.57	N	85.83	W	245	3,490	1,634	N.A.	N.A.	N.A.	N.A.
Hobart	41.53	N	87.25	W	182	3,357	1,760	N.A.	N.A.	N.A.	N.A.
Indianapolis WSFO	39.73	N	86.27	W	241	3,119	1,918	-19	31	23	N.A.
Kokomo	40.42	N	86.05	W	260	3,572	1,654	N.A.	N.A.	N.A.	N.A.
Lafayette	40.35	N	86.87	W	182	3,460	1,705	-21	32	24	N.A.
Marion	40.57	N	85.67	W	240	3,478	1,664	N.A.	N.A.	N.A.	N.A.
Muncie Ball State Univ	40.22	N	85.42	W	286	3,348	1,776	N.A.	N.A.	N.A.	N.A.
Peru/Grissom AFB	40.65	N	86.15	W	248	3,282	1,910	-19	32	24	N.A.
Richmond Wtr Wks	39.88	N	84.88	W	309	3,313	1,669	N.A.	N.A.	N.A.	N.A.
Shelbyville Sewage Plt	39.52	N	85.78	W	228	3,213	1,828	N.A.	N.A.	N.A.	N.A.
South Bend WSO AP	41.70	N	86.32	W	235	3,517	1,622	-19	31	22	635
Terre Haute	39.35	N	87.42	W	169	3,101	1,939	-19	32	24	N.A.
Valparaiso Waterworks	41.52	N	87.03	W	243	3,482	1,634	N.A.	N.A.	N.A.	N.A.
Iowa (IA)											
Ames	42.03	N	93.80	W	334	3,764	1,711	N.A.	N.A.	N.A.	N.A.
Burlington	40.78	N	91.12	W	182	3,302	2,000	-20	33	24	649
Cedar Rapids FAA AP	41.88	N	91.70	W	263	3,847	1,668	-24	32	23	N.A.
Clinton	41.80	N	90.27	W	178	3,513	1,828	N.A.	N.A.	N.A.	N.A.
Des Moines WSFO AP	41.53	N	93.65	W	285	3,609	1,873	-23	32	23	667
Dubuque WSO AP	42.40	N	90.70	W	1,065	4,071	1,484	N.A.	N.A.	N.A.	N.A.
Ft Dodge	42.50	N	94.20	W	339	4,034	1,612	-25	31	23	N.A.
Iowa City	41.65	N	91.53	W	195	3,459	1,908	N.A.	N.A.	N.A.	N.A.
Keokuk Lock and Dam	40.40	N	91.37	W	160	3,316	1,926	N.A.	N.A.	N.A.	N.A.
Marshalltown	42.07	N	92.93	W	265	3,983	1,563	N.A.	N.A.	N.A.	N.A.
Mason City FAA AP	43.17	N	93.33	W	363	4,354	1,474	-26	31	23	610

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Iowa cont.)											
Newton	41.70	N	93.05	W	285	3,768	1,739	N.A.	N.A.	N.A.	N.A.
Ottumwa Airport	41.10	N	92.45	W	256	3,483	1,897	-21	33	24	N.A.
Sioux City WSO AP	42.40	N	96.38	W	336	3,829	1,749	-24	32	23	602
Waterloo WSO AP	42.55	N	92.40	W	264	4,114	1,563	-26	31	23	N.A.
Kansas (KS)											
Atchison	39.57	N	95.12	W	288	2,880	2,189	N.A.	N.A.	N.A.	N.A.
Chanute FAA Airport	37.67	N	95.48	W	298	2,583	2,348	N.A.	N.A.	N.A.	N.A.
Dodge City WSO AP	37.77	N	99.97	W	786	2,778	2,272	-18	36	21	637
El Dorado	37.82	N	96.83	W	408	2,548	2,398	N.A.	N.A.	N.A.	N.A.
Garden City FAA AP	37.93	N	100.72	W	878	2,898	2,187	-19	36	21	N.A.
Goodland WSO AP	39.37	N	101.70	W	1,112	3,319	1,677	-19	34	19	625
Great Bend	38.35	N	98.77	W	563	2,599	2,458	N.A.	N.A.	N.A.	N.A.
Hutchinson	37.93	N	98.03	W	478	2,835	2,281	N.A.	N.A.	N.A.	N.A.
Liberal	37.05	N	100.92	W	863	2,614	2,325	N.A.	N.A.	N.A.	N.A.
Manhattan	39.20	N	96.58	W	324	2,802	2,308	N.A.	N.A.	N.A.	N.A.
Parsons	37.37	N	95.28	W	277	2,559	2,411	N.A.	N.A.	N.A.	N.A.
Russell FAA AP	38.87	N	98.82	W	568	2,966	2,188	-20	36	22	N.A.
Salina FAA AP	38.80	N	97.63	W	383	2,834	2,315	-19	36	23	N.A.
Topeka WSFO AP	39.07	N	95.63	W	267	2,925	2,156	-19	34	24	608
Wichita WSO AP	37.65	N	97.43	W	402	2,662	2,417	-17	36	23	N.A.
Kentucky (KY)											
Ashland	38.45	N	82.62	W	169	2,903	1,822	N.A.	N.A.	N.A.	N.A.
Bowling Green FAA AP	36.97	N	86.42	W	166	2,404	2,296	-14	33	24	N.A.
Covington WSO AP	39.07	N	84.67	W	264	2,916	1,938	-17	32	23	661
Hopkinsville/Campbell	36.67	N	87.50	W	174	2,182	2,585	N.A.	N.A.	N.A.	N.A.
Lexington WSO AP	38.03	N	84.60	W	294	2,657	2,086	-16	32	23	618
Louisville WSFO AP	38.18	N	85.73	W	145	2,508	2,222	-14	32	24	636
Madisonville	37.35	N	87.52	W	134	2,315	2,383	N.A.	N.A.	N.A.	N.A.
Owensboro	37.77	N	87.15	W	123	2,408	2,346	N.A.	N.A.	N.A.	N.A.
Paducah WSO	37.07	N	88.77	W	124	2,377	2,398	-14	34	24	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
Louisiana (LA)											
Alexandria	31.32	N	92.47	W	26	1,113	3,559	-3	34	26	N.A.
Baton Rouge WSO AP	30.53	N	91.13	W	19	927	3,803	-3	33	25	677
Bogalusa	30.78	N	89.87	W	30	1,062	3,587	N.A.	N.A.	N.A.	N.A.
Houma	29.58	N	90.73	W	4	794	3,874	N.A.	N.A.	N.A.	N.A.
Lafayette FAA AP	30.20	N	91.98	W	11	882	3,821	-2	34	26	N.A.
Lake Charels WSO AP	30.12	N	93.22	W	2	898	3,785	-2	33	26	668
Minden	32.58	N	93.28	W	56	1,407	3,235	N.A.	N.A.	N.A.	N.A.
Monroe FAA AP	32.52	N	92.05	W	23	1,337	3,355	-6	34	26	N.A.
Natchitoches	31.77	N	93.08	W	39	1,196	3,485	N.A.	N.A.	N.A.	N.A.
New Orleans WSCMO AP	29.98	N	90.25	W	1	841	3,839	-1	33	26	789
Shreveport WSO AP	32.47	N	93.82	W	77	1,258	3,426	-6	35	25	697
Maine (ME)											
Augusta FAA AP	44.32	N	69.80	W	106	4,194	1,163	-19	29	21	N.A.
Bangor FAA AP	44.80	N	68.82	W	49	4,406	1,064	-22	29	21	669
Caribou WSO AP	46.87	N	68.02	W	190	5,362	817	-26	28	19	692
Lewiston	44.10	N	70.22	W	54	4,024	1,256	N.A.	N.A.	N.A.	N.A.
Millinocket	45.65	N	68.70	W	109	4,946	949	N.A.	N.A.	N.A.	N.A.
Portland WSMO AP	43.65	N	70.32	W	17	4,099	1,079	-19	28	21	665
Waterville Pmp Stn	44.55	N	69.65	W	27	4,101	1,211	N.A.	N.A.	N.A.	N.A.
Maryland (MD)											
Baltimore WSO AP	39.18	N	76.67	W	59	2,615	2,061	-12	33	23	N.A.
Cumberland	39.63	N	78.75	W	222	2,798	1,907	N.A.	N.A.	N.A.	N.A.
Hagerstown	39.65	N	77.73	W	201	2,941	1,856	N.A.	N.A.	N.A.	N.A.
Salisbury	38.37	N	75.58	W	3	2,237	2,223	-11	32	24	N.A.
Massachusetts (MA)											
Boston WSO AP	42.37	N	71.03	W	6	3,134	1,609	-14	31	22	713
Clinton	42.40	N	71.68	W	121	3,721	1,365	N.A.	N.A.	N.A.	N.A.
Framingham	42.28	N	71.42	W	51	3,479	1,497	N.A.	N.A.	N.A.	N.A.
Lawrence	42.70	N	71.17	W	17	3,512	1,471	N.A.	N.A.	N.A.	N.A.
Lowell	42.65	N	71.37	W	33	3,522	1,508	N.A.	N.A.	N.A.	N.A.
New Bedford	41.63	N	70.93	W	36	3,014	1,652	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Massachuesetts cont.)											
Springfield	42.10	N	72.58	W	57	3,197	1,687	N.A.	N.A.	N.A.	N.A.
Taunton	41.90	N	71.07	W	6	3,526	1,367	N.A.	N.A.	N.A.	N.A.
Worcester WSO AP	42.27	N	71.87	W	300	3,877	1,224	-18	28	21	N.A.
Michigan (MI)											
Adrian	41.92	N	84.02	W	231	3,743	1,437	N.A.	N.A.	N.A.	N.A.
Alpena WSO AP	45.07	N	83.57	W	210	4,602	988	-22	29	21	695
Battle Creek/Kellogg	42.30	N	85.23	W	287	3,564	1,888	N.A.	N.A.	N.A.	N.A.
Benton Harbor AP	42.13	N	86.43	W	197	3,502	1,572	N.A.	N.A.	N.A.	N.A.
Detroit City Airport	42.42	N	83.02	W	190	3,426	1,692	-18	31	22	N.A.
Escanaba	45.75	N	87.03	W	182	4,774	924	N.A.	N.A.	N.A.	N.A.
Flint WSO AP	42.97	N	83.75	W	233	3,877	1,362	-19	30	22	634
Grand Rapids WSO AP	42.88	N	85.52	W	215	3,874	1,409	-18	30	22	622
Holland	42.80	N	86.12	W	185	3,748	1,409	N.A.	N.A.	N.A.	N.A.
Jackson FAA AP	42.27	N	84.45	W	306	3,773	1,504	-19	30	23	N.A.
Kalamazoo State Hosp	42.28	N	85.60	W	288	3,461	1,675	N.A.	N.A.	N.A.	N.A.
Lansing WSO AP	42.77	N	84.60	W	256	3,945	1,361	-19	30	22	N.A.
Marquette	46.55	N	87.38	W	202	4,642	961	-25	28	19	N.A.
Mt Pleasant University	43.58	N	84.77	W	242	4,131	1,288	N.A.	N.A.	N.A.	N.A.
Muskegon WSO AP	43.17	N	86.23	W	191	3,847	1,312	-16	28	21	N.A.
Pontiac State Hospital	42.65	N	83.30	W	299	3,696	1,539	N.A.	N.A.	N.A.	N.A.
Port Huron	42.98	N	82.42	W	179	3,832	1,412	N.A.	N.A.	N.A.	N.A.
Saginaw FAA AP	43.53	N	84.08	W	201	3,966	1,376	-18	31	22	N.A.
Sault Ste Marie WSO	46.47	N	84.37	W	220	5,176	789	-24	27	20	733
Traverse City FAA AP	44.73	N	85.58	W	189	4,305	1,182	-19	30	21	679
Ypsilanti East Mich U	42.25	N	83.62	W	237	3,592	1,599	N.A.	N.A.	N.A.	N.A.
Minnesota (MN)											
Albert Lea	43.62	N	93.42	W	374	4,526	1,449	N.A.	N.A.	N.A.	N.A.
Alexandria FAA AP	45.87	N	95.38	W	431	4,999	1,287	-29	30	21	N.A.
Bemidji Airport	47.50	N	94.93	W	419	5,667	989	N.A.	N.A.	N.A.	N.A.
Brainerd	46.37	N	94.20	W	359	5,243	1,088	-31	29	20	N.A.
Duluth WSO AP	46.83	N	92.18	W	435	5,454	853	-29	27	19	650

