STANDARD

ANSI/ASHRAE/IES Standard 90.1-2010
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2007)
Includes ANSI/ASHRAE/IES Addenda listed in Appendix F

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

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

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 (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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This American National Standard (ANS) is a national voluntary consensus standard developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Consensus is defined by the American National Standards Institute (ANSI), of which ASHRAE is a member and which has approved this standard as an ANS, as "substantial agreement reached by directly and materially affected interest categories. This signifies the concurrence of more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution." Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory through legislation.

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, or
d. permission to reprint portions of the Standard.

CONTENTS

ANSI/ASHRAE/IES Standard 90.1-2010,
Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

NOTE

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

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

FOREWORD

The original Standard 90 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 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 are included in the new edition, issued every three years. This procedure allows users to have some certainty of the timing of publication of new editions.

The 2010 edition of the standard has extensive changes resulting from continuous maintenance proposals from the public and the committee volunteers. The committee welcomes suggestions for improving the standard. Users of the standard are encouraged and invited to use the continuous maintenance procedure to suggest changes. A form for submitting continuous maintenance proposals (CMP) to suggest changes is included in the back of this standard. The committee takes formal action on every CMP received.

The Committee's unanimously approved Workplan goal for the 2010 edition was to reduce energy cost by 30% compared to the 2004 version of the standard. Toward that goal, 109 addenda were processed by the committee and approved by the ASHRAE and IES Boards of Directors and are included in this edition.This edition also corrects all known typographical errors in the 2007 standard.

The most significant changes included are:

1. *The Scope has been expanded so that 90.1 can cover receptacles and process loads (e.g. data centers).*
2. *The building envelope (opaque elements and fenestration) requirements have become more stringent. Continuous air barrier and cool/high albedo roof requirements have been added.*
3. *Most interior lighting power densities have been lowered, additional occupant sensing controls and mandatory daylighting requirements are added for specific spaces, and a new five-zone exterior lighting power density table has been added.*
4. *Most equipment efficiencies are higher, energy recovery is required in more applications, economizers are required in more climates, and more energy-conserving controls are required*
5. *Modeling requirements (e.g. for LEED® certification) have been clarified and expanded.*

For brief descriptions and publication dates of the addenda to 90.1-2007, see Appendix F.

At the time of printing, energy cost savings are estimated to be 23.4% and energy savings are estimated at 24.8%; however, not all addenda had been included in analysis for these energy savings estimates. Final saving estimates will be issued by ASHRAE when available.

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

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

1. PURPOSE

To establish the minimum *energy efficiency* requirements of buildings, other than low rise *residential* buildings, for:

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

2. SCOPE

2.1 This standard provides:

a. minimum *energy*-efficient requirements for the design, *construction*, and a plan for operation and maintenance of:
   1. new buildings and their *systems*
   2. new portions of buildings and their *systems*
   3. new *systems* and *equipment* in existing buildings
   4. new *equipment* or building *systems* specifically identified in the standard that are part of industrial or manufacturing processes
b. criteria for determining compliance with these requirements.

2.2 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), or
b. buildings that use neither electricity nor *fossil fuel*.

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

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

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 General. Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this standard. These definitions are applicable to all sections of this standard. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based upon American standard English language usage as documented in an unabridged dictionary accepted by the *adopting authority.*

3.2 Definitions

above-grade wall: see *wall.*

access hatch: see *door.*

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

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

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

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

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

attic and other roofs: see *roof.*

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

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

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

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

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

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

ballast, electronic: a *ballast* constructed using electronic circuitry.

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

ballast, magnetic: a *ballast* constructed with magnetic core and a winding of insulated wire.

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

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

below-grade wall: see *wall.*

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

boiler, packaged: a *boiler* that is shipped complete with heating *equipment*, mechanical draft *equipment*, and *automatic controls*; usually shipped in one or more sections. A *packaged boiler* includes factory-built *boilers* manufactured as a unit or *system*, disassembled for shipment, and reassembled at the site.

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

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

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

building entrance: any doorway, set of *doors*, turnstile, vestibule, or other form of portal that is ordinarily used to gain access to the building by its users and occupants.

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

building envelope, exterior: the elements of a building that separate *conditioned spaces* from the exterior.

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

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

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

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

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

C-factor (thermal conductance): time rate of steady-state heat flow through unit area of a material or *construction*, induced by a unit temperature difference between the body surfaces. Units of *C* are Btu/h·ft^2·°F. 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.

computer room: a room whose primary function is to house *equipment* for the processing and storage of electronic data and that has a design electronic data *equipment* power density exceeding 20 watts/ft^2 of *conditioned floor area.*

conditioned floor area: see *floor area.*

conditioned space: see *space.*

conductance: see *thermal conductance.*

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

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

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

control: to regulate the operation of *equipment*.

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

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

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

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

cooled space: see *space*.

cooling degree-day: see *degree-day*.

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

cooling design wet-bulb temperature: the outdoor wet-bulb temperature for sizing cooling *systems* and evaporative heat rejection *systems* such as cooling towers.

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

daylight area:

a. ***under skylights***: the *daylight area under skylights* is the combined *daylight area* under each *skylight* without double counting overlapping areas. The *daylight area* under each *skylight* is bounded by the opening beneath the *skylight*, plus horizontally in each direction, the smallest of (See Figure 3.1):
    1. 70% of the ceiling height (0.7 × *CH*), or
    2. the distance to any *primary sidelighted area*, or the *daylight area under rooftop monitors*, or
    3. the distance to the front face of any vertical obstruction where any part of the obstruction is farther away than 70% of the distance between the top of the obstruction and the ceiling (0.7 × [CH–OH]), where *CH* = the height of the ceiling at the lowest edge of the *skylight*, and *OH* = the height to the top of the obstruction.
b. ***under rooftop monitors***: the *daylight area under rooftop monitors* is the combined *daylight area* under each *rooftop monitor* without double counting overlapping areas. The *daylight area* under each *rooftop monitor* is the product of the width of the vertical glazing above the ceiling level and the smallest of the

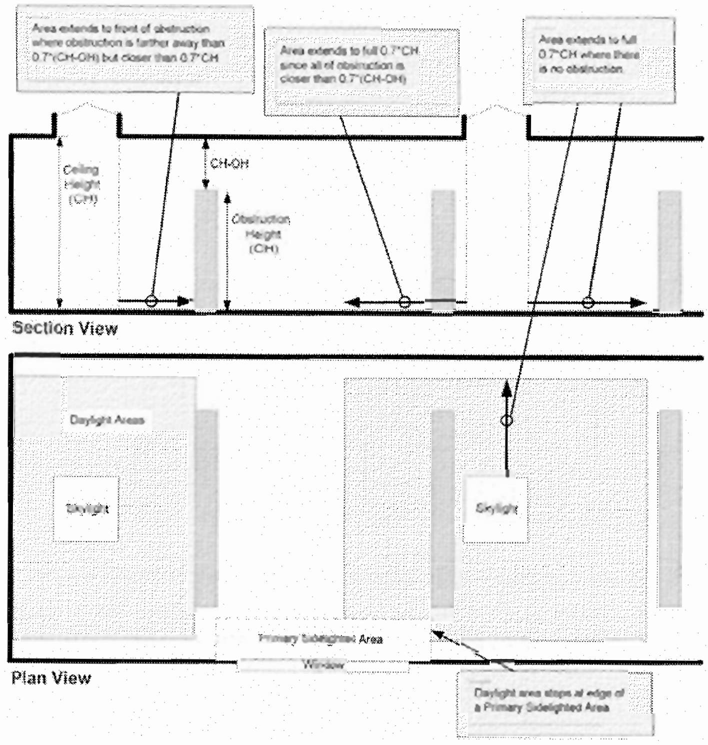


Figure 3.1 Computing the daylight area under skylights.

following horizontal distances inward from the bottom edge of the glazing, (See Figure 3.2):

1. the monitor sill height, MSH, (the vertical distance from the floor to the bottom edge of the monitor glazing), or
2. the distance to the edge of any *primary sidelighted area* or
3. the distance to the front face of any vertical obstruction where any part of the obstruction is farther away than the difference between the height of the obstruction and the monitor sill height (MSH-OH).

daylighted area: the floor area substantially illuminated by daylight.

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

decorative lighting: see *lighting, decorative*.

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

cooling degree-day base 50°F (CDD50): for any one day, when the *mean temperature* is more than 50°F, there are as many *degree-days* as degrees Fahrenheit temperature difference between the *mean temperature* for the day and 50°F. Annual *cooling degree-days* (CDDs) are the sum of the *degree-days* over a calendar year.

heating degree-day base 65°F (HDD65): for any one day, when the *mean temperature* is less than 65°F, there are as many *degree-days* as degrees Fahrenheit temperature difference between the *mean temperature* for the day and 65°F. Annual heating *degree-days* (HDDs) are the sum of the *degree-days* over a calendar year.

demand: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

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

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

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

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

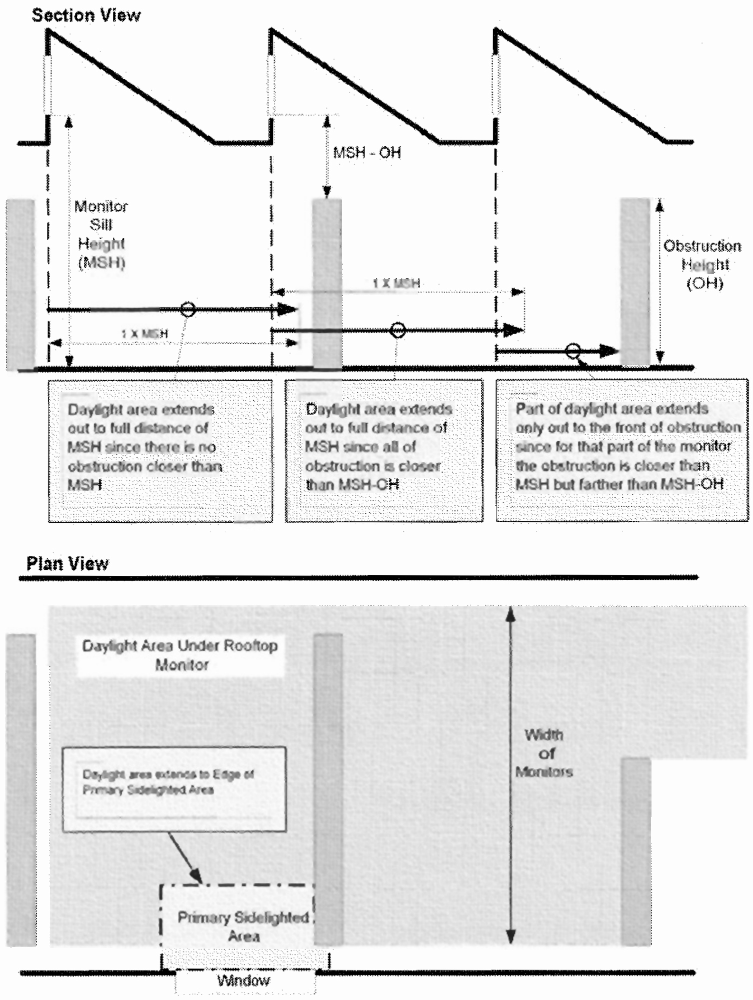


Figure 3.2 Computing the daylight area under rooftop monitors.

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

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

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

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

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

For the purposes of determining *building envelope* requirements, the classifications are defined as follows:

> ***nonswinging:*** roll-up, metal coiling, sliding, and all other *doors* that are not *swinging doors*.
>
> ***metal coiling door:*** an upward acting *nonswinging door* assembly consisting of interlocking horizontal slats or sheets that, upon opening the *door*, roll up around a horizontal barrel above the *door* opening.
>
> ***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*.)

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

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

dynamic glazing: any *fenestration* product that has the fully reversible ability to change its performance properties, including *U-factor*, *SHGC*, or *VT*.

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

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

efficacy (of a lamp): the ratio of the total luminous output of a *lamp* to the total power input to the *lamp*; typically expressed in lumens per watt.

efficiency: performance at specified rating conditions.

emittance: the ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

enclosed space: a volume substantially surrounded by solid surfaces such as *walls*, floors, *roofs*, and openable devices such as *doors* and operable windows.

energy: the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Customary measurement units are joules (Btu).

energy cost budget: the annual energy cost for the *budget building design* intended for use in determining minimum compliance with this standard.

energy efficiency ratio (EER): the ratio of net cooling capacity in British thermal units/hours to total rate of electric input in watts under designated operating conditions. (See *coefficient of performance [COP]—cooling*.)

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

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

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

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

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

1. Hospitals and other health care facilities having surgery or emergency treatment facilities.
2. Fire, rescue and police stations and emergency vehicle garages.
3. Designated earthquake, hurricane or other emergency shelters.
4. Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response.
5. Power-generating stations and other public utility facilities required as emergency backup facilities for other *essential facilities*.
6. Structures containing highly toxic materials where the quantity of the material exceeds the maximum allowable quantities.
7. Aviation *control* towers, air traffic *control* centers and emergency aircraft hangars.
8. Buildings and other structures having critical national defense functions.

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

existing equipment: *equipment* previously installed in an existing building.

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

exterior building envelope: see *building envelope*.

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

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

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

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

fan brake horsepower: the horsepower delivered to the fan's shaft. Brake horsepower (bhp) does not include the mechanical drive losses (belts, gears, etc.).

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

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

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

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

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

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

vertical fenestration: all *fenestration* other than *skylights*. Trombe *wall* assemblies, where glazing is installed within 12 in. of a *mass wall*, are considered *walls*, not *fenestration*.

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

fenestration, field-fabricated: *fenestration* whose frame is made at the *construction* site of materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a *fenestration* product or exterior glazed *door*. *Field fabricated fenestration* does not include site-built *fenestration* designed to be glazed or assembled in the field using specific factory cut or otherwise factory formed framing and glazing units, such as storefront *systems*, curtain *walls*, and atrium *roof systems*.

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

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

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

mass floor: a floor with a *heat capacity* that exceeds (1) 7 Btu/ft^2·°F or (2) 5 Btu/ft^2·°F provided that the floor has a material unit mass not greater than 120 lb/ft^3.

steel-joist floor: a floor that (1) is not a *mass floor* and (2) that has *steel joist* members supported by structural members.

wood-framed and other floors: all other floor types, including wood joist floors.

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

floor area, gross: the sum of the floor areas of the *spaces* within the building, including basements, mezzanine and intermediate-floored tiers, and penthouses with a headroom height of 7.5 ft or greater. It is measured from the exterior faces of exterior *walls* or from the centerline of *walls* separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar *spaces*, pipe trenches, exterior terraces or steps, chimneys, *roof* overhangs, and similar features.

gross building envelope floor area: the *gross floor area* of the *building envelope*, but excluding *slab-on-grade floors*.

gross conditioned floor area: the *gross floor area* of *conditioned spaces*.

gross lighted floor area: the *gross floor area* of lighted *spaces*.

gross semiheated floor area: the *gross floor area* of *semiheated spaces*.

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

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

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

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

general lighting: see *lighting, general*.

General Purpose Electric Motor (subtype I): any electric motor that meets the definition of "general purpose" motor as codified by the Department of Energy rule in 10 CFR 431 in effect on December 19, 2007.

General Purpose Electric Motor (subtype II): any electric motor incorporating the design elements of a *general purpose electric motor* (subtype I) that are configured as a U-frame motor, design C motor, close-coupled pump motor, footless motor, vertical solid shaft, normal thrust motor (tested in a horizontal configuration), 8-pole motor (900 rpm), or polyphase motor with voltage no more than 600 volts (other than 230 or 460 volts).

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*.

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

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

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 Btu) divided by the total electric energy input during the same period.

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

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

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

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

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

indirectly conditioned space: see *space*.

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

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

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

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

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

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

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

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

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

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

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

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

> ***compact fluorescent lamp:*** a *fluorescent lamp* of a small compact shape, with a single base that provides the entire mechanical support function.
>
> ***fluorescent lamp:*** a low-pressure electric discharge *lamp* in which a phosphor coating transforms some of the ultraviolet energy generated by the discharge into light.
>
> ***general service lamp:*** a class of *incandescent lamps* that provide light in virtually all directions. *General service lamps* are typically characterized by bulb shapes such as A, standard; S, straight side; F, flame; G, globe; and PS, pear straight.

high-intensity discharge (HID) lamp: an electric discharge *lamp* in which light is produced when an electric arc is discharged through a vaporized metal such as mercury or sodium. Some HID *lamps* may also have a phosphor coating that contributes to the light produced or enhances the light color.

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

reflector lamp: a class of *incandescent lamps* that have an internal reflector to direct the light. *Reflector lamps* are typically characterized by reflective characteristics such as R, reflector; ER, ellipsoidal reflector; PAR, parabolic aluminized reflector; MR, mirrorized reflector; and others.

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

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

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

lighting power allowance:

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

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

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

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

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

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

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

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

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

mass floor: see *floor*.

mass wall: see *wall*.

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

mechanical 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.

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

1. Activating alternate sets of lights.
2. Activating 100% of the lighting power.
3. Deactivating all lights.

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

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

nameplate horsepower: the nominal motor horsepower rating stamped on the motor nameplate.

nameplate rating: the design load operating conditions of a device as shown by the *manufacturer* on the nameplate or otherwise marked on the device.

nonautomatic: see *manual*.

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

nonrenewable energy: energy derived from a *fossil fuel* source.

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

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

nonswinging door: see *door.*

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

primary sidelighted area: the total *primary sidelighted area* is the combined *primary sidelighted area* without double counting overlapping areas. The floor area for each *primary sidelighted area* is directly adjacent to vertical glazing below the ceiling with an area equal to the product of the *primary sidelighted area* width and the *primary sidelighted area* depth. See Figure 3.3.

The *primary sidelighted area* width is the width of the window plus, on each side, the smallest of:

1. 2 ft or
2. the distance to any 5 ft or higher vertical obstruction.

The *primary sidelighted area* depth is the horizontal distance perpendicular to the glazing which is the smaller of:

1. one window head height (head height is the distance from the floor to the top of the glazing), or
2. the distance to any 5 ft or higher vertical obstruction.

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

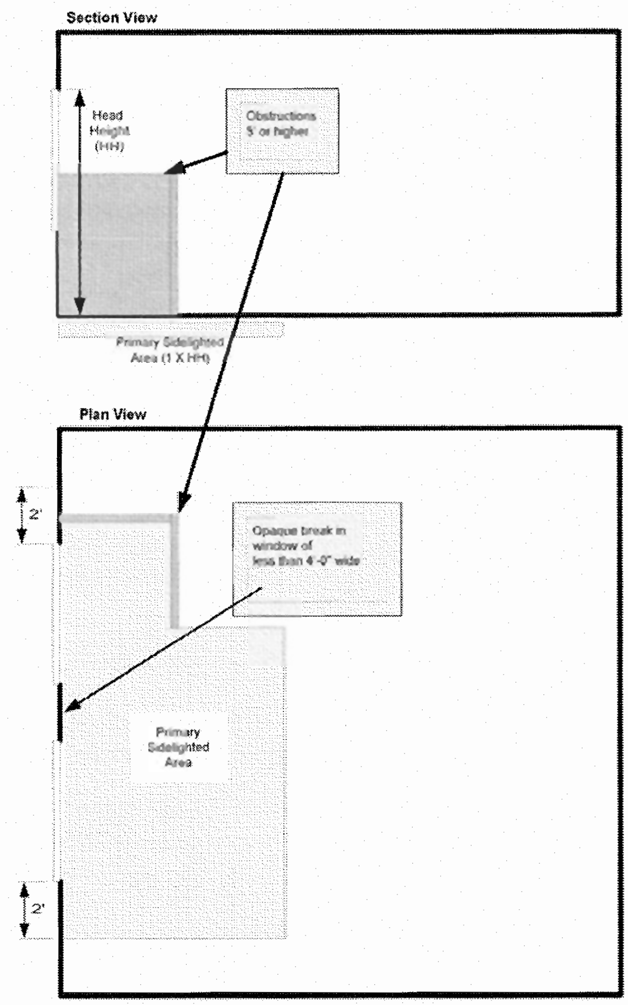


Figure 3.3 Computing the *primary sidelighted area*.

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 motor power: see *motor power, rated*.

rated R-value of insulation: the *thermal resistance* of the insulation alone as specified by the *manufacturer* in units of h·ft^2·°F/Btu at a *mean temperature* of 75°F. Rated R-value refers to the *thermal resistance* of the added insulation in framing cavities or insulated sheathing only and does not include the *thermal resistance* of other *building materials* or air films. (See *thermal resistance*.)

rating authority: the organization or agency that adopts or sanctions use of this rating methodology.

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

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

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

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

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

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

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

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

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

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

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

roof: the upper portion of the *building envelope*, including *opaque* areas and *fenestration*, that is horizontal or tilted at an angle of less than 60° from horizontal. For the purposes of determining *building envelope* requirements, the classifications are defined as follows:

> ***attic and other roofs:*** all other *roofs*, including *roofs* with insulation entirely below (inside of) the *roof* structure (i.e., attics, cathedral ceilings, and single-rafter ceilings), *roofs* with insulation both above and below the *roof* structure, and *roofs* without insulation but excluding *metal building roofs*.
>
> ***metal building roof:*** a *roof* that:
>
> 1. is constructed with a metal, structural, weathering surface,
> 2. has no ventilated cavity, and
> 3. has the insulation entirely below deck (i.e., does not include composite concrete and metal deck *construction* nor a *roof* framing *system* that is separated from the superstructure by a wood substrate) and whose structure consists of one or more of the following configurations:
>   a. metal roofing in direct contact with the steel framing members
>   b. metal roofing separated from the steel framing members by insulation
>   c. insulated metal roofing panels installed as described in a or b
>
> ***roof with insulation entirely above deck:*** a *roof* with all insulation
>
> 1. installed above (outside of) the *roof* structure and
> 2. continuous (i.e., uninterrupted by framing members).
>
> ***single-rafter roof:*** a subcategory of attic *roofs* where the *roof* above and the ceiling below are both attached to the same wood rafter and where insulation is located in the *space* between these wood rafters.

roof area, gross: the area of the *roof* measured from the exterior faces of *walls* or from the centerline of *party walls*. (See *roof* and *wall*.)

rooftop monitors: *vertical fenestration* integral to the *roof*

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.

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

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

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

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

secondary sidelighted area: the total *secondary sidelighted area* is the combined *secondary sidelighted area* without double counting overlapping areas. The floor area for each *secondary sidelighted area* is directly adjacent to a *primary sidelighted area* with an area equal to the product of the *secondary sidelighted area* width and the *secondary sidelighted area* depth. See Figure 3.4.