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Minnesota cont.)											
Faribault	44.30	N	93.27	W	286	4,599	1,388	N.A.	N.A.	N.A.	N.A.
International Falls WSO AP	48.57	N	93.38	W	359	5,826	906	-34	28	19	656
Mankato	44.15	N	94.02	W	254	4,447	1,495	N.A.	N.A.	N.A.	N.A.
Minneapolis-St Paul WSO AP	44.88	N	93.22	W	254	4,434	1,489	-27	31	22	566
Rochester WSO AP	43.92	N	92.50	W	395	4,583	1,320	-27	29	22	652
St Cloud WSO AP	45.55	N	94.07	W	316	4,960	1,194	-29	31	22	N.A.
Virginia	47.50	N	92.55	W	437	5,569	879	N.A.	N.A.	N.A.	N.A.
Willmar State Hospital	45.13	N	95.02	W	343	4,798	1,369	N.A.	N.A.	N.A.	N.A.
Winona	44.05	N	91.63	W	198	4,274	1,497	N.A.	N.A.	N.A.	N.A.
Mississippi (MS)											
Biloxi/Keesler AFB	30.42	N	88.92	W	8	826	3,859	-1	33	26	N.A.
Clarksdale	34.20	N	90.57	W	52	1,771	2,976	N.A.	N.A.	N.A.	N.A.
Columbus AFB	33.65	N	88.45	W	67	1,538	3,092	-7	34	26	N.A.
Greenville	33.38	N	91.02	W	40	1,543	3,145	N.A.	N.A.	N.A.	N.A.
Greenwood FAA AP	33.50	N	90.08	W	47	1,499	3,200	-7	34	26	N.A.
Hattiesburg	31.32	N	89.30	W	49	1,211	3,381	N.A.	N.A.	N.A.	N.A.
Jackson WSFO AP	32.32	N	90.08	W	100	1,371	3,278	-6	34	24	640
Laurel	31.68	N	89.12	W	68	1,293	3,274	N.A.	N.A.	N.A.	N.A.
McComb FAA AP	31.23	N	90.47	W	125	1,175	3,347	-5	33	24	N.A.
Meridian WSO AP	32.33	N	88.75	W	89	1,358	3,224	-6	34	24	719
Natchez	31.55	N	91.38	W	59	1,057	3,543	N.A.	N.A.	N.A.	N.A.
Tupelo WSO AP	34.27	N	88.73	W	110	1,711	2,902	-8	34	24	N.A.
Vicksburg Military Pk	32.35	N	90.85	W	77	1,220	3,366	N.A.	N.A.	N.A.	N.A.
Missouri (MO)											
Cape Girardeau FAA AP	37.23	N	89.57	W	102	2,437	2,422	-14	34	25	N.A.
Columbia WSO AP	38.82	N	92.22	W	270	2,896	2,084	-18	33	24	633
Farmington	37.70	N	90.38	W	284	2,801	2,029	N.A.	N.A.	N.A.	N.A.
Hannibal	39.72	N	91.37	W	217	3,127	2,047	N.A.	N.A.	N.A.	N.A.
Jefferson City Wtr Plt	38.58	N	92.15	W	204	2,946	2,058	N.A.	N.A.	N.A.	N.A.
Joplin FAA AP	37.17	N	94.50	W	298	2,391	2,454	-16	34	24	N.A.
Kansas City WSO AP	39.32	N	94.72	W	296	2,996	2,140	-18	34	24	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Missouri cont.)											
Kirksville Radio KIRX	40.22	N	92.58	W	295	3,259	1,941	N.A.	N.A.	N.A.	N.A.
Mexico	39.18	N	91.88	W	236	3,106	2,036	N.A.	N.A.	N.A.	N.A.
Moberly Radio KWIX	39.40	N	92.43	W	256	2,891	2,193	N.A.	N.A.	N.A.	N.A.
Poplar Bluff R S	36.77	N	90.42	W	115	2,404	2,427	-13	33	24	N.A.
Rolla	38.13	N	91.77	W	350	2,638	2,325	N.A.	N.A.	N.A.	N.A.
Rolla Univ of MO	37.95	N	91.77	W	359	2,755	2,214	N.A.	N.A.	N.A.	N.A.
St Joseph	39.77	N	94.92	W	247	3,106	2,102	N.A.	N.A.	N.A.	N.A.
St Louis WSCMO AP	38.75	N	90.37	W	163	2,643	2,379	-17	34	24	N.A.
Montana (MT)											
Billings WSO AP	45.80	N	108.53	W	1,087	3,980	1,370	-25	32	17	617
Bozeman	45.82	N	110.88	W	1,813	5,504	373	-29	31	16	N.A.
Butte FAA AP	45.95	N	112.50	W	1,688	5,287	640	-30	29	13	N.A.
Cut Bank FAA AP	48.60	N	112.37	W	1,169	4,947	819	-29	29	15	672
Glasgow WSO AP	48.22	N	106.62	W	696	4,858	1,247	-30	32	17	570
Glendive	47.10	N	104.72	W	632	4,543	1,455	N.A.	N.A.	N.A.	N.A.
Great Falls WSCMO AP	47.48	N	111.37	W	1,116	4,301	1,107	-28	31	16	641
Havre WSO AP	48.55	N	109.77	W	787	4,693	1,184	-32	32	17	N.A.
Helena WSO AP	46.60	N	112.00	W	1,186	4,462	1,068	-28	31	15	651
Kalispell WSO AP	48.30	N	114.27	W	903	4,654	747	-24	30	16	N.A.
Lewistown FAA AP	47.07	N	109.45	W	1,259	4,711	878	-28	30	16	673
Livingston FAA AP	45.70	N	110.45	W	1,418	4,011	1,056	N.A.	N.A.	N.A.	N.A.
Miles City FAA AP	46.43	N	105.87	W	801	4,331	1,489	-28	34	18	565
Missoula WSO AP	46.92	N	114.08	W	972	4,329	933	-23	31	16	658
Nebraska (NE)											
Chadron FAA AP	42.83	N	103.08	W	1,009	3,900	1,496	N.A.	N.A.	N.A.	N.A.
Columbus	41.47	N	97.33	W	441	3,635	1,858	N.A.	N.A.	N.A.	N.A.
Fremont	41.43	N	96.48	W	359	3,411	1,901	N.A.	N.A.	N.A.	N.A.
Grand Island WSO AP	40.97	N	98.32	W	561	3,567	1,802	-22	34	22	611
Hastings	40.58	N	98.35	W	586	3,614	1,787	N.A.	N.A.	N.A.	N.A.
Kearney	40.73	N	99.02	W	649	3,638	1,717	N.A.	N.A.	N.A.	N.A.
Lincoln WSO AP	40.85	N	96.75	W	362	3,488	1,919	-22	34	23	N.A.
Mc Cook	40.22	N	100.58	W	786	3,397	1,798	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Nebraska cont.)											
Norfolk WSO AP	41.98	N	97.43	W	472	3,818	1,707	-24	33	22	N.A.
North Platte WSO AP	41.13	N	100.68	W	845	3,811	1,521	-23	33	21	592
Omaha (Eppley Field)	41.30	N	95.90	W	298	3,500	1,888	-22	33	24	N.A.
Scottsbluff WSO AP	41.87	N	103.60	W	1,202	3,738	1,489	-24	33	18	620
Sidney	41.23	N	103.00	W	1,316	3,870	1,338	-22	33	17	N.A.
Nevada (NV)											
Carson City	39.15	N	119.77	W	1,417	3,162	1,284	N.A.	N.A.	N.A.	N.A.
Elko FAA AP	40.83	N	115.78	W	1,546	3,932	1,191	-21	33	15	569
Ely WSO AP	39.28	N	114.85	W	1,908	4,234	954	-21	31	13	683
Las Vegas WSO AP	36.08	N	115.17	W	658	1,337	3,747	-3	41	19	719
Lovelock FAA AP	40.07	N	118.55	W	1,188	3,261	1,603	N.A.	N.A.	N.A.	606
Reno WSFO AP	39.50	N	119.78	W	1,342	3,152	1,391	-13	33	16	752
Tonopah AP	38.07	N	117.08	W	1,653	3,185	1,578	-14	33	14	660
Winnemucca WSO AP	40.90	N	117.80	W	1,309	3,508	1,322	-17	34	16	608
New Hampshire (NH)											
Berlin	44.45	N	71.18	W	283	4,803	954	N.A.	N.A.	N.A.	N.A.
Concord WSO AP	43.20	N	71.50	W	105	4,197	1,159	-22	31	21	683
Keene	42.92	N	72.27	W	146	3,860	1,332	N.A.	N.A.	N.A.	N.A.
Portsmouth/Pease AFB	43.08	N	70.82	W	31	3,651	1,343	-16	29	21	N.A.
New Jersey (NJ)											
Atlantic City WSO AP	39.45	N	74.57	W	42	2,872	1,777	-13	31	23	N.A.
Long Branch Oakhurst	40.27	N	74.00	W	9	2,918	1,698	N.A.	N.A.	N.A.	N.A.
Newark WSO AP	40.70	N	74.17	W	9	2,716	2,082	-12	32	23	644
New Mexico (NM)											
Alamogordo/Holloman	32.85	N	106.10	W	1,248	1,796	2,626	-7	36	17	N.A.
Albuquerque WSFO AP	35.05	N	106.62	W	1,623	2,458	2,171	-11	34	16	703
Artesia	32.77	N	104.38	W	1,011	1,959	2,546	N.A.	N.A.	N.A.	N.A.
Carlsbad FAA AP	32.33	N	104.27	W	985	1,562	3,062	-7	37	19	N.A.
Clovis/Cannon AFB	34.38	N	103.32	W	1,309	2,213	2,321	-12	34	18	N.A.
Farmington	36.73	N	108.23	W	1,677	3,035	1,837	-13	33	16	N.A.
Gallup FAA AP	35.52	N	108.78	W	1,971	3,469	1,308	-18	31	13	N.A.
Grants Airport	35.17	N	107.90	W	1,987	3,282	1,378	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(New Mexico cont.)											
Hobbs	32.70	N	103.13	W	1,101	1,584	2,867	N.A.	N.A.	N.A.	N.A.
Raton Filter Plant	36.92	N	104.43	W	2,112	3,391	1,215	N.A.	N.A.	N.A.	N.A.
Roswell FAA AP	33.30	N	104.53	W	1,118	1,815	2,757	-10	36	18	677
Socorro	34.08	N	106.88	W	1,397	2,263	2,136	N.A.	N.A.	N.A.	N.A.
Tucumcari	35.20	N	103.68	W	1,245	2,173	2,331	-13	35	18	710
New York (NY)											
Albany WSFO AP	42.75	N	73.80	W	83	3,830	1,403	-22	30	21	605
Auburn	42.92	N	76.53	W	234	3,768	1,406	N.A.	N.A.	N.A.	N.A.
Batavia	42.98	N	78.18	W	271	3,698	1,409	N.A.	N.A.	N.A.	N.A.
Binghamton WSO AP	42.22	N	75.98	W	487	4,041	1,218	-19	28	21	662
Buffalo WSCMO AP	42.93	N	78.73	W	214	3,748	1,371	-17	29	21	697
Cortland	42.60	N	76.18	W	344	3,982	1,236	N.A.	N.A.	N.A.	N.A.
Elmira/Chemung Co	42.17	N	76.90	W	290	3,803	1,345	-19	31	22	N.A.
Geneva Research Farm	42.88	N	77.03	W	218	3,855	1,313	N.A.	N.A.	N.A.	N.A.
Glens Falls FAA AP	43.35	N	73.62	W	97	4,242	1,212	-23	29	22	N.A.
Gloversville	43.05	N	74.35	W	247	4,258	1,177	N.A.	N.A.	N.A.	N.A.
Ithaca Cornell Univ	42.45	N	76.45	W	292	4,004	1,176	N.A.	N.A.	N.A.	N.A.
Lockport	43.18	N	78.65	W	158	3,724	1,379	N.A.	N.A.	N.A.	N.A.
Massena FAA AP	44.93	N	74.85	W	65	4,586	1,137	-26	29	22	627
N Y Central Pk WSO City	40.78	N	73.97	W	40	2,669	2,019	N.A.	N.A.	N.A.	790
N Y Kennedy WSO AP	40.65	N	73.78	W	4	2,793	1,857	-12	31	22	N.A.
N Y La Guardia WSO AP	40.77	N	73.90	W	3	2,728	1,971	-11	32	23	790
Oswego East	43.47	N	76.50	W	106	3,741	1,351	N.A.	N.A.	N.A.	N.A.
Plattsburgh AFB	44.65	N	73.47	W	50	4,354	1,208	-23	28	21	N.A.
Poughkeepsie FAA AP	41.63	N	73.88	W	47	3,551	1,479	-17	31	22	N.A.
Rochester WSO AP	43.12	N	77.67	W	166	3,741	1,337	-17	30	22	608
Rome/Griffiss AFB	43.23	N	75.40	W	154	4,025	1,302	-21	30	21	N.A.
Schenectady	42.83	N	73.92	W	67	3,823	1,389	N.A.	N.A.	N.A.	N.A.
Syracuse WSO AP	43.12	N	76.12	W	128	3,797	1,333	-19	29	22	730
Utica	43.10	N	75.28	W	152	3,926	1,308	N.A.	N.A.	N.A.	N.A.
Watertown	43.97	N	75.87	W	151	4,189	1,274	-24	28	21	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
North Carolina (NC)											
Asheville WSO AP	35.43	N	82.55	W	652	2,393	1,869	-12	29	22	915
Charlotte WSO AP	35.22	N	80.93	W	213	1,856	2,613	-8	33	23	777
Durham	36.03	N	78.97	W	123	2,148	2,311	N.A.	N.A.	N.A.	N.A.
Elizabeth City FAA AP	36.27	N	76.18	W	3	1,744	2,647	N.A.	N.A.	N.A.	N.A.
Fayetteville/Pope AFB	35.17	N	79.02	W	66	1,620	2,949	-6	34	24	N.A.
Goldsboro	35.33	N	77.97	W	33	1,689	2,788	-6	34	24	N.A.
Greensboro WSO AP	36.08	N	79.95	W	270	2,147	2,302	-9	32	23	718
Greenville	35.62	N	77.38	W	9	1,738	2,680	N.A.	N.A.	N.A.	N.A.
Henderson	36.37	N	78.42	W	146	2,243	2,223	N.A.	N.A.	N.A.	N.A.
Hickory FAA AP	35.73	N	81.38	W	348	2,071	2,333	-8	33	22	N.A.
Jacksonville/New River	34.70	N	77.43	W	8	1,365	3,154	-5	33	26	N.A.
Lumberton	34.70	N	79.07	W	39	1,784	2,624	N.A.	N.A.	N.A.	N.A.
New Bern FAA AP	35.07	N	77.05	W	5	1,523	2,923	-6	33	26	N.A.
Raleigh-Durham WSFO AP	35.87	N	78.78	W	114	1,921	2,499	-9	32	24	740
Rocky Mount	35.90	N	77.72	W	33	1,845	2,548	N.A.	N.A.	N.A.	N.A.
Wilmington WSO AP	34.27	N	77.90	W	21	1,372	3,087	-5	33	26	N.A.
North Dakota (ND)											
Bismarck WSFO AP	46.77	N	100.77	W	502	4,982	1,191	-29	32	19	556
Devils Lake KDLR	48.12	N	98.87	W	446	5,528	1,096	-31	31	19	N.A.
Dickinson FAA AP	46.78	N	102.80	W	786	4,809	1,196	N.A.	N.A.	N.A.	N.A.
Fargo WSO AP	46.90	N	96.80	W	274	5,141	1,272	-30	31	21	546
Grand Forks FAA AP	47.95	N	97.17	W	258	5,407	1,158	-29	31	21	N.A.
Jamestown FAA AP	46.92	N	98.68	W	454	5,093	1,257	N.A.	N.A.	N.A.	N.A.
Minot FAA AP	48.27	N	101.28	W	522	5,107	1,186	-29	31	19	581
Ohio (OH)											
Akron-Canton WSO AP	40.92	N	81.43	W	368	3,422	1,544	-18	29	22	680
Ashtabula	41.85	N	80.80	W	210	3,572	1,447	N.A.	N.A.	N.A.	N.A.
Bowling Green	41.38	N	83.62	W	205	3,601	1,598	N.A.	N.A.	N.A.	N.A.
Cambridge	40.02	N	81.58	W	243	3,049	1,732	N.A.	N.A.	N.A.	N.A.
Cincinnati-Abbe WSO	39.15	N	84.52	W	231	2,771	2,074	-15	32	24	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Ohio cont.)											
Cleveland WSFO AP	41.42	N	81.87	W	234	3,445	1,531	-17	30	22	N.A.
Columbus WSO AP	40.00	N	82.88	W	247	3,171	1,733	-17	31	23	708
Dayton WSCMO AP	39.90	N	84.20	W	303	3,171	1,805	-18	31	23	611
Defiance	41.28	N	84.38	W	213	3,682	1,561	N.A.	N.A.	N.A.	N.A.
Findlay FAA AP	41.02	N	83.67	W	242	3,501	1,615	-19	31	22	N.A.
Fremont	41.33	N	83.12	W	182	3,577	1,568	N.A.	N.A.	N.A.	N.A.
Lancaster	39.73	N	82.63	W	262	3,327	1,631	N.A.	N.A.	N.A.	N.A.
Lima Sewage Plant	40.72	N	84.13	W	259	3,474	1,694	N.A.	N.A.	N.A.	N.A.
Mansfield WSO AP	40.82	N	82.52	W	394	3,477	1,566	-18	29	22	N.A.
Marion	40.62	N	83.13	W	294	3,559	1,576	N.A.	N.A.	N.A.	N.A.
Newark Water Works	40.08	N	82.42	W	254	3,143	1,726	N.A.	N.A.	N.A.	N.A.
Norwalk	41.27	N	82.62	W	204	3,574	1,508	N.A.	N.A.	N.A.	N.A.
Portsmouth	38.75	N	82.88	W	164	2,729	1,989	N.A.	N.A.	N.A.	N.A.
Sandusky	41.45	N	82.72	W	178	3,406	1,659	N.A.	N.A.	N.A.	N.A.
Springfield New Wtr Wk	39.97	N	83.82	W	283	3,474	1,550	N.A.	N.A.	N.A.	N.A.
Steubenville	40.38	N	80.63	W	302	3,167	1,697	N.A.	N.A.	N.A.	N.A.
Toledo Express WSO AP	41.58	N	83.80	W	203	3,655	1,511	-19	31	22	652
Warren	41.20	N	80.82	W	274	3,557	1,414	N.A.	N.A.	N.A.	N.A.
Wooster Exp Station	40.78	N	81.92	W	310	3,544	1,428	N.A.	N.A.	N.A.	N.A.
Youngstown WSO AP	41.25	N	80.67	W	359	3,636	1,409	-18	29	21	679
Zanesville FAA AP	39.95	N	81.90	W	268	3,174	1,674	-17	31	23	N.A.
Oklahoma (OK)											
Ada	34.78	N	96.68	W	309	1,768	2,954	N.A.	N.A.	N.A.	N.A.
Altus AFB	34.65	N	99.27	W	420	1,750	3,171	-11	38	23	N.A.
Ardmore	34.20	N	97.15	W	262	1,501	3,321	N.A.	N.A.	N.A.	N.A.
Bartlesville	36.75	N	96.00	W	217	2,098	2,764	N.A.	N.A.	N.A.	N.A.
Chickasha Exp Station	35.05	N	97.92	W	330	1,870	2,943	N.A.	N.A.	N.A.	N.A.
Enid	36.42	N	97.87	W	379	2,104	2,844	-15	37	23	N.A.
Lawton	34.62	N	98.45	W	350	1,921	2,927	-11	36	23	N.A.
McAlester FAA AP	34.88	N	95.78	W	231	1,863	2,907	-12	36	24	N.A.
Muskogee	35.77	N	95.33	W	177	1,896	2,881	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Oklahoma cont.)											
Norman	35.18	N	97.45	W	338	1,831	2,929	N.A.	N.A.	N.A.	N.A.
Oklahoma City WSFO AP	35.40	N	97.60	W	390	2,033	2,762	-13	36	23	733
Ponca City FAA AP	36.73	N	97.10	W	304	2,348	2,662	N.A.	N.A.	N.A.	N.A.
Seminole	35.23	N	96.67	W	263	1,721	3,084	N.A.	N.A.	N.A.	N.A.
Stillwater	36.12	N	97.10	W	272	2,238	2,621	N.A.	N.A.	N.A.	N.A.
Tulsa WSO AP	36.18	N	95.90	W	203	2,051	2,861	-13	36	24	591
Woodward	36.45	N	99.38	W	579	2,167	2,713	N.A.	N.A.	N.A.	N.A.
Oregon (OR)											
Astoria WSO AP	46.15	N	123.88	W	2	2,866	798	-4	22	17	1236
Baker FAA AP	44.83	N	117.82	W	1,026	3,975	967	N.A.	N.A.	N.A.	N.A.
Bend	44.07	N	121.28	W	1,115	3,848	781	N.A.	N.A.	N.A.	N.A.
Corvallis State Univ	44.63	N	123.20	W	68	2,735	1,139	N.A.	N.A.	N.A.	N.A.
Eugene WSO AP	44.12	N	123.22	W	110	2,526	1,308	-6	31	18	N.A.
Grants Pass	42.42	N	123.33	W	292	2,344	1,659	N.A.	N.A.	N.A.	N.A.
Klamath Falls	42.20	N	121.78	W	1,249	3,686	1,086	-16	31	17	N.A.
Medford WSO AP	42.38	N	122.88	W	396	2,562	1,661	-6	35	19	749
Pendleton WSO AP	45.68	N	118.85	W	454	2,941	1,548	-16	34	17	N.A.
Portland WSFO AP	45.60	N	122.60	W	6	2,512	1,398	-6	30	19	1060
Roseburg KQEN	43.20	N	123.35	W	141	2,396	1,448	N.A.	N.A.	N.A.	N.A.
Salem WSO AP	44.92	N	123.02	W	59	2,737	1,167	-7	31	19	916
Pennsylvania (PA)											
Allentown WSO AP	40.65	N	75.43	W	118	3,214	1,682	-15	31	22	710
Altoona FAA AP	40.30	N	78.32	W	449	3,411	1,511	-15	30	21	N.A.
Chambersburg	39.93	N	77.63	W	195	3,097	1,700	N.A.	N.A.	N.A.	N.A.
Erie WSO AP	42.08	N	80.18	W	223	3,488	1,473	-17	28	21	716
Harrisburg FAA AP	40.22	N	76.85	W	103	2,971	1,866	-13	32	23	648
Johnstown	40.33	N	78.92	W	370	3,138	1,682	N.A.	N.A.	N.A.	N.A.
Lancaster	40.05	N	76.28	W	82	3,102	1,711	N.A.	N.A.	N.A.	N.A.
Meadville	41.63	N	80.17	W	324	3,852	1,227	N.A.	N.A.	N.A.	N.A.
New Castle	41.02	N	80.37	W	251	3,634	1,390	N.A.	N.A.	N.A.	N.A.
Philadelphia WSCMO AP	39.88	N	75.23	W	3	2,752	2,013	-12	32	23	646

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Pennsylvania cont.)											
Pittsburgh WSCMO2 AP	40.50	N	80.22	W	350	3,316	1,576	-17	30	21	700
Reading	40.37	N	75.93	W	82	3,220	1,678	N.A.	N.A.	N.A.	N.A.
State College	40.80	N	77.87	W	356	3,536	1,461	N.A.	N.A.	N.A.	N.A.
Uniontown	39.92	N	79.72	W	291	3,158	1,618	N.A.	N.A.	N.A.	N.A.
Warren	41.85	N	79.15	W	368	3,828	1,297	N.A.	N.A.	N.A.	N.A.
West Chester	39.97	N	75.63	W	137	2,935	1,827	N.A.	N.A.	N.A.	N.A.
Williamsport WSO AP	41.25	N	76.92	W	159	3,382	1,553	-17	31	22	N.A.
York Pump Station 22	39.92	N	76.75	W	118	2,920	1,819	N.A.	N.A.	N.A.	N.A.
Rhode Island (RI)											
Newport	41.52	N	71.32	W	6	3,144	1,416	N.A.	N.A.	N.A.	N.A.
Providence WSO AP	41.73	N	71.43	W	15	3,269	1,524	-15	30	22	684
South Carolina (SC)											
Anderson	34.53	N	82.67	W	243	1,647	2,722	N.A.	N.A.	N.A.	N.A.
Charleston WSO AP	32.90	N	80.03	W	12	1,118	3,438	N.A.	N.A.	N.A.	N.A.
Charleston WSO City	32.78	N	79.93	W	3	1,037	3,502	-4	33	25	N.A.
Columbia WSFO AP	33.95	N	81.12	W	64	1,472	3,060	-6	34	24	705
Florence FAA AP	34.18	N	79.72	W	44	1,436	3,109	-5	34	24	N.A.
Georgetown	33.35	N	79.25	W	3	1,156	3,304	N.A.	N.A.	N.A.	N.A.
Greenville-Spartanburg WSO AP	34.90	N	82.2	W	296	1,818	2,569	-7	33	23	851
Greenwood	34.17	N	82.20	W	187	1,827	2,596	N.A.	N.A.	N.A.	N.A.
Orangeburg	33.50	N	80.87	W	48	1,408	3,043	N.A.	N.A.	N.A.	N.A.
Spartanburg	34.98	N	81.88	W	256	1,604	2,803	N.A.	N.A.	N.A.	N.A.
Sumter/Shaw AFB	33.97	N	80.48	W	73	1,392	3,029	-4	34	24	N.A.
South Dakota (SD)											
Aberdeen WSO AP	45.45	N	98.43	W	395	4,692	1,387	N.A.	N.A.	N.A.	N.A.
Brookings	44.32	N	96.77	W	500	4,807	1,238	N.A.	N.A.	N.A.	N.A.
Huron WSO AP	44.38	N	98.22	W	390	4,402	1,505	-27	33	22	545
Mitchell	43.72	N	98.00	W	388	4,199	1,625	N.A.	N.A.	N.A.	N.A.
Pierre FAA AP	44.38	N	100.28	W	526	4,117	1,632	-26	35	21	557
Rapid City WSO AP	44.05	N	103.07	W	963	4,056	1,340	-24	33	18	572
Sioux Falls WSFO AP	43.57	N	96.73	W	432	4,338	1,519	-27	32	22	599