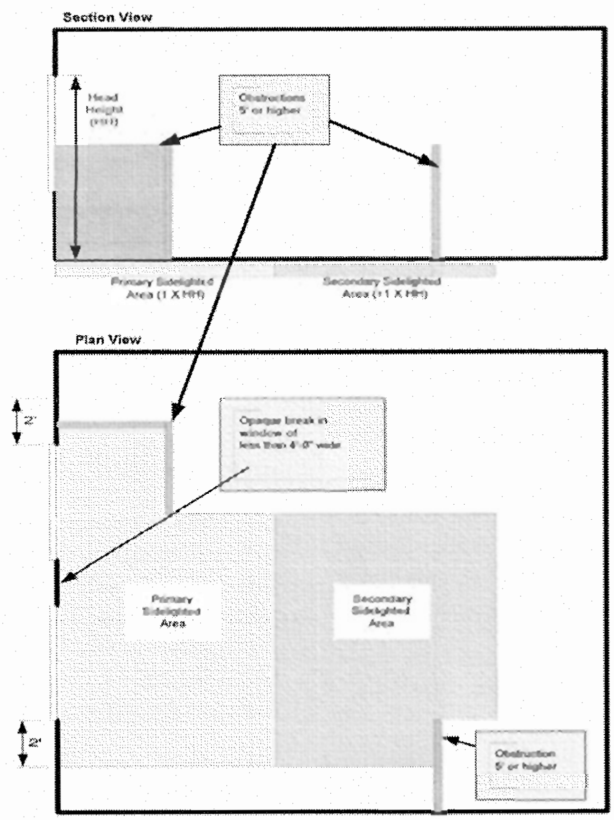


Figure 3-4 Computing the secondary sidelighted area.

The *secondary sidelighted area* width is the width of the window plus, on each side, the smallest of:

1. 2 ft, or
2. the distance to any 5 ft or higher vertical obstruction.

The *secondary sidelighted area* depth is the horizontal distance perpendicular to the glazing which begins at the edge of the *primary sidelighted area* depth and ends at the smaller of:

1. one window head height (head height is the distance from the floor to the top of the glazing), or
2. the distance to any 5 ft or higher vertical obstruction.

If the adjacent *primary sidelighted area* ends at a 5 ft or higher vertical obstruction or beyond the nearest edge of a neighboring *daylight area under skylight* or *primary sidelighted area*, there is no *secondary sidelighted area* beyond such obstruction or the edge of such areas.

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

semiheated floor area: see *floor area.*

semiheated space: see *space.*

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

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

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

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

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

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

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

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

setpoint: point at which the desired temperature (°F) 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 1/8 in. thick clear, double-strength glass. SC, as used herein, does not include interior, exterior, or integral shading devices.

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

$$\text{Sidelighting Effective Aperture} = \frac{\sum \text{window area} \times \text{window VT}}{\text{area of primary sidelighted area}}$$

where window VT is the *visible transmittance* of windows as determined in accordance with Section 5.8.2.6.

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

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

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

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

single-rafter roof: see *roof.*

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

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

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

skylight: see *fenestration*.

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

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

where

skylight area	=	total *fenestration area* of *skylights*
skylight VT	=	area weighted average *visible transmittance* of *skylights* as determined in accordance with Section 5.8.2.6.
WF	=	area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 ft, or 0.7 if light well depth is 2 ft or greater Light well depth is measured vertically from the underside of the lowest point on the *skylight* glazing to the ceiling plane under the *skylight*.

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

slab-on-grade floor: that portion of a slab floor of the building *envelope* that is in contact with the ground and that is either above *grade* or is less than or equal to 24 in. below the final elevation of the nearest exterior *grade*.

> ***heated slab-on-grade floor:*** a *slab-on-grade floor* with a heating source either within or below it.
>
> ***unheated slab-on-grade floor:*** a *slab-on-grade floor* that is not a *heated slab-on-grade floor*.

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

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

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

> ***conditioned space:*** a *cooled space*, *heated space*, or *indirectly conditioned space* defined as follows:
>
> 1. ***cooled space:*** an *enclosed space* within a building that is cooled by a cooling *system* whose sensible output capacity exceeds 5 Btu/h·ft^2 of floor area.

TABLE 3.1 Heated Space Criteria

Heating Output, Btu/h·ft^2	Climate Zone
5	1 and 2
10	3
15	4 and 5
20	6 and 7
25	8

2. ***heated space:*** an *enclosed space* within a building that is heated by a heating *system* whose output capacity relative to the floor area is greater than or equal to the criteria in Table 3.1.
3. ***indirectly conditioned space:*** an *enclosed space* within a building that is not a *heated space* or a *cooled space*, which is heated or cooled indirectly by being connected to adjacent *space(s)* provided:

   a. the product of the *U-factor(s)* and surface area(s) of the *space* adjacent to connected *space(s)* exceeds the combined sum of the product of the *U-factor(s)* and surface area(s) of the *space* adjoining the outdoors, *unconditioned spaces*, and to or from *semiheated spaces* (e.g., corridors) or
   b. that air from heated or *cooled spaces* is intentionally transferred (naturally or mechanically) into the *space* at a rate exceeding 3 ach (e.g., atria).

semiheated space: an *enclosed space* within a building that is heated by a heating *system* whose output capacity is greater than or equal to 3.4 Btu/h·ft^2 of floor area but is not a *conditioned space*.

unconditioned space: an *enclosed space* within a building that is not a *conditioned space* or a *semiheated space*. Crawlspaces, attics, and parking garages with natural or mechanical *ventilation* are not considered *enclosed spaces*.

space-conditioning category:

nonresidential conditioned space,

residential conditioned space, and

nonresidential and *residential semiheated space*.

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

steel-framed wall: see *wall*.

steel-joist floor: see *floor*.

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.

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

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

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

thermal block: a collection of one or more *HVAC zones* grouped together for simulation purposes. *Spaces* need not be contiguous to be combined within a single *thermal block*.

thermal conductance: see *C-factor*.

thermally effective panel surface: any exterior surface of a panel, which is intended to transfer heat between the panel and the occupants and/or the indoor *space*. In this standard, it is called effective panel surface.

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

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 h·ft^2·°F/Btu.

thermal transmittance: see *U-factor*.

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

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

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

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

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

dry-type transformer: a *transformer* in which the core and coils are in a gaseous or dry compound.

liquid-immersed transformer: a *transformer* in which the core and coils are immersed in an insulating liquid.

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

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 Btu/h·ft^2·°F.

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

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*.

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

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

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

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

ventilation system motor nameplate hp: the sum of the motor *nameplate horsepower* (hp) of all fans that are required to operate as part of the *system*.

vertical fenestration: see *fenestration*.

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

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

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

above-grade wall: a *wall* that is not a *below-grade wall*.

below-grade wall: that portion of a *wall* in the *building envelope* that is entirely below the finish *grade* and in contact with the ground.

mass wall: a *wall* with an *HC* exceeding (1) 7 Btu/ft^2·°F or (2) 5 Btu/ft^2·°F, provided that the *wall* has a material unit weight not greater than 120 lb/ft^3.

metal building wall: a *wall* whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain *wall systems*).

steel-framed wall: a *wall* with a cavity (insulated or otherwise) whose exterior surfaces are separated by steel framing members (i.e., typical steel stud *walls* and curtain *wall systems*).

wood-framed and other walls: all other *wall* types, including wood stud *walls*.

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

warm-up: increase in *space* temperature to occupied *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
AHRI	Air-Conditioning, Heating and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASTM	American Society for Testing and Materials
bhp	brake horsepower
BSR	Board of Standards Review
Btu	British thermal unit
Btu/h	British thermal unit per hour
Btu/ft^2·°F	British thermal unit per square foot per degree Fahrenheit
Btu/h·ft^2	British thermal unit per hour per square foot Btu/h·ft·°F
British thermal unit per hour per linear foot per degree Fahrenheit	
Btu/h·ft^2·°F	British thermal unit per hour per square foot per degree Fahrenheit
CDD	cooling degree-day
CDD50	cooling degree-days base 50°F
cfm	cubic feet per minute
c.i.	continuous insulation
COP	coefficient of performance
CTI	Cooling Technology Institute
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
F	Fahrenheit
ft	foot
h	hour
HC	heat capacity
HDD	heating degree-day
HDD65	heating degree-days base 65°F
h·ft^2·°F/Btu	hour per square foot per degree Fahrenheit per British thermal unit
HID	high-intensity discharge
hp	horsepower
HSPF	heating seasonal performance factor
HVAC	heating, ventilating, and air conditioning
IES	Illuminating Engineering Society of North America
in.	inch
I-P	inch-pound
IPLV	integrated part-load value
J	joule
K	kelvin
kJ	kilojoule
kVA	kilovolt-ampere
lin	linear
lin ft	linear foot
LPD	lighting power density
Ls	liner system
MICA	Midwest Insulation Contractors Association
NAECA	U.S. National Appliance Energy Conservation Act of 1987
NFPA	National Fire Protection Association
NFRC	National Fenestration Rating Council
NPLV	nonstandard part-load value
PF	projection factor
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
R	R-value (thermal resistance)
R_c	thermal resistance of a material or construction from surface to surface
R_u	total thermal resistance of a material or construction including air film resistances
rpm	revolutions per minute
SC	shading coefficient
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SL	standby loss
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
T_{db}	dry-bulb temperature
T_{wb}	wet-bulb temperature
UL	Underwriters Laboratories Inc.
VAV	variable-air-volume
VT	visible transmittance
W	watt
W/ft^2	watts per square foot
WF	well factor
Wh	watt-hour

4. ADMINISTRATION AND ENFORCEMENT

4.1 General

4.1.1 Scope

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

4.1.1.2 Additions to Existing Buildings. 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: When an *addition* to an *existing building* cannot comply by itself, trade-offs will be allowed by modification to one or more of the existing components of the *existing building*. Modeling of the modified components of the *existing building* and *addition* shall employ the procedures of Section 11; the *addition* shall not increase the *energy* consumption of the *existing building* plus the *addition* beyond the *energy* that would be consumed by the *existing building* plus the *addition* if the *addition* alone did comply.

4.2.1.3 Alterations of Existing Buildings. *Alterations* of *existing buildings* shall comply with the provisions of Sections 5, 6, 7, 8, 9, and 10, provided, however, that nothing in this standard shall require compliance with any provision of this standard if such compliance will result in the increase of *energy* consumption of the building.

Exceptions:

a. A building that has been specifically designated as historically significant by the *adopting authority* or is listed in The National Register of Historic Places or has been determined to be eligible for listing by the US Secretary of the Interior need not comply with these requirements.

b. Where one or more components of an *existing building* or portions thereof are being replaced, the annual *energy* consumption of the comprehensive design shall not be greater than the annual *energy* consumption of a substantially identical design, using the same *energy* types, in which the applicable requirements of Sections 5, 6, 7, 8, 9, and 10, as provided in Section 4.2.1.3, and such compliance is verified by a *design professional*, by the use of any calculation methods acceptable to the *authority having jurisdiction.*

4.2.2 Compliance Documentation

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

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

4.2.2.3 Manuals. Operating and maintenance information shall be provided to the building owner. This information shall include, but not be limited to, the information specified in Sections 6.7.2.2, 8.7.2, and 9.7.2.2.

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

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

a. *wall* insulation after the insulation and vapor retarder are in place but before concealment

b. *roof*/ceiling insulation after *roof*/insulation is in place but before concealment

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

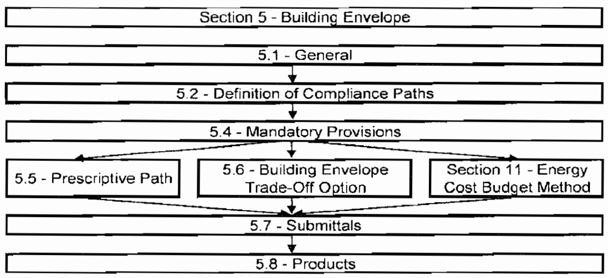
d. *fenestration* after all glazing materials are in place

e. *continuous air barrier* after installation but before concealment

f. mechanical *systems* and *equipment* and insulation after installation but before concealment

g. electrical *equipment* and *systems* after installation but before concealment

5. BUILDING ENVELOPE



5.1 General

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

5.1.2 Space-Conditioning Categories

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

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

5.1.2.3 *Spaces* shall be assumed to be *conditioned spaces* and shall comply with the requirements for *conditioned 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.