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(South Dakota cont.)											
Watertown FAA AP	44.92	N	97.15	W	532	4,653	1,388	N.A.	N.A.	N.A.	N.A.
Yankton	42.88	N	97.35	W	359	4,058	1,631	N.A.	N.A.	N.A.	N.A.
Tennessee (TN)											
Athens	35.43	N	84.58	W	286	2,252	2,244	N.A.	N.A.	N.A.	N.A.
Bristol WSO AP	36.48	N	82.40	W	464	2,448	2,012	-13	31	22	N.A.
Chattanooga WSO AP	35.03	N	85.20	W	210	1,993	2,561	-9	33	24	684
Clarksville Sew Plt	36.55	N	87.37	W	116	2,311	2,356	N.A.	N.A.	N.A.	N.A.
Columbia	35.63	N	87.08	W	198	2,337	2,248	N.A.	N.A.	N.A.	N.A.
Dyersburg FAA AP	36.02	N	89.40	W	102	1,964	2,783	N.A.	N.A.	N.A.	N.A.
Greeneville Exp Stn	36.10	N	82.85	W	402	2,440	2,061	N.A.	N.A.	N.A.	N.A.
Jackson FAA AP	35.60	N	88.92	W	131	1,967	2,731	-11	34	24	N.A.
Knoxville WSO AP	35.80	N	84.00	W	289	2,187	2,313	-11	32	23	703
Memphis FAA-AP	35.05	N	90.00	W	80	1,712	3,037	-9	34	25	851
Murfreesboro	35.92	N	86.37	W	167	2,218	2,372	N.A.	N.A.	N.A.	N.A.
Nashville WSO AP	36.12	N	86.68	W	176	2,072	2,605	-12	33	24	749
Tullahoma	35.35	N	86.20	W	319	2,017	2,457	N.A.	N.A.	N.A.	N.A.
Texas (TX)											
Abilene WSO AP	32.42	N	99.68	W	543	1,436	3,361	-9	36	22	648
Alice	27.73	N	98.07	W	61	590	4,512	N.A.	N.A.	N.A.	N.A.
Amarillo WSO AP	35.23	N	101.70	W	1,094	2,366	2,293	-14	34	19	680
Austin WSO AP	30.30	N	97.70	W	181	938	3,984	-4	36	23	664
Bay City Waterworks	28.98	N	95.98	W	15	761	4,006	N.A.	N.A.	N.A.	N.A.
Beaumont Research Ctr	30.07	N	94.28	W	8	932	3,724	-2	33	26	N.A.
Beeville	28.45	N	97.70	W	77	762	4,107	-2	37	25	N.A.
Big Spring	32.25	N	101.45	W	761	1,540	3,123	N.A.	N.A.	N.A.	N.A.
Brownsville WSO AP	25.90	N	97.43	W	5	353	4,876	2	34	25	422
Brownwood	31.72	N	99.00	W	422	1,222	3,599	N.A.	N.A.	N.A.	N.A.
Corpus Christi WSO AP	27.77	N	97.50	W	13	564	4,457	0	34	26	543
Corsicana	32.08	N	96.47	W	129	1,331	3,407	N.A.	N.A.	N.A.	N.A.
Dallas FAA AP	32.85	N	96.85	W	134	1,255	3,659	-8	37	23	N.A.
Del Rio/Laughlin AFB	29.37	N	100.78	W	329	870	4,004	-2	37	23	732

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Texas cont.)											
Denton	33.20	N	97.10	W	192	1,481	3,231	N.A.	N.A.	N.A.	N.A.
Eagle Pass	28.70	N	100.48	W	245	801	4,268	N.A.	N.A.	N.A.	N.A.
El Paso WSO AP	31.80	N	106.40	W	1,194	1,504	3,049	-6	37	18	735
Ft Worth/Meacham	32.82	N	97.35	W	211	1,280	3,643	-7	37	23	N.A.
Galveston WSO City	29.30	N	94.80	W	2	702	4,099	N.A.	N.A.	N.A.	N.A.
Greenville	33.20	N	96.22	W	185	1,641	3,071	N.A.	N.A.	N.A.	N.A.
Harlingen	26.20	N	97.67	W	11	452	4,669	N.A.	N.A.	N.A.	N.A.
Houston/Hobby	29.65	N	95.28	W	15	762	4,087	-2	34	25	N.A.
Houston–Bush International Airport	29.97	N	95.35	W	29	888	3,820	-3	34	25	N.A.
Huntsville	30.72	N	95.55	W	150	1,034	3,721	N.A.	N.A.	N.A.	N.A.
Killeen/Robert-Gray	31.07	N	97.83	W	309	1,182	3,598	-7	36	23	N.A.
Lamesa	32.70	N	101.93	W	903	1,755	2,837	N.A.	N.A.	N.A.	N.A.
Laredo	27.57	N	99.50	W	131	569	4,719	0	38	23	598
Longview	32.47	N	94.73	W	100	1,352	3,289	N.A.	N.A.	N.A.	N.A.
Lubbock WSFO AP	33.65	N	101.82	W	991	1,906	2,685	-12	35	19	743
Lufkin FAA AP	31.23	N	94.75	W	85	1,084	3,626	-5	35	25	681
McAllen	26.20	N	98.22	W	37	432	4,776	1	37	24	N.A.
Midland/Odessa WSO AP	31.95	N	102.18	W	870	1,528	3,104	-8	36	19	729
Mineral Wells FAA AP	32.78	N	98.07	W	284	1,458	3,342	N.A.	N.A.	N.A.	N.A.
Palestine	31.78	N	95.60	W	141	1,114	3,586	N.A.	N.A.	N.A.	N.A.
Pampa No 2	35.53	N	100.98	W	990	2,421	2,295	N.A.	N.A.	N.A.	N.A.
Pecos	31.42	N	103.50	W	795	1,392	3,329	N.A.	N.A.	N.A.	N.A.
Plainview	34.18	N	101.70	W	1,027	2,065	2,479	N.A.	N.A.	N.A.	N.A.
Port Arthur WSO AP	29.95	N	94.02	W	4	833	3,886	N.A.	N.A.	N.A.	697
San Angelo WSO AP	31.37	N	100.50	W	580	1,341	3,372	-7	36	21	619
San Antonio WSFO	29.53	N	98.47	W	242	913	3,968	-3	36	23	N.A.
Sherman	33.63	N	96.62	W	219	1,606	3,157	N.A.	N.A.	N.A.	721
Snyder	32.72	N	100.92	W	711	1,769	2,877	N.A.	N.A.	N.A.	N.A.
Temple	31.08	N	97.37	W	213	1,196	3,604	N.A.	N.A.	N.A.	N.A.
Tyler	32.35	N	95.40	W	166	1,219	3,645	N.A.	N.A.	N.A.	N.A.
Vernon	34.08	N	99.30	W	366	1,770	3,114	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State								Heating Design Temperature	Cooling Design Temperature		No. Hrs.
									Dry-Bulb	Wet-Bulb	8 a.m.-4 p.m.
City	Latitude		Longitude		Elev. (m)	HDD18	CDD10	99.6%	1.0%	1.0%	13<Tdb<21
(Texas cont.)											
Victoria WSO AP	28.85	N	96.92	W	31	720	4,171	-2	34	24	N.A.
Waco WSO AP	31.62	N	97.22	W	152	1,211	3,704	-6	37	24	622
Wichita Falls WSO AP	33.97	N	98.48	W	302	1,690	3,176	N.A.	N.A.	N.A.	723
Utah (UT)											
Cedar City FAA AP	37.70	N	113.10	W	1,709	3,312	1,539	-17	33	15	629
Logan Utah State Univ	41.75	N	111.80	W	1,459	3,808	1,412	N.A.	N.A.	N.A.	N.A.
Moab	38.60	N	109.60	W	1,208	2,497	2,420	N.A.	N.A.	N.A.	N.A.
Ogden Sugar Factory	41.23	N	112.03	W	1,304	3,306	1,696	N.A.	N.A.	N.A.	N.A.
Richfield Radio KSVC	38.77	N	112.08	W	1,606	3,537	1,278	N.A.	N.A.	N.A.	N.A.
Saint George	37.10	N	113.57	W	841	1,786	3,013	N.A.	N.A.	N.A.	N.A.
Salt Lake City NWSFO	40.78	N	111.95	W	1,286	3,203	1,820	-14	34	17	586
Vernal Airport	40.45	N	109.52	W	1,603	4,201	1,297	N.A.	N.A.	N.A.	N.A.
Vermont (VT)											
Burlington WSO AP	44.47	N	73.15	W	101	4,317	1,238	-24	29	21	637
Rutland	43.60	N	72.97	W	188	3,926	1,303	N.A.	N.A.	N.A.	N.A.
Virginia (VA)											
Charlottesville	38.03	N	78.52	W	265	2,347	2,168	N.A.	N.A.	N.A.	N.A.
Danville-Bridge St	36.58	N	79.38	W	124	2,191	2,353	N.A.	N.A.	N.A.	N.A.
Fredericksburg Natl Pk	38.32	N	77.45	W	27	2,530	2,086	N.A.	N.A.	N.A.	N.A.
Lynchburg WSO AP	37.33	N	79.20	W	279	2,411	2,071	-11	32	23	N.A.
Norfolk WSO AP	36.90	N	76.20	W	6	1,942	2,488	-7	33	24	685
Richmond WSO AP	37.50	N	77.33	W	49	2,202	2,346	-10	33	24	716
Roanoke WSO AP	37.32	N	79.97	W	350	2,422	2,064	-11	32	22	713
Staunton Sewage Plant	38.15	N	79.03	W	422	2,929	1,669	N.A.	N.A.	N.A.	N.A.
Winchester	39.18	N	78.12	W	207	2,927	1,786	N.A.	N.A.	N.A.	N.A.
Washington (WA)											
Aberdeen	46.97	N	123.82	W	3	2,936	827	N.A.	N.A.	N.A.	N.A.
Bellingham FAA AP	48.80	N	122.53	W	45	3,116	838	-9	24	18	N.A.
Bremerton	47.57	N	122.67	W	49	2,844	1,022	N.A.	N.A.	N.A.	N.A.
Ellensburg	46.97	N	120.55	W	451	3,761	1,111	N.A.	N.A.	N.A.	N.A.
Everett	47.98	N	122.18	W	18	2,951	922	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Washington cont.)											
Kennewick	46.22	N	119.10	W	118	2,719	1,775	N.A.	N.A.	N.A.	N.A.
Longview	46.15	N	122.92	W	3	2,830	1,032	N.A.	N.A.	N.A.	N.A.
Olympia WSO AP	46.97	N	122.90	W	58	3,142	866	-8	28	18	985
Port Angeles	48.12	N	123.40	W	12	3,164	698	N.A.	N.A.	N.A.	N.A.
Seattle EMSU WSO	47.65	N	122.30	W	6	2,562	1,178	N.A.	N.A.	N.A.	N.A.
Seattle-Tacoma WSCMO AP	47.45	N	122.30	W	137	2,727	1,123	-5	27	18	982
Spokane WSO AP	47.63	N	117.53	W	718	3,801	1,129	N.A.	N.A.	N.A.	640
Tacoma/McChord AFB	47.15	N	122.48	W	98	2,864	1,011	-8	28	17	N.A.
Walla Walla FAA AP	46.10	N	118.28	W	355	2,754	1,756	-16	35	18	N.A.
Wenatchee	47.42	N	120.32	W	195	3,099	1,642	-16	33	18	N.A.
Yakima WSO AP	46.57	N	120.53	W	324	3,315	1,304	-16	33	18	703
West Virginia (WV)											
Beckley WSO AP	37.78	N	81.12	W	763	3,088	1,494	N.A.	N.A.	N.A.	N.A.
Bluefield FAA AP	37.30	N	81.22	W	874	2,906	1,615	-15	28	21	N.A.
Charleston WSFO AP	38.37	N	81.60	W	309	2,581	2,031	-14	31	23	704
Clarksburg	39.27	N	80.35	W	288	3,062	1,674	N.A.	N.A.	N.A.	N.A.
Elkins WSO AP	38.88	N	79.85	W	607	3,400	1,311	-19	28	21	N.A.
Huntington WSO AP	38.37	N	82.55	W	252	2,592	2,008	-14	32	23	N.A.
Martinsburg FAA AP	39.40	N	77.98	W	161	2,884	1,871	-13	33	23	N.A.
Morgantown FAA AP	39.65	N	79.92	W	377	2,979	1,753	-16	31	22	N.A.
Parkersburg	39.27	N	81.57	W	187	2,830	1,948	-16	31	22	N.A.
Wisconsin (WI)											
Appleton	44.25	N	88.37	W	228	4,274	1,396	N.A.	N.A.	N.A.	N.A.
Ashland Exp Farm	46.57	N	90.97	W	198	4,978	1,006	N.A.	N.A.	N.A.	N.A.
Beloit	42.50	N	89.03	W	237	3,978	1,521	N.A.	N.A.	N.A.	N.A.
Eau Claire FAA AP	44.87	N	91.48	W	270	4,628	1,337	-28	31	22	661
Fond du Lac	43.80	N	88.45	W	231	4,189	1,429	N.A.	N.A.	N.A.	N.A.
Green Bay WSO AP	44.48	N	88.13	W	207	4,494	1,209	-25	29	22	651
La Crosse FAA AP	43.87	N	91.25	W	198	4,162	1,550	-26	31	23	644
Madison WSO AP	43.13	N	89.33	W	261	4,263	1,327	-24	31	22	658
Manitowoc	44.10	N	87.68	W	201	4,221	1,218	N.A.	N.A.	N.A.	N.A.

TABLE D-1 *(continued)*
U.S. and U.S. Territory Climatic Data

State City	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%	No. Hrs. 8 a.m.-4 p.m. 13<Tdb<21
(Wisconsin cont.)											
Marinette	45.10	N	87.63	W	184	4,477	1,262	N.A.	N.A.	N.A.	N.A.
Milwaukee WSO AP	42.95	N	87.90	W	204	4,069	1,327	-22	30	22	618
Racine	42.70	N	87.77	W	181	3,982	1,366	N.A.	N.A.	N.A.	N.A.
Sheboygan	43.75	N	87.72	W	197	3,937	1,328	N.A.	N.A.	N.A.	N.A.
Stevens Point	44.50	N	89.57	W	328	4,449	1,292	N.A.	N.A.	N.A.	N.A.
Waukesha	43.02	N	88.23	W	262	3,954	1,477	N.A.	N.A.	N.A.	N.A.
Wausau FAA AP	44.92	N	89.62	W	364	4,682	1,212	-26	29	21	N.A.
Wyoming (WY)											
Casper WSO AP	42.92	N	106.47	W	1,627	4,268	1,157	-25	32	14	535
Cheyenne WSFO AP	41.15	N	104.82	W	1,865	4,070	1,048	-22	29	14	608
Cody	44.52	N	109.07	W	1,539	4,128	1,143	-26	31	14	N.A.
Evanston	41.27	N	110.95	W	2,075	4,914	714	N.A.	N.A.	N.A.	N.A.
Lander WSO AP	42.82	N	108.73	W	1,636	4,383	1,213	-26	31	14	N.A.
Laramie FAA AP	41.32	N	105.68	W	2,214	5,004	687	N.A.	N.A.	N.A.	N.A.
Newcastle	43.85	N	104.22	W	1,344	4,037	1,399	N.A.	N.A.	N.A.	N.A.
Rawlins FAA AP	41.80	N	107.20	W	2,053	4,708	892	N.A.	N.A.	N.A.	N.A.
Rock Springs FAA AP	41.60	N	109.07	W	2,054	4,647	963	-23	29	12	552
Sheridan WSO AP	44.77	N	106.97	W	1,208	4,336	1,124	-26	32	16	574
Torrington Exp Farm	42.08	N	104.22	W	1,249	3,822	1,349	N.A.	N.A.	N.A.	N.A.
District of Columbia (DC)											
Ronald Reagan Airport	38.85	N	77.03	W	20	2,248	2,439	-9	34	24	657
Puerto Rica (PR)											
San Juan/Isla Verde WSFO	18.43	N	66.00	W	3	0	6,337	21	32	26	N.A.
Pacific Islands (PI)											
Guam (GU) - Andersen AFB	13.58	N	144.93	E	185	0	5,939	23	31	26	N.A.
Marshall Island (MH) - Kwajalein Atoll	8.73	N	167.73	E	8	0	6,483	24	31	26	N.A.
Midway Island (MH) - Midway Island NAF	28.22	N	177.37	W	4	74	4,624	15	30	24	N.A.
Samoa (WS) - Pago Pago WSO Airport	14.33	S	170.72	W	3	0	6,121	22	31	27	N.A.
Wake Island - Wake Island WSO Airport	19.28	N	166.65	E	4	0	6,165	22	31	26	N.A.

TABLE D-2
Canadian Climatic Data

Province City	Latitude		Longitude		Elev. (m)	HDD18	CDD10	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Wet-Bulb 1.0%
Alberta (AB)										
Calgary International A	51.12	N	114.02	W	3,533	9,855	1,167	-22	80	59
Edmonton International A	53.30	N	113.58	W	2,345	11,023	1,069	-28.1	78	63
Grande Prairie A	55.18	N	118.88	W	2,185	11,240	1,031	-32	78	60
Jasper	52.88	N	118.07	W	1,060	5,691	471	N.A.	N.A.	N.A.
Lethbridge A	49.63	N	112.80	W	3,047	8,783	1,730	-22	84	61
Medicine Hat A	50.02	N	110.72	W	716	4,993	1101	-31	31	17
Red Deer A	52.18	N	113.90	W	904	5,981	608	-33	26	16
British Columbia (BC)										
Dawson Creek A	55.73	N	120.18	W	654	6,353	494	N.A.	N.A.	N.A.
Ft Nelson A	58.83	N	122.58	W	381	7,189	563	-36	26	16
Kamloops	50.67	N	120.33	W	378	3,766	1297	-22	31	17
Nanaimo A	49.05	N	123.87	W	29	3,363	816	N.A.	N.A.	N.A.
New Westminster BC Pen	49.22	N	122.90	W	17	3,067	939	N.A.	N.A.	N.A.
Penticton A	49.47	N	119.60	W	343	3,611	1112	-15	31	18
Prince George	53.88	N	122.67	W	691	5,275	503	-32	26	15
Prince Rupert A	54.30	N	130.43	W	33	4,250	318	-14	17	14
Vancouver International A	49.18	N	123.17	W	2	3,157	853	-8	23	18
Victoria Gonzales Hts	48.42	N	123.32	W	69	3,052	714	-5	24	17
Manitoba (MB)										
Brandon CDA	49.87	N	99.98	W	362	6,094	923	-34	29	19
Churchill A	58.73	N	94.07	W	27	9,288	153	-38	22	16
Dauphin A	51.10	N	100.05	W	304	6,246	844	-33	29	19
Flin Flon	54.77	N	101.85	W	334	6,837	751	N.A.	N.A.	N.A.
Portage La Prairie A	49.90	N	98.27	W	269	5,886	1004	-32	29	19
The Pas A	53.97	N	101.10	W	270	6,939	684	-36	26	18
Winnipeg International A	49.90	N	97.23	W	238	6,032	991	-33	29	19
New Brunswick (NB)										
Chatham A	47.02	N	65.45	W	33	5,016	851	-24	28	19
Fredericton A	45.87	N	66.53	W	16	4,814	906	-24	28	20

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

Province City	Latitude		Longitude		Elev. (m)	HDD18	CDD10	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	 Wet-Bulb 1.0%
(New Brunswick cont.)										
Moncton A	46.12	N	64.68	W	70	4,851	793	-23	27	19
Saint John A	45.33	N	65.88	W	102	4,876	655	-23	24	18
Newfoundland (NF)										
Corner Brook	48.95	N	57.95	W	4	4,864	597	N.A.	N.A.	N.A.
Gander International A	48.95	N	54.57	W	150	5,197	531	-20	24	17
Goose A	53.32	N	60.42	W	145	6,676	421	-31	25	16
St John's A	47.62	N	52.73	W	133	4,938	471	-16	23	18
Stephenville A	48.53	N	58.55	W	7	4,927	529	-19	22	18
Northwest Territories (NW)										
Ft Smith A	60.02	N	111.95	W	202	7,884	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	8,642	473	-39	23	15
Nova Scotia (NS)										
Halifax International A	44.88	N	63.52	W	126	4,518	813	-19	26	19
Kentville CDA	45.07	N	64.48	W	48	4,268	925	N.A.	N.A.	N.A.
Sydney A	46.17	N	60.05	W	55	4,647	715	-18	26	19
Truro	45.37	N	63.27	W	39	4,776	719	-23	25	19
Yarmouth A	43.83	N	66.08	W	42	4,175	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	4,198	1251	N.A.	N.A.	N.A.
Cornwall	45.02	N	74.75	W	63	4,479	1215	N.A.	N.A.	N.A.
Hamilton RBG	43.28	N	79.88	W	101	3,818	1361	N.A.	N.A.	N.A.
Kapuskasing A	49.42	N	82.47	W	226	6,523	616	-34	27	18
Kenora A	49.78	N	94.37	W	406	6,047	903	-33	27	18
Kingston A	44.22	N	76.60	W	92	4,348	1089	N.A.	N.A.	N.A.
London A	43.03	N	81.15	W	277	4,203	1181	-19	28	21
North Bay A	46.35	N	79.43	W	357	5,441	838	-28	26	19
Oshawa WPCP	43.87	N	78.83	W	83	4,029	1170	N.A.	N.A.	N.A.
Ottawa International A	45.32	N	75.67	W	115	4,762	1136	-25	28	21

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

Province City	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%
(Ontario cont.)										
Owen Sound MOE	44.58	N	80.93	W	178	4,294	1053	N.A.	N.A.	N.A.
Peterborough	44.28	N	78.32	W	193	4,465	1097	N.A.	N.A.	N.A.
St Catharines	43.20	N	79.25	W	90	3,722	1424	N.A.	N.A.	N.A.
Sudbury A	46.62	N	80.80	W	347	5,550	865	-28	27	19
Thunder Bay A	48.37	N	89.32	W	198	5,868	666	-30	27	19
Timmins A	48.57	N	81.37	W	294	6,319	681	-33	27	18
Toronto Downsview A	43.75	N	79.48	W	197	4,059	1317	-20	29	21
Windsor A	42.27	N	82.97	W	189	3,677	1488	-17	30	22
Prince Edward Island (PE)										
Charlottetown A	46.28	N	63.13	W	47	4,777	778	-21	25	19
Summerside A	46.43	N	63.83	W	23	4,673	853	-21	25	19
Quebec (PQ)										
Bagotville A	48.33	N	71.00	W	158	5,891	722	-31	27	18
Drummondville	45.88	N	72.48	W	81	4,778	1124	N.A.	N.A.	N.A.
Granby	45.38	N	72.70	W	167	4,648	1102	N.A.	N.A.	N.A.
Montreal Dorval International A	45.47	N	73.75	W	30	4,603	1192	-24	28	21
Quebec A	46.80	N	71.38	W	69	5,249	873	-27	27	20
Rimouski	48.45	N	68.52	W	35	5,369	675	N.A.	N.A.	N.A.
Sept-Iles A	50.22	N	66.27	W	54	6,271	383	-29	21	15
Shawinigan	46.57	N	72.75	W	121	5,137	956	N.A.	N.A.	N.A.
Sherbrooke A	45.43	N	71.68	W	237	5,258	762	-29	27	20
St Jean de Cherbourg	48.88	N	67.12	W	350	6,265	445	N.A.	N.A.	N.A.
St Jerome	45.80	N	74.05	W	169	5,095	984	N.A.	N.A.	N.A.
Thetford Mines	46.10	N	71.35	W	380	5,382	792	N.A.	N.A.	N.A.
Trois Rivieres	46.37	N	72.60	W	52	5,069	981	N.A.	N.A.	N.A.
Val d'Or A	48.07	N	77.78	W	336	6,253	663	-33	27	18
Valleyfield	45.28	N	74.10	W	45	4,491	1260	N.A.	N.A.	N.A.
Saskatchewan (SK)										
Estevan A	49.22	N	102.97	W	571	5,607	996	-32	30	18
Moose Jaw A	50.33	N	105.55	W	576	5,549	1007	-33	31	18

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

Province City	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%
(Saskatchewan cont.)										
North Battleford A	52.77	N	108.25	W	547	6,182	818	-35	28	17
Prince Albert A	53.22	N	105.68	W	427	6,672	696	-37	27	18
Regina A	50.43	N	104.67	W	576	5,985	900	-34	29	18
Saskatoon A	52.17	N	106.68	W	500	6,177	854	-35	29	17
Swift Current A	50.28	N	107.68	W	817	5,627	856	-32	29	17
Yorkton A	51.27	N	102.47	W	497	6,351	820	-34	28	18
Yukon Territory (YT)										
Whitehorse A	60.72	N	135.07	W	702	7,109	339	-37	23	13

TABLE D-3 International Climatic Data

Province 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%
Argentina											
Buenos Aires/Ezeiza		34.82	S	58.53	W	20	1,228	2,607	-1	32	22
Cordoba		31.32	S	64.22	W	474	1,009	2,879	-1	33	22
Tucuman/Pozo		26.85	S	65.10	W	440	637	3,679	N.A.	N.A.	N.A.
Australia											
Adelaide	SA	34.95	S	138.53	E	6	1,157	2,434	4	33	18
Alice Springs	NT	23.80	S	133.90	E	543	634	4,321	1	39	18
Brisbane	QL	27.43	S	153.08	E	2	303	3,894	7	30	22
Darwin Airport	NT	12.43	S	130.87	E	29	0	6,520	18	33	24
Perth/Guildford	WA	31.92	S	115.97	E	17	837	2,974	5	35	19
Sydney/K Smith	NSW	33.95	S	151.18	E	6	751	2,922	6	29	19
Azores											
Lajes	Terceira	38.75	N	27.08	W	55	711	2,718	8	26	22
Bahamas											
Nassau		25.05	N	77.47	W	3	16	5,431	14	32	26

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

Province 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%
Belgium											
Brussels Airport		50.90	N	4.47	E	39	3,033	1,034	-9	26	19
Bermuda											
St Georges/Kindley		32.37	N	64.68	W	6	94	4,647	N.A.	N.A.	N.A.
Bolivia											
La Paz/El Alto		16.50	S	68.18	W	4,050	3,994	132	-4	17	7
Brazil											
Belem		1.43	S	48.48	W	24	0	6,418	22	32	26
Brasilia		15.77	S	47.93	W	1,161	32	4,413	9	31	18
Fortaleza		3.72	S	38.55	W	19	1	6,527	22	32	26
Porto Alegre		30.08	S	51.18	W	7	501	3,931	4	33	24
Recife/Curado		8.13	S	34.92	W	11	1	6,084	21	33	26
Rio de Janeiro		22.90	S	43.17	W	5	8	5,382	15	37	25
Salvador/Ondina		13.00	S	38.52	W	51	0	5,992	20	31	26
Sao Paulo		23.50	S	46.62	W	795	248	4,011	9	31	21
Bulgaria											
Sofia		42.82	N	23.38	E	595	3,127	1,393	-12	29	18
Chile											
Concepcion		36.77	S	73.05	W	12	1,977	1,268	2	23	17
Punta Arenas/Chabunco		53.03	S	70.85	W	33	4,337	219	-5	16	12
Santiago/Pedahuel		33.38	S	70.88	W	480	1,567	1,928	-2	31	18
China											
Shanghai/Hongqiao		31.17	N	121.43	E	5	1,768	2,847	-3	33	27
Cuba											
Guantanamo Bay NAS	Ote.	19.90	N	75.15	W	23	0	6,511	19	34	26
Cyprus											
Akrotiri		34.58	N	32.98	E	23	715	3,415	4	32	22
Larnaca		34.88	N	33.63	E	2	807	3,349	3	33	22
Paphos		34.75	N	32.40	E	9	711	3,291	4	30	24