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

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

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

a. installation of storm windows over existing glazing
b. replacement of glazing in existing sash and frame provided the *U-factor* and *SHGC* will be equal to or lower than before the glass replacement
c. *alterations* to *roof*/ceiling, *wall*, or floor cavities, which are insulated to full depth with insulation having a minimum nominal value of R-3.0/in.
d. *alterations* to *walls* and floors, where the existing structure is without framing cavities and no new framing cavities are created
e. replacement of a *roof* membrane where either the *roof* sheathing or *roof* insulation is not exposed or, if there is existing *roof* insulation, below the *roof* deck
f. replacement of existing *doors* that separate *conditioned space* from the exterior shall not require the installation of a vestibule or revolving *door*, provided, however, that an existing vestibule that separates a *conditioned space* from the exterior shall not be removed
g. replacement of existing *fenestration*, provided, however, that the area of the replacement *fenestration* does not exceed 25% of the total *fenestration area* of an *existing building* and that the *U-factor* and *SHGC* will be equal to or lower than before the *fenestration* replacement

5.1.4 Climate. Determine the climate zone for the location. For US locations, follow the procedure in Section 5.1.4.1. For international locations, follow the procedure in Section 5.1.4.2.

5.1.4.1 United States Locations. Use Figure B-1 or Table B-1 in Appendix B to determine the required climate zone.

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

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

5.2 Compliance Paths

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

a. 5.5, Prescriptive *Building Envelope* Option, provided that
   1. the *vertical fenestration area* does not exceed 40% of the *gross wall area* for each *space-conditioning category* and
   2. the *skylight fenestration area* does not exceed 5% of the *gross roof area* for each *space-conditioning category*, or
b. 5.6, *Building Envelope* Trade-Off Option.

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

5.3 Simplified Building (Not Used)

5.4 Mandatory Provisions

5.4.1 Insulation. Where insulation is required in Section 5.5 or 5.6, it shall comply with the requirements found in Sections 5.8.1.1 through 5.8.1.9.

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

5.4.3 Air Leakage

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

Exceptions to 5.4.3.1:

a. *Semiheated spaces* in climate zones 1 thru 6.
b. Single wythe concrete masonry buildings in climate zone 2B

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

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

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

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

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

a. Materials that have an air permeance not exceeding 0.004 cfm/ft^2 under a pressure differential of 0.3 in. w.g. (1.57 psf) when tested in accordance with ASTM E 2178. The following materials meet the requirements of 5.4.3.1.3 a:

   1. Plywood—minimum 3/8 in.
   2. Oriented strand board—minimum 3/8 in.
   3. Extruded polystyrene insulation board—minimum 1/2 in.
   4. Foil-faced urethane insulation board—minimum 1/2 in.
   5. Exterior gypsum sheathing or interior gypsum board—minimum 1/2 in.
   6. Cement board—minimum 1/2 in.
   7. Built up roofing membrane
   8. Modified bituminous *roof* membrane
   9. Fully adhered single-ply *roof* membrane
   10. A Portland cement/sand parge, stucco, or gypsum plaster—minimum 1/2 in. thick
   11. Cast-in-place and precast concrete.
   12. Sheet metal.
   13. Closed cell 2 lb/ft^3 nominal density spray polyurethane foam—minimum 1 in.

b. Assemblies of materials and components (sealants, tapes, etc.) that have an average air leakage not to exceed 0.04 cfm/ft^2 under a pressure differential of 0.3 in. w.g. (1.57 psf) when tested in accordance with ASTM E 2357 ASTM E 1677, ASTM E 1680 or ASTM E283; The following assemblies meet the requirements of 5.4.3.1.3 b.

   1. Concrete masonry *walls* that are:

      i. Fully grouted, or
      ii. Painted to fill the pores.

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

a. 1.0 cfm/ft^2 for glazed swinging entrance *doors* and revolving *doors*, tested at a pressure of at least 1.57 pounds per square foot (psf) in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283.
b. 0.06 cfm/ft^2 for curtainwall and storefront glazing, tested at a pressure of at least 1.57 pounds per square foot (psf) or higher in accordance with NFRC 400 or ASTM E283.
c. 0.3 cfm/ft^2 for unit *skylights* having condensation weepage openings, when tested at a pressure of at least 1.57 pounds per square foot (psf) in accordance with AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC

400, or 0.5 cfm/ft^2 when tested at a pressure of at least 6.24 pounds per square foot (psf) in accordance with AAMA/WDMA/CSA 101/I.S.2/A440.

d. 0.4 cfm/ft^2 for *nonswinging opaque doors*, tested at a pressure of at least 1.57 pounds per square foot (psf) or higher in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.

e. 0.2 cfm/ft^2 for all other products when tested at a pressure of at least 1.57 pounds per square foot (psf) in accordance with AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400, or 0.3 cfm/ft^2 when tested at a pressure of at least 6.24 pounds per square foot (psf) in accordance with AAMA/WDMA/CSA 101/I.S/A440.

Exceptions:

a. *Field-fabricated fenestration* and *doors*.
b. *Metal coiling doors* in *semiheated spaces* in climate zones 1 through 6.

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

5.4.3.4 Vestibules. *Building entrances* that separate *conditioned space* from the exterior shall be protected with an enclosed vestibule, with all *doors* opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior *doors* to open at the same time. Interior and exterior *doors* shall have a minimum distance between them of not less than 7 ft when in the closed position.The exterior envelope of conditioned vestibules shall comply with the requirements for a *conditioned space*. The interior and exterior envelope of unconditioned vestibules shall comply with the requirements for a *semiheated space*.

Exceptions:

a. *Building entrances* with revolving *doors*.
b. *Doors* not intended to be used as a *building entrance.*
c. *Doors* opening directly from a *dwelling unit*.
d. *Building entrances* in buildings located in climate zone 1 or 2.
e. *Building entrances* in buildings located in climate zone 3 that are less than four stories above *grade* and less than 10,000 ft^2 in area.
f. *Building entrances* in buildings located in climate zone 4, 5, 6, 7, or 8 that are less than 1000 ft^2 in area.
g. *Doors* that open directly from a *space* that is less than 3000 ft^2 in area and is separate from the *building entrance*.

5.5 Prescriptive Building Envelope Option

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

5.5.2 If a building contains any *semiheated space* or *unconditioned space*, then the *semi-exterior building envelope* shall comply with the requirements for *semiheated space* in Tables 5.5-1 through 5.5-8 for the appropriate climate. (See Figure 5.1.)

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

a. Minimum *rated R-values of insulation* for the *thermal resistance* of the added insulation in framing cavities and *continuous insulation* only. Specifications listed in Normative Appendix A for each *class of construction* shall be used to determine compliance.
b. Maximum *U-factor, C-factor,* or *F-factor* for the entire assembly. The values for typical *construction* assemblies listed in Normative Appendix A shall be used to determine compliance.

Exceptions to Section 5.5.3:

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

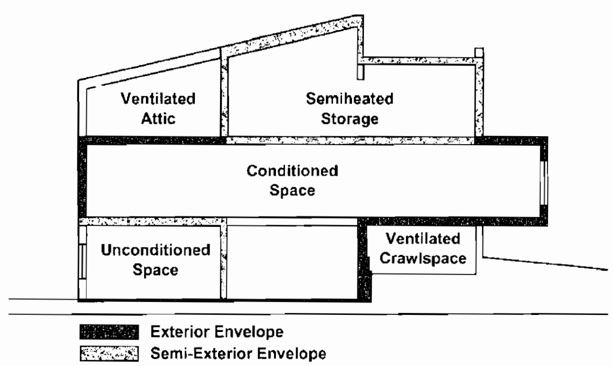


Figure 5.1 Exterior and semi-exterior building envelope.

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

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 c.i.	U-0.048	R-20.0 c.i.	U-0.218	R-3.8 ci
Metal Building[a]	U-0.065	R-19.0	U-0.065	R-19.0	U-0.167	R-6.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.580	NR	U-0.151[b]	R-5.7 c.i.[b]	U-0.580	NR
Metal Building	U-0.093	R-16.0	U-0.093	R-16.0	U-0.113	R-13.0
Steel-Framed	U-0.124	R-13.0	U-0.124	R-13.0	U-0.352	NR
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.292	NR
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel-Joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood-Framed and Other	U-0.282	NR	U-0.282	NR	U-0.282	NR
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-1.450		U-1.450	

Fenestration	Nonresidential Assembly Max. U	Nonresidential Assembly Max. SHGC	Residential Assembly Max. U	Residential Assembly Max. SHGC	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-1.20	SHGC-0.25 all	U-1.20	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-1.20		U-1.20		U-1.20	
Metal framing (entrance door)[d]	U-1.20		U-1.20		U-1.20	
Metal framing (all other)[d]	U-1.20		U-1.20		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.98	$SHGC_{all}$–0.36	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–0.16	U_{all}–1.98	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–1.90	$SHGC_{all}$–0.34	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–1.36	$SHGC_{all}$–0.36	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR

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

[a] When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.

[b] Exception to Section A3.1.3.1 applies.

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

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

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

	Nonresidential		Residential		Semiheated	
Opaque Elements	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.218	R-3.8 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.151[b]	R-5.7 c.i.[b]	U-0.123	R-7.6 c.i.	U-0.580	NR
Metal Building	U-0.093	R-16.0	U-0.093	R-16.0	U-0.113	R-13.0
Steel-Framed	U-0.124	R-13.0	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.107	R-6.3 c.i.	U-0.087	R-8.3 c.i.	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.052	R-19.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-0.500		U-1.450	

Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.75	SHGC-0.25 all	U-0.75	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.70		U-0.70		U-1.20	
Metal framing (entrance door)[d]	U-1.10		U-1.10		U-1.20	
Metal framing (all other)[d]	U-0.75		U-0.75		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.98	$SHGC_{all}$–0.36	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–1.90	$SHGC_{all}$–0.39	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.90	$SHGC_{all}$–0.34	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–1.36	$SHGC_{all}$–0.36	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR

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

[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.

[b]Exception to Section A3.1.3.1 applies.

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

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

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

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building[a]	U-0.055	R-13.0 + R13.0	U-0.055	R-13.0 + R13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.123	R-7.6 c.i.	U-0.104	R-9.5 c.i.	U-0.580	NR
Metal Building	U-0.084	R-19.0	U-0.084	R-19.0	U-0.113	R-13.0
Steel-Framed	U-0.084	R-13.0 + R-3.8 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.107	R-6.3 c.i.	U-0.087	R-8.3 c.i.	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.052	R-19.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.900	R-10 for 24 in.	F-0.900	R-10 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.65	SHGC-0.25 all	U-0.65	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.60		U-0.60		U-1.20	
Metal framing (entrance door)[d]	U-0.90		U-0.90		U-1.20	
Metal framing (all other)[d]	U-0.65		U-0.65		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-1.17	$SHGC_{all}$-0.36	U_{all}-1.98	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.17	$SHGC_{all}$-0.19	U_{all}-1.17	$SHGC_{all}$-0.19	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}-1.30	$SHGC_{all}$-0.65	U_{all}-1.30	$SHGC_{all}$-0.27	U_{all}-1.90	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.30	$SHGC_{all}$-0.34	U_{all}-1.30	$SHGC_{all}$-0.27	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-0.69	$SHGC_{all}$-0.36	U_{all}-1.36	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-0.69	$SHGC_{all}$-0.19	U_{all}-0.69	$SHGC_{all}$-0.19	U_{all}-1.36	$SHGC_{all}$-NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), NR = no (insulation) requirement.
[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.
[b]Exception to Section A3.1.3.1 applies.
[c]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[d]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance *doors*.