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

Province 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%
Czech Republic (Former Czechoslovakia)											
Prague/Libus		50.00	N	14.45	E	305	3,542	1,029	-16	27	18
Dominican Republic											
Santo Domingo		18.47	N	69.88	W	13	0	6,034	N.A.	N.A.	N.A.
Egypt											
Cairo		30.13	N	31.40	E	74	463	4,441	7	36	21
Luxor		25.67	N	32.70	E	88	323	5,472	4	42	22
Finland											
Helsinki/Seutula		60.32	N	24.97	E	51	5,028	632	-24	24	16
France											
Lyon/Satolas		45.73	N	5.08	E	248	2,739	1,449	-8	30	21
Marseille		43.45	N	5.22	E	8	1,774	2,185	-4	31	21
Nantes		47.17	N	1.60	W	27	2,381	1,378	-5	28	20
Nice		43.65	N	7.20	E	10	1,467	2,213	2	28	23
Paris/Le Bourget		48.97	N	2.45	E	66	2,803	1,228	-8	28	20
Strasbourg		48.55	N	7.63	E	153	3,074	1,218	-11	29	20
Germany											
Berlin/Schoenfeld		52.38	N	13.52	E	47	3,517	1,011	-12	28	18
Hamburg		53.63	N	9.98	E	16	3,511	872	-12	26	18
Hannover		52.47	N	9.70	E	55	3,385	961	-13	27	18
Mannheim		49.53	N	8.50	E	97	3,016	1,257	N.A.	N.A.	N.A.
Greece											
Souda	Crete	35.55	N	24.12	E	127	982	3,040	4	32	19
Thessalonika/Mikra		40.52	N	22.97	E	8	1,883	2,286	-4	32	21
Greenland											
Narssarssuaq		61.18	N	45.42	W	24	6,401	162	-28	17	9
Hungary											
Budapest/Lorinc		47.43	N	19.18	E	140	3,074	1,471	-13	30	20
Iceland											
Reykjavik		64.13	N	21.93	W	61	5,159	163	-10	14	11

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

Province 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%
India											
Ahmedabad		23.07	N	72.63	E	55	17	6,471	11	41	23
Bangalore		12.97	N	77.58	E	920	1	5,227	15	33	19
Bombay/Santa Cruz		19.12	N	72.85	E	8	1	6,318	17	34	23
Calcutta/Dum Dum		22.65	N	88.45	E	5	14	6,147	12	36	26
Madras		13.00	N	80.18	E	16	0	6,891	20	37	25
Nagpur Sonegaon		21.10	N	79.05	E	309	10	6,263	12	42	22
New Delhi/Safdarjung		28.58	N	77.20	E	214	267	5,589	7	41	22
Indonesia											
Djakarta/Halimperda	Java	6.25	S	106.90	E	30	0	6,376	N.A.	N.A.	N.A.
Kupang Penfui	Sunda Island	10.17	S	123.67	E	108	1	6,492	N.A.	N.A.	N.A.
Makassar	Celebes	5.07	S	119.55	E	17	2	6,378	N.A.	N.A.	N.A.
Medan	Sumatra	3.57	N	98.68	E	26	0	6,384	N.A.	N.A.	N.A.
Palembang	Sumatra	2.90	S	104.70	E	10	0	6,425	N.A.	N.A.	N.A.
Surabaja Perak	Java	7.22	S	112.72	E	3	0	6,716	N.A.	N.A.	N.A.
Ireland											
Dublin Airport		53.43	N	6.25	W	85	3,059	709	-2	21	16
Shannon Airport		52.68	N	8.92	W	20	2,837	808	-2	22	17
Israel											
Jerusalem		31.78	N	35.22	E	809	1,346	2,561	1	30	18
Tel Aviv Port		32.10	N	34.78	E	10	531	3,806	7	30	23
Italy											
Milano/Linate		45.43	N	9.28	E	107	2,504	1,853	-6	31	22
Napoli/Capodichino		40.88	N	14.30	E	72	1,477	2,389	0	32	23
Roma/Fiumicino		41.80	N	12.23	E	2	1,491	2,318	-1	30	23
Jamaica											
Kingston/Manley		17.93	N	76.78	W	14	0	6,589	22	37	26
Montego Bay/Sangster		18.50	N	77.92	W	1	1	6,064	21	32	26
Japan											
Fukaura		40.65	N	139.93	E	68	3,068	1,629	-1	33	26
Sapporo		43.05	N	141.33	E	17	3,752	1,399	-11	27	22
Tokyo		35.68	N	139.77	E	36	1,659	2,638	-1	31	25

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

Province 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%
Jordan											
Amman		31.98	N	35.98	E	767	1,298	3,015	1	33	18
Kenya											
Nairobi Airport		1.32	S	36.93	E	1,624	152	3,432	9	28	16
Korea											
Pyonggang		38.40	N	127.30	E	371	3,742	1,578	-16	29	23
Seoul		37.57	N	126.97	E	86	2,782	2,198	N.A.	N.A.	N.A.
Malaysia											
Kuala Lumpur		3.13	N	101.55	E	17	0	6,406	22	34	26
Penang/Bayan Lepas		5.30	N	100.27	E	3	0	6,373	N.A.	N.A.	N.A.
Mexico											
Mexico City	Distrito Federal	19.40	N	99.20	W	1,589	389	3,401	4	28	14
Guadalajara	Jalisco	20.67	N	103.38	W	9	6	6,179	N.A.	N.A.	N.A.
Monterrey	Nuevo Laredo	25.87	N	100.20	W	1,941	414	3,079	N.A.	N.A.	N.A.
Tampico	Tamaulipas	22.22	N	97.85	W	168	0	5,978	10	32	27
Veracruz	Veracruz	19.15	N	96.12	W	2,181	1,221	2,139	14	33	27
Merida	Yucatan	20.98	N	89.65	W	22	662	5,799	14	37	24
Netherlands											
Amsterdam/Schiphol		52.30	N	4.77	E	-4	3,162	899	-8	25	18
New Zealand											
Auckland Airport		37.02	S	174.80	E	7	1,246	2,028	2	24	19
Christchurch		43.48	S	172.55	E	36	2,422	1,175	-2	26	16
Wellington		41.28	S	174.77	E	128	1,998	1,254	2	22	17
Norway											
Bergen/Florida		60.38	N	5.33	E	39	3,823	563	-9	20	14
Oslo/Fornebu		59.90	N	10.62	E	16	4,456	739	-18	25	17
Pakistan											
Karachi Airport		24.90	N	67.13	E	23	642	6,138	N.A.	N.A.	N.A.
Papua New Guinea											
Port Moresby		9.43	S	147.22	E	28	1	6,262	N.A.	N.A.	N.A.

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

Province 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%
Paraguay											
Asuncion/Stroessner		25.27	S	57.63	W	101	261	5,003	5	35	24
Peru											
Lima-Callao/Chavez		12.00	S	77.12	W	13	144	3,747	14	29	23
San Juan de Marcona		15.35	S	75.15	W	60	170	3,758	N.A.	N.A.	N.A.
Talara		4.57	S	81.25	W	86	2	4,985	16	31	24
Philippines											
Manila Airport	Luzon	14.52	N	121.00	E	23	0	6,361	21	34	27
Philippines (PH) - Angeles, Clark AFB		15.18	N	120.55	E	196	0	6,267	20	35	25
Poland											
Krakow/Balice		50.08	N	19.80	E	237	3,847	1,115	-18	27	19
Puerto Rico											
San Juan/Isla Verde WSFO		18.43	N	66.0	W	3	0	6,337	21	32	26
Romania											
Bucuresti/Bancasa		44.50	N	26.13	E	94	3,034	1,638	-13	31	21
Russia (Former Soviet Union)											
Kaliningrad	East Prussia	54.70	N	20.62	E	27	3,953	883	-19	25	18
Krasnoiarsk		56.00	N	92.88	E	194	6,266	751	-34	27	17
Moscow Observatory		55.75	N	37.57	E	156	4,776	949	-23	26	18
Petropavlovsk		53.02	N	158.72	E	7	5,615	294	-15	19	14
Rostov-Na-Donu		47.25	N	39.82	E	79	3,533	1,675	-17	30	20
Vladivostok		43.12	N	131.90	E	138	4,953	960	-22	24	19
Volgograd		48.68	N	44.35	E	145	4,199	1,578	-21	31	18
Saudi Arabia											
Dhahran		26.27	N	50.17	E	22	212	6,076	N.A.	N.A.	N.A.
Riyadh		24.70	N	46.73	E	611	298	5,958	5	43	18
Senegal											
Dakar/Yoff		14.73	N	17.50	W	27	3	5,417	16	31	25
Singapore											
Singapore/Changi		1.37	N	103.98	E	15	0	6,664	23	32	26

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

Province 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%
South Africa											
Cape Town/D F Malan		33.97	S	18.60	E	46	936	2,474	3	28	19
Johannesburg		26.13	S	28.23	E	1,694	1,066	2,362	1	28	16
Pretoria		25.73	S	28.18	E	1,330	639	3,238	4	31	17
Spain											
Barcelona		41.28	N	2.07	E	4	1,466	2,203	0	29	23
Madrid		40.47	N	3.57	W	582	2,038	2,057	-4	34	20
Valencia/Manises		39.50	N	0.47	W	203	1,942	5,045	34	88	72
Sweden											
Stockholm/Arlanda		59.65	N	17.95	E	61	4,513	721	-19	25	16
Switzerland											
Zurich		47.38	N	8.57	E	569	3,342	1,108	-11	27	18
Syria											
Damascus Airport		33.42	N	36.52	E	610	1,539	2,941	-4	37	18
Taiwan											
Tainan		22.95	N	120.20	E	16	83	5,405	11	33	27
Taipei		25.03	N	121.52	E	8	243	4,942	9	34	27
Tanzania											
Dar es Salaam		6.88	S	39.20	E	55	2	5,975	N.A.	N.A.	N.A.
Thailand											
Bangkok		13.73	N	100.57	E	16	0	6,906	18	36	26
Tunisia											
Tunis/El Aouina		36.83	N	10.23	E	5	921	3,205	5	34	23
Turkey											
Adana		37.00	N	35.42	E	66	1,026	3,388	0	34	22
Ankara/Etimesgut		39.95	N	32.68	E	806	2,868	1,709	-17	30	17
Istanbul/Yesilkoy		40.97	N	28.82	E	37	1,963	2,098	-3	29	21
United Kingdom											
Birmingham	England	52.45	N	1.73	W	99	3,259	753	-6	24	17
Edinburgh	Scotland	55.95	N	3.35	W	41	3,526	556	-6	21	16

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

Province 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%
(UK cont.)											
Glasgow Apt	Scotland	55.87	N	4.43	W	7	3,493	578	-6	22	16
London/Heathrow	England	51.48	N	0.45	W	24	2,786	1,052	-4	26	18
Uruguay											
Montevideo/Carrasco		34.83	S	56.03	W	33	1,180	2,557	2	30	22
Venezuela											
Caracas/Maiquetia		10.60	N	66.98	W	72	5	6,389	21	33	28
Vietnam											
Hanoi/Gialam		21.02	N	105.80	E	8	183	5,482	N.A.	N.A.	N.A.
Saigon (Ho Chi Minh)		10.82	N	106.67	E	19	0	6,698	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 90.1-2004 and to acknowledge source documents when appropriate. Some documents are also included in Section 12 – Normative References because there are other citations of that document 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, Illinois 61801
http://www.bso.uiuc.edu/BLAST/index.html

DOE-2
Building Energy Simulation news
http://simulationresearch.lbl.gov/un.html

MICA
Midwest Insulation Contractors Association
16712 Elm Circle
Omaha, NE 68130
http://www.micainsulation.org

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

SMACNA
Sheet Metal & Air Conditioning Contractors' National Association
4201 Lafayette Center Drive
Chantilly, VA 20151
info@smacna.org
http://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
http://resourcecenter.ashrae.org/store/ashrae/

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

Subsection No.	Reference	Title/Source
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
11.2.1	DOE-2	Support provided by Lawrence Berkeley National Lab 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 90.1-2004 incorporates ANSI/ASHRAE/IESNA Standard 90.1-2001 and Addenda a, b, c, d, e, g, h, i, j, k, m, n, o, p, q, r, s, t, u, x, y, z, aa, ab, ac, ae, ag, ah, ai, ak, al, and am to ANSI/ASHRAE/IESNA Standard 90.1-2001. Table F-1 lists each addendum and describes the way in which the text is affected by the change. Table F-2 states the ASHRAE and ANSI approval dates.

TABLE F-1 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2001, Changes Identified

Addenda to 90.1-2001	Sections Affected	Description of Changes[a]
90.1a	4. Administration and Enforcement	Addendum deletes Section 4.4.7 in its entirety. Requirements for *transformer*s were deleted from a prior draft of the standard, and Section 4.4.7 was inadvertently not deleted at the same time the transformer requirements were deleted. Without the transformer requirements in Section 8, or any sort of indication as to what transformers were to be labeled, the requirement for labeling transformers with their "energy-efficiency level" in Section 4.4.7 became meaningless or confusing.
90.1b	6. Heating, Ventilating, and Air Conditioning	Change to 6.2.1, Mechanical Equipment Efficiency, relates to the certification program for product performance verification.
90.1c	6. Heating, Ventilating, and Air Conditioning	This change modifies Table 6.2.4.3B, Duct Seal Levels, with regard to pressure-sensitive tape.
90.1d	6. Heating, Ventilating, and Air Conditioning	This change to Table 6.2.1D establishes minimum efficiency standards for single-package vertical air-conditioners (SPVAC) and heat pumps (SPVHP). It is consistent with DOE's decision to regulate SPVUs under EPACT.
90.1e	11. Energy Cost Budget Method	New Informative Appendix G is for use in rating the performance of building designs. This is an informative appendix because it is not to be included as part of the minimum requirements to comply with code. The appendix parallels Section 11, on which it is based, and is an attempt at providing a generic method that can be referenced by any rating agency.
90.1g	Tables 9.3.1.1 and 9.3.1.2 Lighting Power Densities	This replacement of Tables 9.3.1.1 and 9.3.1.2 of 90.1-2001 including the Lighting Power Density (LPD) values represents a complete review and update of the inputs to the space and building models used to derive these values.
90.1h	12. Normative References and Normative Appendix A	This addendum updates the references in Section 12 and the test procedure references in Sections A9.3.1 and A9.3.2.
90.1i	6. Heating, Ventilating, and Air Conditioning	This addendum revises Tables 6.2.1A and 6.2.1B to reflect newly adopted DOE efficiency standards for single-phase air conditioners and heat pumps less than 65,000 Btu/h.
90.1j	9. Lighting	This addendum applies to the exceptions to 9.3.1, Interior Lighting Power, specifically exception (n), athletic playing areas.
90.1k	6. Heating, Ventilating, and Air Conditioning	Change to 6.2.3.1.1, General, relates to zone and loop controllers.
90.1m	7. Service Water Heating	Addendum added requirement for heat pump pool heaters to Table 7.2.2.
90.1n	6. Heating, Ventilating, and Air Conditioning	Addendum provides detailed explanations of control means to clarify the intent of supplemental heater control requirements in 6.1.3 (g), Simplified Approach Option for HVAC Systems.
90.1o	6. Heating, Ventilating, and Air Conditioning	This addendum deletes exception (d) in Section 6.3.1.
90.1p	11. Energy Cost Budget Method	This addendum adds a new Section 11.2.1.4 containing a reference to ASHRAE Standard 140.
90.1q	9. Lighting	This addendum revises the exterior lighting requirements in Sections 9.2.1.3 and 9.3.2 as well as Table 9.3.2.
90.1r	6. Heating, Ventilating, and Air Conditioning	This addendum adds requirements for return duct insulation to Table 6.2.4.2B.

TABLE F-1 *(continued)* Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2001, Changes Identified

Addenda to 90.1-2001	Sections Affected	Description of Changes[a]
90.1s	6. Heating, Ventilating, and Air Conditioning	This addendum revises exceptions (g) and (i) in Section 6.3.6.1.
90.1t	9. Lighting	Change to the exceptions to the automatic control device requirement for building lighting in exceptions to 9.2.1.1.
90.1u	6. Heating, Ventilating, and Air Conditioning	Change to Tables 6.3.1.1.3.A and 6.3.1.1.3B to add dew point or mixing ration with temperature shutoff control types and required high-limit values for these type of controls.
90.1x	6. Heating, Ventilating, and Air Conditioning	Change to Sections 6.1.3i and 6.2.3.2, and the addition of a new Section 6.2.3.3.5, Ventilation Fan Controls.
90.1y	6. Heating, Ventilating, and Air Conditioning	Change to Section 6.3.3.2.1, Part-Load Fan Power Limitation, to reduce the requirement for VAV fans with motors from 30 hp to 15 hp.
90.1z	6. Heating, Ventilating, and Air Conditioning	Change to the Exception to 6.2.1.
90.1aa	6. Heating, Ventilating, and Air Conditioning and 12. Normative References	Change to update all of the normative references in Section 12 including the test procedure references in Tables 6.2.1A and 6.2.1B to reflect the newly published ARI Standard 210/240-2003.
90.1ab	6. Heating, Ventilating, and Air Conditioning	Change to exceptions to 6.3.6.1 (d), Exhaust Air Energy Recovery, relating to commercial kitchen hoods.
90.1ac	11. Energy Cost Budget Method	Change to Sections 11.3.1, exceptions to 11.3.6, 11.3.8, 11.3.9, Note 7 of Table 11.4.3A, and Section 11.4.3.
90.1ae	9. Lighting	Change to Section 9.2.1.1, Space Control.
90.1ag	Table 9.3.1.2	This revision of the retail “sales area” LPD value is a correction of the previously approved Addendum g to the 90.1-2001 standard. When the initial table of space-by-space method LPDs was prepared for Addendum g public review, the “Retail Sales area” was inadvertently left at the previous 90.1-2001 value of 2.1 W/ft^2 (23 W/m^2). The correct value produced by the applicable space type models is 1.7 W/ft^2 (18 W/m^2), which should have been included in Addendum g to 90.1-2001. This addendum seeks to correct this oversight.
90.1ah	Tables D-1 and D-3	This addendum is intended to add new weather data for nine new locations, including the District of Columbia (to remedy an earlier omission) plus six locations in the U.S. Territories and a new location in the Philippines. These additions do not impact the stringency of the standard but simply increase its usability.
90.1ai	9. Lighting	Change to Section 9.2.3, Exit Signs, to require a maximum of 5 watt per face of exit signs.
90.1ak	Table 6.2.1G, Performance Requirements for Heat Rejection Equipment, and Section 6.2.1	Change to 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.
90.1al	Informative Appendix E, Informative References	Change to Appendix E to update references related to building energy simulation software and annual weather data.
90.1am	5. Building Envelope and 6. HVAC	Changes to Sections 5 and 6 plus Appendices B and D to reduce the climatic data tables from 26 to 8 climate zones. This is consistent with the DOE and IECC climate tables.

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

TABLE F-2 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2001, Approval Dates

Addenda to 90.1-2001	ASHRAE Standards Committee Approval Date	ASHRAE Board of Directors Approval Date	ANSI Approval Date	IESNA Board of Directors Approval Date
90.1a	January 25, 2003	January 30, 2003	April 3, 2003	December 7, 2002
90.1b	June 22, 2002	June 27, 2002	July 30, 2002	June 2, 2002
90.1c	June 22, 2002	June 27, 2002	July 30, 2002	June 2, 2002
90.1d	June 22, 2002	June 27, 2002	July 30, 2002	June 2, 2002
90.1e	January 24, 2004	January 29, 2004	March 31, 2004	December 6, 2003
90.1g	June 28, 2003	July 3, 2003	August 6, 2003	March 3, 2003
90.1h	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1i	June 28, 2003	July 3, 2003	August 6, 2003	August 3, 2003
90.1j	June 28, 2003	July 3, 2003	August 6, 2003	August 3, 2003
90.1k	September 17, 2002	October 14, 2002	December 17, 2002	December 7, 2002
90.1m	January 25, 2003	January 30, 2003	April 3, 2003	December 7, 2002
90.1n	June 28, 2003	July 3, 2003	September 25, 2003	August 3, 2003
90.1o	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1p	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1q	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004
90.1r	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1s	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1t	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1u	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004
90.1x	May 10, 2004	July 1, 2004	August 5, 2004	March 30, 2004
90.1y	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1z	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1aa	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1ab	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1ac	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004
90.1ae	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004
90.1ag	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1ah	April 28, 2004	July 1, 2001	July 1, 2001	March 30, 2004
90.1ai	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004
90.1al	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004
90.1am	June 26, 2004	July 1, 2001	July 1, 2001	July 25, 2004

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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, it 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 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met.These sections contain the mandatory provisions of the standard, and are prerequisites for this rating method.The improved performance of the proposed building design is calculated in accordance with provisions of this appendix using the following formula:Percentage improvement = 100 × (*Baseline building performance - Proposed building performance*) / *Baseline building performance*

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, and
(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) 8,760 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 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*.

G2.3 Climate Data. The *simulation program* shall perform the simulation using hourly values of climate data, such as temperature and humidity from representative climate data, for the site in which the *proposed design* is to be located. For cities or urban regions with several climate 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 (http://www.eia.doe.gov/).

Exception to G2.4: 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.

Exceptions to G3.1.1:

(a) Use additional system type(s) for non-predominant 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

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.

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.

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. (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 9.5.1 or 9.6.1. The user shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories. More than one building type category may be used in a building if it is a mixed-use facility. If space type categories are used, the user may simplify the placement of the various space types within the building model, provided that building-total areas for each space type are accurate.	Same as Proposed Design

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

No.	Proposed Building Performance	Baseline Building Performance
4. Schedules		
	Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation shall be used. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *rating authority.* **HVAC Fan Schedules**. Schedules for HVAC fans shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours. **Exception:** Where no heating and/or cooling system is to be installed and a heating or cooling system is being simulated only to meet the requirements described in this table, heating and/or cooling system fans shall not be simulated as running continuously during occupied hours but shall be cycled on and off to meet heating and cooling loads during all hours.	Same as Proposed Design. **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.
5. Building Envelope		
	All components of the *building envelope* in the *proposed design* shall be modeled as shown on architectural drawings or as built for existing building envelopes. **Exceptions:** The following building elements are permitted to differ from architectural drawings. (a) All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor stabs, concrete floor beams over parking garages) shall be separately modeled. 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. Reflectance values shall be based on testing in accordance with ASTM E903, ASTM E1175, or ASTM E1918, and the emittance values shall be based on testing in accordance with ASTM C835, ASTM C1371, or ASTM E408. 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.	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, 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 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 uniformly in horizontal bands across the four orientations. Fenestration U-factors shall match the appropriate requirements in Tables 5.5-1 through 5.5-8 for the applicable vertical glazing percentage for U_{fixed}. Fenestration solar heat gain coefficient (SHGC) shall match the appropriate requirements in Tables 5.5-1 through 5.5-8 using the value for $SHGC_{all}$ for the applicable vertical glazing percentage. All vertical glazing shall be modeled as fixed and 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 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.

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

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 shall be used in the model. (b) Where a lighting system has been designed, lighting power shall be determined in accordance with 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 living 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, but exclude these loads when calculating the *baseline building performance* and *proposed building performance*. (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 9.2, 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 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.

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

No.	Proposed Building Performance	Baseline Building Performance
8.	**Thermal Blocks – HVAC Zones Not Designed**	
	Where the HVAC zones and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines: (a) Separate *thermal blocks* shall be assumed for interior and perimeter spaces. Interior spaces shall be those located greater than 5 m from an exterior wall. Perimeter spaces shall be those located within 5 m of an exterior wall. (b) Separate *thermal blocks* shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except that orientations that differ by less than 45 degrees may be considered to be the same orientation. Each zone shall include all floor area that is 5 m or less from a glazed perimeter wall, except that floor area within 5 m of glazed perimeter walls having more than one orientation shall be divided proportionately between zones. (c) Separate *thermal blocks* shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. (d) Separate *thermal blocks* shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features.	Same as Proposed Design.
9.	**Thermal Blocks - Multifamily Residential Buildings**	
	Residential spaces shall be modeled using at least one *thermal block* per living unit, except that those units facing the same orientations may be combined into one *thermal block*. Corner units and units with roof or floor loads shall only be combined with units sharing these features.	Same as Proposed Design.
10.	**HVAC Systems**	
	The HVAC system type and all related performance parameters in the *proposed design*, such as equipment capacities and efficiencies, shall be determined as follows: (a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. (b) Where an HVAC system has been designed, 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 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 G3.1.1, shall meet the general HVAC system requirements specified in G3.1.2, and shall meet any system-specific requirements in G3.1.3 that are applicable to the baseline HVAC system type(s).

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

No.	Proposed Building Performance	Baseline Building Performance
11. Service Hot Water Systems		
	The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed design* shall be determined as follows: (a) Where a complete service hot water system exists, the *proposed design* shall reflect the actual system type using actual component capacities and efficiencies. (b) Where a service hot water system has been specified, the service hot water model shall be consistent with design documents. (c) Where no service hot water system exists or has been specified but the building will have service hot water loads, a service hot water system shall be modeled that matches the system in the *baseline building design* and serves the same hot water loads. (d) For buildings that will have no service hot water loads, no service hot water system shall be modeled.	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 a complete service hot water system exists, the *baseline building design* shall reflect the actual system type using actual component capacities and efficiencies. (b) Where a new service hot water system has been specified, 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 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 6.5.6.2, and no heat-recovery system shall be included in the *proposed* or *baseline building designs*.
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*. 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.
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 & Purchased Heat	Electric and Other
Residential	System 1 – PTAC	System 2 - PTHP
Nonresidential & 3 Floors or Less & < 7,000 m^2	System 3 – PSZ-AC	System 4 – PSZ-HP
Nonresidential & 4 or 5 Floors & < 7,000 m^2 or 5 Floors or Less & 7,000 m^2 to 14,000 m^2	System 5 - Packaged VAV w/ Reheat	System 6 - Packaged VAV w/PFP Boxes
Nonresidential & More than 5 Floors or > 14,000 m^2	System 7 - VAV w/Reheat	System 8 - VAV w/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.

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 w/ Reheat	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Hot Water Fossil Fuel Boiler
6. Packaged VAV w/PFP Boxes	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Electric Resistance
7. VAV w/Reheat	Packaged rooftop variable air volume with reheat	VAV	Chilled Water	Hot Water Fossil Fuel Boiler
8. VAV w/PFP Boxes	Variable air volume with reheat	VAV	Chilled Water	Electric Resistance

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 8,760 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.

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

Exception to G3.1.2.5: When modeling demand-control ventilation in the *proposed design* when its use is not required by 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 and 4 as specified in Table G3.1.2.6A based on building conditioned floor area, whether the zone served is an interior or perimeter zone, and climate. *Outdoor air* economizers shall be included in *baseline* HVAC Systems 5 through 8 based on climate as specified in Table G3.1.2.6B. Any zone having more than half of its floor area more than 5 m from a glazed exterior wall is considered an interior zone for purposes of applying Tables G3.1.2.6A and B.

TABLE G3.1.2.6A Minimum Building Conditioned Floor Areas at which Economizers are Included for Baseline Systems 3 and 4

Climate Zone	Area Interior	Area Perimeter
1a,1b,2a,3a,4a	N.R.	N.R.
2b,5a,6a,7,8	1,400 m^2	N.R.
3b,3c,4b,4c,5b,5c,6b	900 m^2	2,300 m^2

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 Climate Conditions under which Economizers are Included for Baseline Systems 5 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 G3.1.2.6C 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

Exceptions to G3.1.2.6: 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 6.1.2 of ANSI/ASHRAE Standard 62. This exception shall be used only if the system in the *proposed design* does not match *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 G3.1.2.6C.