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

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.084	R-19.0	U-0.084	R-19.0	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.087	R-8.3 c.i.	U-0.074	R-10.4 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.40	SHGC-0.40 all	U-0.40	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.50		U-0.50		U-1.20	
Metal framing (entrance door)[d]	U-0.85		U-0.85		U-1.20	
Metal framing (all other)[d]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.17	$SHGC_{all}$–0.49	U_{all}–0.98	$SHGC_{all}$–0.36	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.17	$SHGC_{all}$–0.39	U_{all}–0.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–1.30	$SHGC_{all}$–0.65	U_{all}–1.30	$SHGC_{all}$–0.62	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.30	$SHGC_{all}$–0.34	U_{all}–1.30	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–0.69	$SHGC_{all}$–0.49	U_{all}–0.58	$SHGC_{all}$–0.36	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.69	$SHGC_{all}$–0.39	U_{all}–0.58	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), NR = no (insulation) requirement.
[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.
[b]Exception to Section A3.1.3.1 applies.
[c]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[d]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance *doors*.

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

Opaque Elements	Nonresidential		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-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.119	R-7.6 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0	U-0.083	R-13.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.090	R-11.4 c.i.	U-0.080	R-13.3 c.i.	U-0.151[b]	R-5.7 c.i.[b]
Metal Building	U-0.069	R-13.0 + R-5.6 c.i.	U-0.069	R-13.0 + R-5.6 c.i.	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.064	R-13.0 + R-3.8 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.074	R-10.4 c.i.	U-0.064	R-12.5 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.051	R-19.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.35		U-0.35		U-1.20	
Metal framing (curtainwall/storefront)[d]	U-0.45	SHGC-0.40 all	U-0.45	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (entrance door)[d]	U-0.80		U-0.80		U-1.20	
Metal framing (all other)[d]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.17	$SHGC_{all}$–0.49	U_{all}–1.17	$SHGC_{all}$–0.49	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.17	$SHGC_{all}$–0.39	U_{all}–1.17	$SHGC_{all}$–0.39	U_{all}–1.98	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–1.10	$SHGC_{all}$–0.77	U_{all}–1.10	$SHGC_{all}$–0.77	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.10	$SHGC_{all}$–0.62	U_{all}–1.10	$SHGC_{all}$–0.62	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–0.69	$SHGC_{all}$–0.49	U_{all}–0.69	$SHGC_{all}$–0.49	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.69	$SHGC_{all}$–0.39	U_{all}–0.69	$SHGC_{all}$–0.39	U_{all}–1.36	$SHGC_{all}$–NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), NR = no (insulation) requirement.
[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.
[b]Exception to Section A3.1.3.1 applies.
[c]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[d]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance *doors*.

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

Opaque Elements	Nonresidential		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-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.093	R-10.0 c.i.
Metal Building[a]	U-0.049	R-13.0 + R-19.0	U-0.049	R-13.0 + R-19.0	U-0.072	R-16.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.034	R-30.0
Walls, Above-Grade						
Mass	U-0.080	R-13.3 c.i.	U-0.071	R-15.2 c.i.	U-0.151[b]	R-5.7 c.i.[b]
Metal Building	U-0.069	R-13.0 + R-5.6 c.i.	U-0.069	R-13.0 + R-5.6 c.i.	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.051	R-13.0 + R-7.5 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.064	R-12.5 c.i.	U-0.057	R-14.6 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.032	R-38.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.051	R-19.0
Slab-On-Grade Floors						
Unheated	F-0.540	R-10 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.688	R-20 for 48 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.35	SHGC-0.40 all	U-0.35	SHGC-0.40 all	U-0.65	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.45		U-0.45		U-0.60	
Metal framing (entrance door)[d]	U-0.80		U-0.80		U-0.90	
Metal framing (all other)[d]	U-0.55		U-0.55		U-0.65	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-0.98	$SHGC_{all}$-0.46	U_{all}-1.98	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-0.98	$SHGC_{all}$-0.36	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}-0.87	$SHGC_{all}$-0.71	U_{all}-0.74	$SHGC_{all}$-0.65	U_{all}-1.90	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-0.87	$SHGC_{all}$-0.58	U_{all}-0.74	$SHGC_{all}$-0.55	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-0.58	$SHGC_{all}$-0.49	U_{all}-1.36	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-0.58	$SHGC_{all}$-0.39	U_{all}-1.36	$SHGC_{all}$-NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), NR = no (insulation) requirement.
[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.
[b]Exception to Section A3.1.3.1 applies.
[c]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[d]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance *doors*.

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

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.093	R-10.0 c.i.
Metal Building[a]	U-0.049	R-13.0 + R-19.0	U-0.049	R-13.0 + R-19.0	U-0.072	R-16.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.034	R-30.0
Walls, Above-Grade						
Mass	U-0.071	R-15.2 c.i.	U-0.071	R-15.2 c.i.	U-0.123	R-7.6 c.i.
Metal Building	U-0.057	R-19.0 + R-5.6 c.i.	U-0.057	R-19.0 + R-5.6 c.i.	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.042	R-13.0 + R-15.6 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.051	R-13.0 + R-7.5 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.092	R-10.0 c.i.	C-1.140	NR
Floors						
Mass	U-0.064	R-12.5 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-6.3 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.032	R-38.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.051	R-19.0
Slab-On-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.500		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.35	SHGC-0.45 all	U-0.35	SHGC-NR all	U-0.65	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.40		U-0.40		U-0.60	
Metal framing (entrance door)[d]	U-0.80		U-0.80		U-0.90	
Metal framing (all other)[d]	U-0.45		U-0.45		U-0.65	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.17	$SHGC_{all}$–0.68	U_{all}–1.17	$SHGC_{all}$–0.64	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.17	$SHGC_{all}$–0.64	U_{all}–1.17	$SHGC_{all}$–0.64	U_{all}–1.98	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–0.87	$SHGC_{all}$–0.77	U_{all}–0.61	$SHGC_{all}$–0.77	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.87	$SHGC_{all}$–0.71	U_{all}–0.61	$SHGC_{all}$–0.77	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–0.69	$SHGC_{all}$–0.68	U_{all}–0.69	$SHGC_{all}$–0.64	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.69	$SHGC_{all}$–0.64	U_{all}–0.69	$SHGC_{all}$–0.64	U_{all}–1.36	$SHGC_{all}$–NR

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

[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.

[b]Exception to Section A3.1.3.1 applies.

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

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

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

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.063	R-15.0 c.i.
Metal Building[a]	U-0.035	R-11.0 + R-19.0 Ls	U-0.035	R-11.0 + R-19.0 Ls	U-0.065	R-19.0
Attic and Other	U-0.021	R-49.0	U-0.021	R-49.0	U-0.034	R-30.0
Walls, Above-Grade						
Mass	U-0.071	R-15.2 c.i.	U-0.052	R-25.0 c.i.	U-0.104	R-9.5 c.i.
Metal Building	U-0.057	R-19.0 + R-5.6 c.i.	U-0.057	R-19.0 + R-5.6 c.i.	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.037	R-13.0 + R-18.8 c.i.	U-0.084	R-13.0 + R-3.8 c.i.
Wood-Framed and Other	U-0.036	R-13.0 + R-15.6 c.i.	U-0.036	R-13.0 + R-15.6 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.075	R-12.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.087	R-8.3 c.i.
Steel-Joist	U-0.032	R-38.0	U-0.032	R-38.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.033	R-30.0
Slab-On-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.510	R-20 for 24 in.	F-0.730	NR
Heated	F-0.688	R-20 for 48 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10.0 for 24 in.
Opaque Doors						
Swinging	U-0.500		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-0.500	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.35	SHGC-0.45 all	U-0.35	SHGC-NR all	U-0.65	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.40		U-0.40		U-0.60	
Metal framing (entrance door)[d]	U-0.80		U-0.80		U-0.90	
Metal framing (all other)[d]	U-0.45		U-0.45		U-0.65	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–0.98	$SHGC_{all}$–NR	U_{all}–0.98	$SHGC_{all}$–NR	U_{all}–1.30	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.98	$SHGC_{all}$–NR	U_{all}–0.98	$SHGC_{all}$–NR	U_{all}–1.30	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–0.61	$SHGC_{all}$–NR	U_{all}–0.61	$SHGC_{all}$–NR	U_{all}–1.10	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.61	$SHGC_{all}$–NR	U_{all}–0.61	$SHGC_{all}$–NR	U_{all}–1.10	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–0.58	$SHGC_{all}$–NR	U_{all}–0.58	$SHGC_{all}$–NR	U_{all}–0.81	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.58	$SHGC_{all}$–NR	U_{all}–0.58	$SHGC_{all}$–NR	U_{all}–0.81	$SHGC_{all}$–NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), Ls = *Liner System* (See Section A 2.3.2.4), NR = no (insulation) requirement.
[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.
[b]Exception to Section A3.1.3.1 applies.
[c]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[d]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance *doors*.

TABLE 5.5.3.1.2 Increased Roof Insulation Levels

Roofs	Non-Residential		Residential	
Opaque Elements	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Insulation Entirely Above Deck	U-0.030	R-33	U-0.029	R-34
Metal Buildings	U-0.028	R-35		

5.5.3.1 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-5.0, whichever is less.

5.5.3.1.1 Roof Solar Reflectance and Thermal Emittance. *Roofs*, in climate zones 1 through 3 shall have one of the following:

a. a minimum three-year-aged solar *reflectance* of 0.55 when tested in accordance with ASTM C1549 or ASTM E1918, and in addition, a minimum three-year-aged thermal *emittance* of 0.75 when tested in accordance with ASTM C1371 or ASTM E408.
b. a minimum three-year-aged Solar Reflectance Index of 64 when determined in accordance with the Solar Reflectance Index method in ASTM E1980 using a convection coefficient of 2.1 Btu/h·ft^2·°F
c. increased *roof* insulation levels found in Table 5.5.3.1.2.

Exceptions:

a. Ballasted *roofs* with a minimum stone *ballast* of 17 lbs/ft^2 or 23 lbs/ft^2 pavers.
b. *Vegetated Roof Systems* that contain a minimum thickness of 2.5 in. of growing medium and covering a minimum of 75% of the *roof* area with durable plantings.
c. *Roofs*, where a minimum of 75% of the *roof* area:
   1. Is shaded during the peak sun angle on June 21 by permanent components or features of the building, or
   2. Is covered by off-set photovoltaic arrays, building-integrated photovoltaic arrays, or solar air or water collectors, or
   3. Is permitted to be interpolated using a combination of parts i and ii above.
d. Steep sloped *roofs*.
e. Low sloped *metal building roofs* in climate zones 2 and 3.
f. *Roofs* over ventilated attics or *roofs* over *semi-heated spaces* or *roofs* over *conditioned spaces* that are not *cooled spaces*.
g. Asphaltic membranes in climate zones 2 and 3.

The values for three-year-aged solar *reflectance* and three-year-aged thermal *emittance* shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the Cool Roof Rating Council CRRC-1 Product Rating Program, and shall be *labeled* and certified by the *manufacturer*.

5.5.3.2 Above-Grade Wall Insulation. All *above-grade walls* shall comply with the insulation values specified in Tables 5.5-1 through 5.5-8. When a *wall* consists of both *above-grade* and *below-grade* portions, the entire *wall* for that *story* shall be insulated on either the exterior or the interior or be integral.

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

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

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

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

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

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

5.5.4 Fenestration

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

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

5.5.4.2 Fenestration Area

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

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

5.5.4.2.2 Maximum Skylight Fenestration Area. The total *skylight area* shall not exceed 5% of the *gross roof area*.

5.5.4.2.3 Minimum Skylight Fenestration Area. In any *enclosed space* in a building that is four stories or less and that is:

a. 5,000 ft^{2}and greater and,
b. directly under a *roof* with ceiling heights greater than 15 ft, and
c. one of the following *space* types: office, lobby, atrium, concourse, corridor, non-refrigerated warehouse or storage, gymnasium/exercise center, convention center, automotive service, manufacturing, retail, distribution/sorting area, transportation, or workshop,

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

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

These *skylights* shall have a glazing material or diffuser with a measured haze value greater than 90% when tested according to ASTM D1003. *General lighting* in the *daylight area* shall be controlled as described in Section 9.4.1.5.

Exceptions to 5.5.4.2.3:

a. *Enclosed spaces* in climate zones 6 through 8.
b. *Enclosed spaces* with designed *general lighting* power densities less than 0.5 W/ft^2.
c. *Enclosed spaces* where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the *roof* over the *enclosed space* for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
d. *Enclosed spaces* where the *daylight area under rooftop monitors* is greater than 50% of the *enclosed space* floor area.
e. *Enclosed spaces* where it is documented that 90% of the *skylight* area is shaded on June 21in the Northern Hemisphere (December 21 in the Southern Hemisphere) at noon by permanent architectural features of the building.
f. The required *daylight area under skylights* may be reduced by the amount of *primary sidelighted area* with a *sidelighting effective aperture* greater than 0.15 and with *general lighting* controlled as described in Section 9.4.1.4 without the use of any exceptions in Section 9.4.1.4.
g. The required *daylight area under skylights* may be reduced by the amount of *secondary sidelighted area* with a *sidelighting effective aperture* greater than 0.30 and with *general lighting* controlled by *continuous daylight dimming.*

5.5.4.3 Fenestration U-Factor. *Fenestration* shall have a *U-factor* not greater than that specified in Tables 5.5-1 through 5.5-8 for the appropriate *fenestration area.*

5.5.4.4 Fenestration Solar Heat Gain Coefficient (SHGC)

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

Exceptions:

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

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

where

O_s = percent opacity of the shading device

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

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

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

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

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

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

1. the street side of the street-level *story* does not exceed 20 ft in height,
2. the *fenestration* has a continuous overhang with a weighted average *PF* greater than 0.5, and
3. the *fenestration area* for the street side of the street-level *story* is less than 75% of the *gross wall area* for the street side of the street-level *story*.

When this exception is utilized, separate calculations shall be performed for these sections of the *building envelope*, and these values shall not be averaged with any others for compliance purposes. No credit shall be given here or elsewhere in the building for not fully utilizing the *fenestration area* allowed.

d. For *dynamic glazing*, the minimum *SHGC* shall be used to demonstrate compliance with this section. *Dynamic glazing* shall be considered separately from other *vertical fenestration*, and area-weighted averaging with other *vertical fenestration* that is not *dynamic glazing* shall not be permitted.

5.5.4.4.2 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*.

Exception: *Skylights* are exempt from SHGC requirements provided they:

a. Have a glazing material or diffuser with a measured haze value greater than 90% when tested according to ASTM D1003.
b. Have a *Skylight* VT greater than 0.40, and;
c. Have all *general lighting* in the *daylight area under skylights* controlled by multilevel photocontrols in accordance with Section 9.4.1.5.
d. For *dynamic glazing*, the minimum *SHGC* shall be used to demonstrate compliance with this section. *Dynamic glazing* shall be considered separately from other *vertical fenestration*, and area-weighted averaging with other *vertical fenestration* that is not *dynamic glazing* shall not be permitted.

5.5.4.5 Fenestration Orientation. The *vertical fenestration area* shall meet the following requirement:

$$A_S \geq A_W \text{ and } A_S \geq A_E$$

where

A_s = south oriented *vertical fenestration area* (oriented less than or equal to 45 degrees of true south)

A_n = north oriented *vertical fenestration area* (oriented less than or equal to 45 degrees of true north)

A_w = west oriented *vertical fenestration area* (oriented less than 30 degrees of true west)

A_e = east oriented *vertical fenestration area* (oriented less than 30 degrees of true east)

In the southern hemisphere, replace A_s with A_n in the formulae above.

Exceptions to 5.5.4.5:

a. *Vertical fenestration* that complies with the exception to 5.5.4.4.1 (c).
b. Buildings that have an *existing building* or existing permanent infrastructure within 20 ft to the south (north in the southern hemisphere) which is at least half as tall as the proposed building.
c. Buildings with shade on 75% of the west and east oriented *vertical fenestration* areas from permanent projections, existing buildings, existing permanent infrastructure, or topography at 9 a.m. and 3 p.m. on the summer solstice (June 21 in the northern hemisphere).
d. *Alterations* and *additions* with no increase in *vertical fenestration area*.

5.6 Building Envelope Trade-Off Option

5.6.1 The *building envelope* complies with the standard if:

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

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

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

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

5.7 Submittals

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

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

5.7.3 Visible Transmittance. Test results required in 5.8.2.6 for *skylight* glazing or diffusers shall be included with *construction documents* submitted with each application for a permit.

5.8 Product Information and Installation Requirements

5.8.1 Insulation

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

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

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

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

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

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

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

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

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

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

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

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

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

5.8.1.7.2 Foundation vents shall not interfere with the insulation.

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

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

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

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

5.8.2 Fenestration and Doors

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

5.8.2.2 Labeling of Fenestration Products. All manufactured *fenestration* products shall have a permanent nameplate, installed by the *manufacturer*, listing the *U-factor*, SHGC, air leakage rate, and where required by the Exception to 5.5.4.4.2, *Visible Transmittance* (VT).

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

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

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

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

Exceptions:

a. *U-factors* from Section A8.1 shall be an acceptable alternative for determining compliance with the *U-factor* criteria for *skylights*. Where credit is being taken for a low-emissivity coating, the emissivity of the coating shall be determined in accordance with NFRC 300. Emissivity shall be verified and certified by the *manufacturer*.

b. *U-factors* from Section A8.2 shall be an acceptable alternative for determining compliance with the *U-factor* criteria for *vertical fenestration*.
c. *U-factors* from Section A7 shall be an acceptable alternative for determining compliance with the *U-factor* criteria for *opaque doors*.
d. For garage *doors*, ANSI/DASMA105 shall be an acceptable alternative for determining *U-factors*.

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

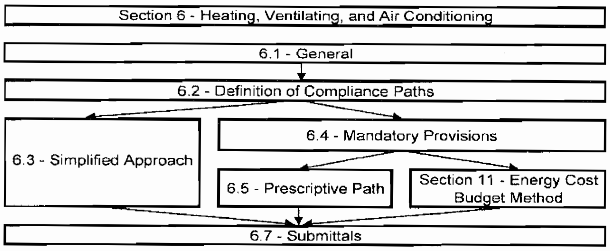
Exceptions:

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

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

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

6. HEATING, VENTILATING, AND AIR CONDITIONING



6.1 General

6.1.1 Scope

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

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

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

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

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

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

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

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

6.1.1.3.5 New and replacement piping shall comply with Section 6.4.4.1.

Exceptions: Compliance shall not be required:

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

6.2 Compliance Path(s)

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

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

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

6.3 Simplified Approach Option for HVAC Systems

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

a. building is two stories or fewer in height
b. *gross floor area* is less than 25,000 ft^2
c. each *HVAC system* in the building complies with the requirements listed in Section 6.3.2

6.3.2 Criteria. The *HVAC system* must meet ALL of the following criteria:

a. The *system* serves a single *HVAC zone*.
b. The *equipment* must meet the variable flow requirements of Section 6.4.3.10.
c. Cooling (if any) shall be provided by a unitary packaged or split-system air conditioner that is either air-cooled or evaporatively cooled with *efficiency* meeting the requirements shown in Table 6.8.1A (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.
d. The *system* shall have an *air economizer* meeting the requirements of Section 6.5.1.
e. Heating (if any) shall be provided by a unitary packaged or split-system heat pump that meets the applicable *efficiency* requirements shown in Table 6.8.1B (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*).
f. The *system* shall meet the exhaust air *energy* recovery requirements of Section 6.5.6.1.

TABLE 6.3.2 Eliminate Required Economizer for Comfort Cooling by Increasing Cooling Efficiency

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

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

g. The *system* shall be controlled by a *manual* changeover or dual *setpoint thermostat*.
h. If a heat pump equipped with auxiliary internal *electric resistance* heaters is installed, *controls* shall be provided that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and *setback* recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles. The heat pump must be controlled by either (1) a digital or electronic *thermostat* designed for heat pump use that energizes auxiliary heat only when the heat pump has insufficient capacity to maintain *setpoint* or to warm up the *space* at a sufficient rate or (2) a multistage *space thermostat* and an *outdoor air thermostat* wired to energize auxiliary heat only on the last stage of the *space thermostat* and when outside air temperature is less than 40°F. Heat pumps whose minimum *efficiency* is regulated by NAECA and whose ratings meet the requirements shown in Table 6.8.1B and include all usage of internal *electric resistance* heating are exempted from the *control* requirements of this part (Section 6.3.2[h]).
i. The *system controls* shall not permit reheat or any other form of simultaneous heating and cooling for humidity *control*.
j. *Systems* serving *spaces* other than hotel/motel guest rooms, and other than those requiring continuous operation, which have both a cooling or heating capacity greater than 15,000 Btu/h and a supply fan motor power greater than 0.75 hp, shall be provided with a time clock that (1) can start and stop the *system* under different schedules for seven different day-types per week, (2) is capable of retaining programming and time setting during a loss of power for a period of at least ten hours, (3) includes an accessible *manual* override that allows temporary operation of the *system* for up to two hours, (4) is capable of temperature *setback* down to 55°F during off hours, and (5) is capable of temperature setup to 90°F during off hours.
k. Except for piping within *manufacturers'* units, HVAC piping shall be insulated in accordance with Tables 6.8.3A and 6.8.3B. Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation.
l. *Ductwork* and *plenums* shall be insulated in accordance with Tables 6.8.2A and 6.8.2B and shall be sealed in accordance with Section 6.4.4.2.1.
m. *Construction documents* shall require a ducted *system* to be air balanced in accordance with industry-accepted procedures.
n. *Outdoor air* intake and exhaust *systems* shall meet the requirements of Section 6.4.3.4.
o. Where separate heating and cooling *equipment* serves the same temperature zone, *thermostats* shall be interlocked to prevent simultaneous heating and cooling.
p. *Systems* with a design supply air capacity greater than 10,000 cfm shall have *optimum start controls.*
q. The *system* shall comply with the *demand control ventilation* requirements in section 6.4.3.9.

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 6.8.1K shall have a minimum performance at the specified rating conditions when tested in accordance with the specified test procedure. Where multiple rating conditions or performance requirements are provided, the *equipment* shall satisfy all stated requirements, unless otherwise exempted by footnotes in the table. *Equipment* covered under the Federal Energy Policy Act of 1992 (EPACT) shall have no minimum *efficiency* requirements for operation at minimum capacity or other than standard rating conditions. *Equipment* used to provide water heating functions as part of a combination *system* shall satisfy all stated requirements for the appropriate *space* heating or cooling category.