G3.1.2.8 Design Air Flow Rates. System design supply air flow rates for the *baseline 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 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 Supply Fan Power. System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:

$$P_{fan} = 746 / (1 - e^{[-0.2437839 \times \ln(bhp) - 1.685541]}) \times bhp$$

where

P_{fan} = electric power to fan motor (watts) and

bhp = brake horsepower of *baseline* fan motor from Table G3.1.2.9, where cfm represents design supply flow rate.

Exception to 3.1.2.9. If systems in the *proposed design* require air filtering systems with pressure drops in excess of 1 in. w.c. when filters are clean, the allowable fan system power in the *baseline design* system serving the same space may be increased using the following pressure credit:

$$\text{Pressure Credit (watts)} = CFM_{filter} * (Sp_{filter} - 1)/4.984$$

where

CFM_{filter} = supply air volume of the proposed system with air filtration system in excess of 250 Pa

Sp_{filter} = air pressure drop of the filtering system in w.g. when the filters are clean.

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.

TABLE G3.1.2.9 Baseline Fan Brake Horsepower

Supply Air Volume	*Baseline* Fan Motor Brake Horsepower	
	Constant Volume Systems 1 – 4	Variable Volume Systems 5 – 8
< 9400 L/s	17.25 + (cfm - 20000) x 0.0008625	24 + (cfm - 20000) x 0.0012
≥ 9400 L/s	17.25 + (cfm - 20000) x 0.000825	24 + (cfm - 20000) x 0.001125

Exceptions to G3.1.2.10: 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 air* flow. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.

(g) Systems requiring dehumidification that employ energy recovery in series with the cooling coil. This exception shall only be used if exhaust air energy recovery and series-style energy recovery coils are not used in the *proposed design.*

G3.1.3 System-Specific *Baseline* HVAC System Requirements. *Baseline* HVAC systems shall conform with provisions in this section, where applicable, to the specified *baseline* system types as indicated in section headings.

G3.1.3.1 Heat Pumps (Systems 2 and 4). Electric air-source heat pumps shall be modeled with electric auxiliary heat. The systems shall be controlled with multi-stage 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 under 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.

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 conditioned floor area.

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 serving 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 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 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. 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.

G3.1.3.12 Supply Air Temperature Reset (Systems 5 through 8). Supply air temperature shall be reset based on zone demand from the design temperature difference to a

TABLE G3.1.3.7 Type and Number of Chillers

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

5.6°C temperature difference under minimum load conditions. Design air flow rates shall be sized for the reset supply air temperature, i.e., a 5.6°C temperature difference.

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.

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 Devices(s)	Non-24-hr and ≤ 460m^2	All Other
(1) Programmable timing control	10%	0%
(2) Occupancy sensor	15%	10%
(3) Occupancy sensor and programmable timing control	15%	10%

Notes: 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 at the Annual Meeting (normally June) if proposed changes are received by the MOS no later than December 31. Proposals received after December 31 shall be considered by the SSPC no later than at the Annual Meeting of the following year.

Proposed changes must be submitted to the Manager of Standards (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.

FORM FOR SUBMITTAL OF PROPOSED CHANGE TO ASHRAE STANDARD UNDER CONTINUOUS MAINTENANCE

NOTE: Use separate form for each comment. Submittals (MS Word 2000 preferred) may be attached to e-mail (preferred), submitted on diskettes or 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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2. **Number and year of standard**:

3. **Clause (section), sub-clause or paragraph number; and page number**:

4. **I propose to**: (*check one*)
   - [ ] Change to read as follows
   - [ ] Delete and substitute as follows
   - [ ] Add new text as follows
   - [ ] Delete without substitution

Use underscores to show material to be added (added) and strike through material to be deleted (~~deleted~~). Use additional pages if needed.

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6. **Reason and substantiation**:

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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 Microsoft Word 7 (preferred) or higher or WordPerfect 5.1 for DOS format. Please save each change proposal file with a different name (example, prop001.doc, prop002.doc, etc., for Word files—prop001.wpm, prop002.wpm, etc., for WordPerfect files). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as wordprocessed or scanned documents.

Electronic change proposals may be submitted either as files (MS Word 7 preferred) attached to an e-mail (uuencode preferred) or on 3.5" floppy disk. ASHRAE will accept the following as equivalent to the signature required on the change submittal form to convey non-exclusive copyright:

Files attached to e-mail:	Electronic signature on change submittal form (as a picture; *.tif, or *.wpg).
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Submit e-mail or disks containing 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: 404-321-5478.)

The form and instructions for electronic submittal may be obtained from the Standards section of ASHRAE's Home Page, *http://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.
Email: *standards.section@ashrae.org.*

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86248
PC 1/05

ANSI/ASHRAE/IESNA Addendum *ad* to
ANSI/ASHRAE/IESNA Standard 90.1-2004

ASHRAE STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

Approved by the ASHRAE Standards Committee on February 3, 2005; by the ASHRAE Board of Directors on February 10, 2005; and by the American National Standards Institute on March 11, 2005.

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 U.S. and Canada).

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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.

Approved American National Standard
ANSI

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
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ASHRAE obtains consensus through participation of its national and international members, associated societies, and public review.

ASHRAE Standards are prepared by a Project Committee appointed specifically for the purpose of writing the Standard. The Project Committee Chair and Vice-Chair must be members of ASHRAE; while other committee members may or may not be ASHRAE members, all must be technically qualified in the subject area of the Standard. Every effort is made to balance the concerned interests on all Project Committees.

The Manager of Standards of ASHRAE should be contacted for:

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,
d. permission to reprint portions of the Standard.

ASHRAE INDUSTRIAL ADVERTISING POLICY ON STANDARDS

ASHRAE Standards and Guidelines are established to assist industry and the public by offering a uniform method of testing for rating purposes, by suggesting safe practices in designing and installing equipment, by providing proper definitions of this equipment, and by providing other information that may serve to guide the industry. The creation of ASHRAE Standards and Guidelines is determined by the need for them, and conformance to them is completely voluntary.

In referring to this Standard or Guideline and in marking of equipment and in advertising, no claim shall be made, either stated or implied, that the product has been approved by ASHRAE.

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

FOREWORD

The Cool Roof Rating Council is a not-for-profit organization that was established for a number of purposes, one of which is to implement and communicate fair, accurate, and credible radiative energy performance rating systems for roof surfaces.

In 2002 the Cool Roof Rating Council completed its task of initiating a roofing product rating program. The intent of the CRRC was to develop a program that was uniform for determining radiative properties of roofing products. The program allows manufacturers and sellers to have the opportunity to label their roofing products. The radiative properties (e.g., solar reflectance and thermal emittance) are determined and verified through both laboratory testing and a process of random testing.

This addendum identifies the CRRC program as a way to establish a common and uniform evaluation to determine compliance with the standard. Verification of a roofing product is available through two means: (1) a "label" that may be placed directly on the product, on the wrapping or container, or on the manufacturer's technical literature and (2) the Cool Roof Rating Council's Web site directory (http://www.coolroofs.org).

This addendum also deletes two of the ASTM standard test methods. The basis for this is that the CRRC determined through its development of the product rating program that, although those two test methods (ASTM C835 and E1175) were recognized as opportunities for compliance, the availability of these test methods (e.g., the number of testing laboratories open to the general public) is restricted.

The new test method (ASTM C1549) recognizes a test procedure that is considered comparable to the ASTM solar reflectance test methods currently cited. Although CRRC-1 cites its own testing procedure, it is effectively identical to the ASTM test. The reason for two test standards is directly related to the date of publication for each document. The CRRC-1 document was produced prior to ASTM producing their document.

Addendum *ad* to 90.1-2004 (I-P and SI editions)

Revise the following exception as shown:

Exception to 5.5.3.1: For roofs where the exterior surface has a minimum total solar reflectance of 0.70 when tested in accordance with one of the solar reflectance test methods listed below, and has a minimum thermal emittance of 0.75 when tested in accordance with one of the thermal emittance test methods below, other than roofs with ventilated attics or roofs with semiheated spaces, the U-factor of the proposed roof shall be permitted to be adjusted using Equation 5-1 for demonstrating compliance~~:~~. 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.

$$U_{roofadj} = U_{roofproposed} \times Factor_{roofmultiplier} \quad (5\text{-}1)$$

where

$U_{roofadj}$ = the adjusted roof U-factor for use in demonstrating compliance;

$U_{roofproposed}$ = the U-factor of the proposed roof, as designed;

$Factor_{roofmultiplier}$ = the roof U-factor multiplier from Table 5.5.3.1.

Solar Reflectance Test Methods: ASTM C1549, ASTM E903, ~~ASTM E1175,~~ or ASTM E1918.

Thermal Emittance Test Methods: ~~ASTM C835,~~ ASTM C1371~~,~~ or ASTM E408

Revise the normative references in Section 12 as follows:

12. NORMATIVE REFERENCES

American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959

~~ASTM C835-95 (1999), Standard Test Method for Total hemispherical Emittance of Surfaces from 20°C to 1400°C.~~

ASTM C1549-02, Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer.

~~ASTM E1175-87 (1996), Standard Test Method for Determining Solar or Photoic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere.~~

Revise the informative references in Appendix E as follows:

Informative Appendix E
Informative References

CRRC

Cool Roof Rating Council

1738 Excelsior Avenue
Oakland, CA 94602
(T) 866-465-2523

(T) 510-482-4420
(F) 510-482-4421

http://www.coolroofs.org

Subsection No.	Reference	Title/Source
Exception to 5.5.3.1	CRRC-1-2002	Cool Roof Rating Council Product Rating Program

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ERRATA SHEET FOR THE FIRST PRINTING OF ANSI/ASHRAE/IESNA STANDARD 90.1-2004 (SI edition) Energy Standard for Buildings Except Low-Rise Residential Buildings

April 20, 2005

The corrections listed in this errata sheet apply to the first printing of ANSI/ASHRAE/IESNA Standard 90.1-2004, SI edition, identified as "86248 PC 1/05"on the outside back cover of the standard.

More than one errata sheet may be required for a specific document. Please review the entire list on the ASHRAE website related to the applicable document and download all that apply.

NOTICE: ASHRAE now has a list server for Standing Standards Project Committee 90.1 (SSPC 90.1). Interested parties can now subscribe and unsubscribe to the list server and be automatically notified via e-mail when activities and information related to the Standard and the User's Manual is available. To sign up for the list server please visit **Standards List Servers** on the Standards and Codes section of the ASHRAE website at http://www.ashrae.org/template/AssetDetail/assetid/22410.

Page(s)	Erratum
22 through 30	**TABLES 5.5-1 through 5.5-8 Building Envelope Requirements.** Add a footnote to the bottom of Tables 5.5-1 through 5.5-8 as follows: "The following definitions apply: ci = continuous insulation (see Section 3.2), NR = no (insulation) requirement."
24	**TABLE 5.5-3 Building Envelope Requirements for Climate Zone 3 (A, B, C).** In footnote "b" of Table 5.5-3 change "non-residential" to "nonresidential".
43 and 44	**TABLE 6.8.1A Air Conditioners and Condensing Units.** Change the title of Table 6.8.1A from "Air Conditioners and Condensing Units" to "Electronically Operated Unitary Air Conditioners and Condensing Units – Minimum Efficiency Requirements".
45	**TABLE 6.8.1B Electrically Operated Unitary and Applied Heat Pumps – Minimum Efficiency Requirements.** In Table 6.8.1B for equipment type "Air Cooled (Cooling Mode)", under size category "≥70 kW", change the minimum efficiency from "2.78 COP_C" to "2.64 COP_C" for "Electric Resistance (or None)" and from "2.72 COP_C" to "2.58 COP_C" for "All other" heating section type.
130	**Normative Appendix D Climatic Data.** At the top of the page delete the second sentence that reads "Table numbers corresponding to the envelope criteria tables in Normative Appendix B are also included."

INTERPRETATION IC 90.1-2004-1 OF
ANSI/ASHRAE/IESNA STANDARD 90.1-2004
Energy Standard for Buildings Except Low-Rise Residential Buildings

Date Approved June 25, 2005

Request from: Roger Chang (E-mail: roger.chang@arup.com), Associate Member, 155 Avenue of the Americas, New York, NY 10013.

Reference: This request for interpretation refers to the requirements presented in ANSI/ASHRAE/IESNA Standard 90.1-2004, Section 5.2.1 Compliance, relating to gross wall area.

Background: Standard 90.1-2004 does not appear to be clear as to what gross wall area means. International Energy Conservation Code is clear that prescriptive requirements are based on window to above-grade wall area. This impacts all sections of the code where the window-to-wall area ratio is taken into consideration.

Interpretation: Gross wall area refers to above-grade wall only.

Question: Is this interpretation correct?

Answer: No.

Comments:

Section 3.2 defines “building envelope” to include “the elements of a building…that enclose...spaces through which thermal energy may be transferred to or from the exterior”.

Section 3.2, in the definition of “wall” states “this includes above- and below-grade walls, between floor spandrels, peripheral edges of floors, and foundation walls”.

Section 3.2 defines “gross wall area” as “the area of the wall measured on the exterior face from the top of the floor to the bottom of the roof”.

Therefore, for buildings with conditioned space below-grade, the gross wall area extends from the top of the surface of the floor of the lowest conditioned space to the bottom of the roof of the highest conditioned space.

(Note that the use of a similar term in a document from another organization is irrelevant to an interpretation of Standard 90.1.)