Tables are as follows:

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

f. Table 6.8.1F—*Boilers*
g. Table 6.8.1G—Heat Rejection Equipment
h. Table 6.8.1H—Heat Transfer Equipment
i. Table 6.8.1 I—Variable Refrigerant Flow Air Conditioners
j. Table 6.8.1 J—Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps
k. Table 6.8.1K—Air Conditioners Serving *Computer Rooms*

All furnaces with input ratings of ≥225,000 Btu/h, including electric furnaces, that are not located within the *conditioned space* shall have jacket losses not exceeding 0.75% of the input rating. Air conditioners primarily serving *computer rooms* and covered by ASHRAE Standard 127 shall meet the requirements in Table 6.8.1K. All other air conditioners shall meet the requirements in Table 6.8.1A.

6.4.1.2 Minimum Equipment Efficiencies—Listed Equipment—Nonstandard Conditions.

6.4.1.2.1 Water-cooled centrifugal chilling packages. *Equipment* not designed for operation at AHRI Standard 550/590 test conditions of 44°F leaving chilled-fluid temperature and 85°F entering condenser-fluid temperature with 3 gpm/ton condenser-fluid flow (and, thus, cannot be tested to meet the requirements of Table 6.8.1C) shall have maximum full-load kW/ton and *NPLV* ratings adjusted using the following equation:

$$\text{Adjusted maximum full-load kW/ton rating} = (\text{full-load kW/ton from Table 6.8.1C}/K_{adj})$$

$$\text{Adjusted maximum NPLV rating} = \text{IPLV from Table 6.8.1C}/K_{adj})$$

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

where

A	=	$0.00000014592 \times (\text{LIFT})^4 - 0.0000346496 \times (\text{LIFT})^3 + 0.00314196 \times (\text{LIFT})^2 - 0.147199 \times (\text{LIFT}) + 3.9302$
B	=	$0.0015 \times \text{LvgEvap} + 0.934$
LIFT	=	LvgCond – LvgEvap
LvgCond	=	Full-load condenser leaving fluid temperature (°F)
LvgEvap	=	Full-load evaporator leaving temperature (°F)

The adjusted full-load and *NPLV* values are only applicable for centrifugal chillers meeting all of the following full-load design ranges:

- Minimum Evaporator Leaving Temperature:36°F
- Maximum Condenser Leaving Temperature:115°F
- LIFT ≥ 20°F and ≤ 80°F

Manufacturers shall calculate the adjusted maximum kW/ton and NPLV before determining whether to label the chiller per 6.4.1.5. Compliance with 90.1-2007 or -2010 or both shall be *labeled* on chillers within the scope of the Standard.

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

Example: Path A 600 ton centrifugal chiller Table 6.8.1C efficiencies

Full Load = 0.570 kW/ton

IPLV = 0.539 kW/ton

LvgCond = 91.16°F

LvgEvap = 42°F

LIFT = 91.16 – 42 = 49.16°F

$K_{adj} = A \times B$

$$A = 0.00000014592 \times (49.16)^4 - 0.0000346496 \times (49.16)^3 + 0.00314196 \times (49.16)^2 - 0.147199 \times (49.16) + 3.9302 = 1.0228$$

$B = 0.0015 \times 42 + 0.934 = 0.9970$

Adjusted full load = $0.570/(1.0228 \times 0.9970) = 0.559$ kW/ton

NPLV = $0.539/(1.0228 \times 0.9970) = 0.529$ kW/ton

6.4.1.2.2 Positive displacement (air- and water-cooled) chilling packages. *Equipment* with an evaporator leaving fluid temperature higher than 32°F shall show compliance with Table 6.8.1C when tested or certified with water at standard rating conditions, per the referenced test procedure.

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

6.4.1.4 Verification of Equipment Efficiencies. *Equipment efficiency* information supplied by *manufacturers* shall be verified as follows:

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

6.4.1.5 Labeling

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

6.4.1.5.2 Packaged Terminal Air Conditioners. Nonstandard size *packaged terminal air conditioner*s and heat pumps with existing sleeves having an external *wall* opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in^2 shall be factory *labeled* as follows: *Manufactured for nonstandard size applications only: not to be installed in new construction projects.*

6.4.2 Calculations.

6.4.2.1 Load Calculations. Heating and cooling *system* design loads for the purpose of sizing *systems* and *equipment* shall be determined in accordance with ANSI/ASHRAE/ACCA Standard 183, Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise *Residential* Buildings.

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

6.4.3 Controls

6.4.3.1 Zone Thermostatic Controls

6.4.3.1.1 General. The supply of heating and cooling *energy* to each *zone* shall be individually controlled by *thermostatic controls* responding to temperature within the *zone*. For the purposes of Section 6.4.3.1, a *dwelling unit* shall be permitted to be considered a single *zone.*

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

a. the perimeter *system* includes at least one *thermostatic control* zone for each building exposure having exterior *walls* facing only one *orientation* for 50 contiguous feet 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 5°F within which the supply of heating and cooling *energy* to the zone is shut off or reduced to a minimum.

Exceptions:

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

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

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

Exceptions:

a. *HVAC systems* intended to operate continuously.
b. *HVAC systems* having a design heating capacity and cooling capacity less than 15,000 Btu/h that are equipped with *readily accessible manual* ON/OFF *controls*.

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

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

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

6.4.3.3.2 Setback Controls. Heating *systems* located in climate zones 2–8 shall be equipped with *controls* that have the capability to automatically restart and temporarily operate the *system* as required to maintain *zone* temperatures above a heating *setpoint* adjustable down to 55°F 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 90°F or higher or to prevent high *space* humidity levels.

Exception: Radiant floor and ceiling heating *systems.*

6.4.3.3.3 Optimum Start Controls. Individual heating and cooling air *distribution systems* with a total design supply air capacity exceeding 10,000 cfm, served by one or more supply fans, shall have *optimum start controls*. The *control* algorithm shall, as a minimum, be a function of the difference between *space* temperature and occupied *setpoint* and the amount of time prior to scheduled occupancy.

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

Exceptions: *Isolation devices* and *controls* are not required for the following:

a. Exhaust air and *outdoor air* connections to isolation *zones* when the fan *system* to which they connect is 5000 cfm and smaller.
b. Exhaust airflow from a single isolation *zone* of less than 10% of the design airflow of the exhaust *system* to which it connects.
c. *Zones* intended to operate continuously or intended to be inoperative only when all other *zones* are inoperative.

6.4.3.4 Ventilation System Controls

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

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

Exceptions:

a. Backdraft gravity (nonmotorized) dampers are acceptable for exhaust and relief in buildings less than three stories in height and for *ventilation* air intakes and exhaust and relief dampers in buildings of any height located in climate zones 1, 2, and 3. Backdraft dampers for *ventilation* air intakes must be protected from direct exposure to wind.
b. Backdraft gravity (nonmotorized) dampers are acceptable in *systems* with a design *outdoor air* intake or exhaust capacity of 300 cfm or less.
c. Dampers are not required in *ventilation* or exhaust *systems* serving *unconditioned spaces*.
d. Dampers are not required in exhaust *systems* serving Type 1 kitchen exhaust hoods.

6.4.3.4.3 Damper Leakage. Where *outdoor air* supply and exhaust/relief dampers are required by Section 6.4.3.4, they shall have a maximum leakage rate when tested in accordance with AMCA Standard 500 as indicated in Table 6.4.3.4.3.

6.4.3.4.4 Ventilation Fan Controls. Fans with motors greater than 0.75 hp shall have *automatic controls* complying with Section 6.4.3.3.1 that are capable of shutting off fans when not required.

Exception: *HVAC systems* intended to operate continuously.

TABLE 6.4.3.4.3 Maximum Damper Leakage, cfm per ft^2 at 1.0 in. w.g.

Climate Zone	Ventilation Air Intake		Exhaust/Relief	
	Non-motorized[1]	Motorized	Non-motorized[1]	Motorized
1,2	–	–	–	
any height	20	4	20	4
3	–	–	–	
any height	20	10	20	10
4,5b,5c	–	–	–	
less than 3 stories	not allowed	10	20	10
3 or more stories	not allowed	10	not allowed	10
5a,6,7,8	–	–	–	
less than 3 stories	not allowed	4	20	4
3 or more stories	not allowed	4	not allowed	4

[1] Dampers smaller than 24 in. in either dimension may have leakage of 40 cfm/ft^2.

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

Exceptions:

a. Garages less than 30,000 ft^2 with *ventilation systems* that do not utilize *mechanical cooling* or *mechanical heating*
b. Garages that have a garage area to *ventilation system motor nameplate hp* ratio that exceeds 1500 ft^2/hp and do not utilize *mechanical cooling* or *mechanical heating.*
c. Where not permitted by the *authority having jurisdiction.*

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

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

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

6.4.3.7 Humidification and Dehumidification. Where a *zone* is served by a *system* or *systems* with both humidification and dehumidification capability, means (such as limit switches, mechanical stops, or, for DDC *systems*, software programming) shall be provided capable of preventing simultaneous operation of humidification and dehumidification *equipment.*

Exceptions:

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

6.4.3.8 Freeze Protection and Snow/Ice Melting Systems. Freeze protection *systems*, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include *automatic controls* capable of shutting off the *systems* when *outdoor air* temperatures are above 40°F 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 50°F and no precipitation is falling and an *automatic* or *manual control* that will allow shutoff when the outdoor temperature is above 40°F so that the potential for snow or ice accumulation is negligible.

6.4.3.9 Ventilation Controls for High-Occupancy Areas. *Demand control ventilation* (DCV) is required for *spaces* larger than 500 ft^2 and with a design occupancy for *ventilation* of greater than 40 people per 1000 ft^2 of floor area and served by *systems* with one or more of the following:

a. an air-side economizer,
b. *automatic* modulating *control* of the *outdoor air* damper, or
c. a design *outdoor air*flow greater than 3000 cfm.

Exceptions:

a. *Systems* with the exhaust air *energy* recovery complying with Section 6.5.6.1.
b. Multiple-zone *systems* without DDC of individual zones communicating with a central *control* panel.
c. *Systems* with a design outdoor airflow less than 1200 cfm.
d. *Spaces* where the supply airflow rate minus any makeup or outgoing *transfer air* requirement is less than 1200 cfm.

6.4.3.10 Single Zone Variable-Air-Volume Controls. *HVAC systems* shall have variable airflow *controls* as follows:

a. Air-handling and fan-coil units with chilled-water cooling coils and supply fans with motors greater than or equal to 5 hp shall have their supply fans controlled by two-speed motors or variable-speed drives. At cooling demands less than or equal to 50%, the supply fan *controls* shall be able to reduce the airflow to no greater than the larger of the following:

    1. One half of the full fan speed, or
    2. The volume of *outdoor air* required to meet the *ventilation* requirements of Standard 62.1.

b. Effective January 1, 2012, all air-conditioning *equipment* and air-handling units with direct expansion cooling and a cooling capacity at AHRI conditions greater than or equal to 110,000 Btu/h that serve single zones shall have their supply fans controlled by two-speed motors or variable-speed drives. At cooling demands less than or equal to 50%, the supply fan *controls* shall be able to reduce the airflow to no greater than the larger of the following:

    1. Two-thirds of the full fan speed, or
    2. The volume of *outdoor air* required to meet the *ventilation* requirements of Standard 62.1.

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 Informative Appendix E). These requirements do not apply to HVAC *equipment.* Insulation shall be protected from damage, including that due to sunlight, moisture, *equipment* maintenance and wind, but not limited to the following:

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

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

Exceptions:

a. Factory-installed *plenums*, casings, or *ductwork* furnished as a part of HVAC *equipment* tested and rated in accordance with Section 6.4.1.
b. Ducts or *plenums* located in *heated spaces*, *semiheated spaces*, or *cooled spaces*.
c. For runouts less than 10 ft in length to air *terminals* or air outlets, the *rated R-value of insulation* need not exceed R-3.5.
d. Backs of air outlets and outlet *plenums* exposed to unconditioned or *indirectly conditioned spaces* with face areas exceeding 5 ft^2 need not exceed R-2; those 5 ft^2 or smaller need not be insulated.

6.4.4.1.3 Piping Insulation. Piping shall be thermally insulated in accordance with Tables 6.8.3A and 6.8.3B.

Exceptions:

a. Factory-installed piping within HVAC *equipment* tested and rated in accordance with Section 6.4.1.
b. Piping that conveys fluids having a design operating temperature range between 60°F and 105°F, inclusive.
c. Piping that conveys fluids that have not been heated or cooled through the use of *fossil fuels* or electricity (such as *roof* and condensate drains, domestic cold water supply, natural gas piping),
d. Where heat gain or heat loss will not increase *energy* usage (such as liquid refrigerant piping).
e. In piping 1 in. or less, insulation is not required for strainers, control valves, and balancing valves.

6.4.4.1.4 Sensible Heating Panel Insulation. All *thermally ineffective panel surfaces* of *sensible heating panels*, including U-bends and headers, shall be insulated with a minimum of R-3.5. Adjacent envelope insulation counts toward this requirement.

6.4.4.1.5 Radiant Floor Heating. The bottom surfaces of floor structures incorporating radiant heating shall be insulated with a minimum of R-3.5. Adjacent envelope insulation counts toward this requirement.

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

6.4.4.2 Ductwork and Plenum Leakage

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

6.4.4.2.2 Duct Leakage Tests. *Ductwork* that is designed to operate at static pressures in excess of 3 in. w.c. and all *ductwork* located outdoors shall be leak-tested according to industry-accepted test procedures (see Informative Appendix E). Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. All sections shall be selected by the building owner or the designated representative of the building owner. Positive pressure leakage testing is acceptable for negative pressure *ductwork*.The maximum permitted duct leakage shall be

$$L_{max} = C_L P^{0.65}$$

where

L_{max}	=	maximum permitted leakage cfm/100 ft^2 duct surface area;
C_L	=	6, duct leakage class, cfm/100 ft^2 duct surface area at 1 in. w.c.; and
P	=	test pressure, which shall be equal to the design duct pressure class rating, in. w.c.

6.5 Prescriptive Path

6.5.1 Economizers. Each cooling *system* that has a fan shall include either an air or *water economizer* meeting the requirements of Sections 6.5.1.1 through 6.5.1.4.

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

a. Individual fan-cooling units with a supply capacity less than the minimum listed in Table 6.5.1A for comfort cooling applications and Table 6.5.1B for *computer room applications*.
b. *Systems* that include nonparticulate air treatment as required by Section 6.2.1 in Standard 62.1.
c. In hospitals and ambulatory surgery centers, where more than 75% of the air designed to be supplied by the *system* is to *spaces* that are required to be

TABLE 6.5.1A Minimum Fan-Cooling Unit Size for Which an Economizer is Required for Comfort Cooling

Climate Zones	Cooling Capacity for Which an Economizer is Required
1a, 1b	No economizer requirement
2a, 2b, 3a, 4a, 5a, 6a 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	≥54,000 Btu/h

TABLE 6.5.1B Minimum Fan-Cooling Unit Size for Which an Economizer is Required for Computer Rooms

Climate Zones	Cooling Capacity for Which an Economizer is Required
1a, 1b, 2a, 3a, 4a	No economizer requirement
2b, 5a, 6a, 7, 8	≥135,000 Btu/h
3b, 3c, 4b, 4c, 5b, 5c, 6b	≥65,000 Btu/h

humidified above 35°F dew-point temperature to comply with applicable codes or accreditation standards. In all other buildings, where more than 25% of the air designed to be supplied by the *system* is to *spaces* that are designed to be humidified above 35°F dew-point temperature to satisfy process needs. This exception does not apply to *computer rooms*.

d. *Systems* that include a condenser heat recovery *system* with a minimum capacity as defined in 6.5.6.2.2a or 6.5.6.2.2b.
e. *Systems* that serve *residential spaces* where the *system* capacity is less than five times the requirement listed in Table 6.5.1A.
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 60°F.
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. For comfort cooling where the cooling *efficiency* meets or exceeds the *efficiency* improvement requirements in Table 6.3.2.
j. *Systems* primarily serving *computer rooms* where:
    1. the total design cooling load of all *computer rooms* in the building is less than 3,000,000 Btu/h and the building in which they are located is not served by a centralized chilled water plant, or
    2. the room total design cooling load is less than 600,000 Btu/h and the building in which they are located is served by a centralized chilled water plant., or
    3. the local water authority does not allow cooling towers, or
    4. less than 600,000 Btu/h of *computer room* cooling *equipment* capacity is being added to an existing building
k. Dedicated *systems* for *computer rooms* where a minimum of 75% of the design load serves:
    1. those *spaces* classified as an *essential facility*
    2. those *spaces* having a *mechanical cooling* design of Tier IV as defined by ANSI/TIA-942
    3. those *spaces* classified under NFPA 70 Article 708 – Critical Operations Power Systems (COPS)
    4. those *spaces* where core clearing and settlement services are performed such that their failure to settle pending financial transactions could present systemic risk as described in "The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System, April 7, 2003"

6.5.1.1 Air Economizers

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

6.5.1.1.2 Control Signal. Economizer dampers shall be capable of being sequenced with the *mechanical cooling equipment* and shall not be controlled by only mixed air temperature.

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

6.5.1.1.3 High-Limit Shutoff. All *air economizers* shall be capable of automatically reducing *outdoor air* intake to the design minimum *outdoor air* quantity when *outdoor air* intake will no longer reduce cooling *energy* usage. High-limit shutoff *control* types for specific climates shall be chosen from Table 6.5.1.1.3A. High-limit shutoff *control* settings for these *control* types shall be those listed in Table 6.5.1.1.3B.

6.5.1.1.4 Dampers. Return, exhaust/relief, and *outdoor air* dampers shall meet the requirements of Section 6.4.3 Ventilation System Controls.

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

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

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

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

Device Type	Climate	Required High Limit (Economizer Off When):	
		Equation	Description
Fixed dry bulb	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 5a, 6a	$T_{OA} > 75°F$ $T_{OA} > 70°F$	Outdoor air temperature exceeds 75°F Outdoor air temperature exceeds 70°F
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	2a, 3a, 4a, 5a, 6a	$h_{OA} > 28$ Btu/lb[a]	Outdoor air enthalpy exceeds 28 Btu/lb of dry air[a]
Electronic enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outdoor air temperature/RH exceeds the "A" setpoint curve[b]
Differential enthalpy	All	$h_{OA} > h_{RA}$	Outdoor air enthalpy exceeds return air enthalpy
Dew-point and dry-bulb temperatures	All	$DP_{oa} > 55°F$ or $T_{oa} > 75°F$	Outdoor air dry bulb exceeds 75°F or outside dew point exceeds 55°F (65 gr/lb)

[a] At altitudes substantially different than sea level, the Fixed Enthalpy limit shall be set to the enthalpy value at 75°F and 50% relative humidity. As an example, at approximately 6000 ft elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.
[b] *Setpoint* "A" corresponds to a curve on the psychrometric chart that goes through a point at approximately 75°F 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.

6.5.1.1.5 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 50°F dry bulb/ 45°F wet bulb and below.

Exceptions:

a. *Systems* primarily serving *computer rooms* in which 100% of the expected *system* cooling load at 40°F dry bulb/35°F wet bulb is met with evaporative *water economizers*.
b. *Systems* primarily serving *computer rooms* with dry cooler *water economizers* which satisfy 100% of the expected *system* cooling load at 35°F dry bulb.
c. *Systems* where dehumidification requirements cannot be met using *outdoor air* temperatures of 50°F dry bulb/45°F wet bulb and where 100% of the expected *system* cooling load at 45°F dry bulb/40°F wet bulb is met with evaporative *water economizers*.

6.5.1.2.2 Maximum Pressure Drop. Precooling coils and water-to-water heat exchangers used as part of a *water economizer system* shall either have a water-side pressure drop of less than 15 ft of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the *system* is in the normal cooling (noneconomizer) mode.

6.5.1.3 Integrated Economizer Control. Economizer *systems* shall be integrated with the *mechanical cooling sys-*

tem and be capable of providing partial cooling even when additional *mechanical cooling* is required to meet the remainder of the cooling load.

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

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

6.5.2 Simultaneous Heating and Cooling Limitation

6.5.2.1 Zone Controls. *Zone thermostatic controls* shall prevent

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

Exceptions:

a. *Zones* for which the volume of air that is reheated, recooled, or mixed is less than the larger of the following:
   1. 30% of the *zone* design peak supply rate;
   2. The *outdoor airflow* rate required to meet the *ventilation* requirements of Section 6.2 of ASHRAE Standard 62.1 for the *zone*;
   3. Any higher rate that can be demonstrated, to the satisfaction of the *authority having jurisdiction*, to reduce overall *system* annual *energy* usage by offsetting reheat/recool *energy* losses through a reduction in *outdoor air* intake for the *system*.
   4. The air flow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.
b. *Zones* that comply with all of the following:
   1. The air flow rate in *dead band* between heating and cooling does not exceed the larger of the following:
      i. 20% of the *zone* design peak supply rate;
      ii. The *outdoor air* flow rate required to meet the *ventilation* requirements of Section 6.2 of ASHRAE Standard 62.1 for the *zone*;
      iii. 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.
   2. The air flow rate that is reheated, recooled, or mixed in peak heating *demand* shall be less than 50% of the *zone* design peak supply rate.
   3. Airflow between *dead band* and full heating or full cooling shall be modulated.
c. Laboratory exhaust *systems* that comply with 6.5.7.2.
d. *Zones* where at least 75% of the *energy* for *reheating* or for providing warm air in mixing *systems* is provided from a *site-recovered* (including condenser heat) or *site-solar energy source*.

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

Exceptions:

a. Laboratory exhaust *systems* that comply with 6.5.7.2.
b. During preoccupancy building *warm-up* and *setback*

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

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

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

a. The *system* is designed to allow a *dead band* between changeover from one mode to the other of at least 15°F *outdoor air* temperature.
b. The *system* is designed to operate and is provided with *controls* that will allow operation in one mode for at least four hours before changing over to the other mode.
c. *Reset controls* are provided that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F apart.

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

a. *Controls* that are capable of providing a heat pump water supply temperature *dead band* of at least 20°F between initiation of heat rejection and heat addition by the central devices (e.g., tower and *boiler*).
b. For climate zones 3 through 8, if a closed-circuit tower (fluid cooler) is used, either an *automatic* valve shall be installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers shall be provided. If an open-circuit tower is used directly in the heat pump loop, an *automatic* valve shall be installed to bypass all heat pump water flow around the tower. If an open-circuit tower is used in conjunction with a separate heat

exchanger to isolate the tower from the heat pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

Exception: Where a *system* loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of *demand* and capacity, *dead bands* of less than 20°F shall be allowed.

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

Exceptions:

a. The *system* is capable of reducing supply air volume to 50% or less of the design airflow rate or the minimum *outdoor air ventilation* rate specified in ASHRAE Standard 62.1 or other applicable federal, state, or local code or recognized standard, whichever is larger, before simultaneous heating and cooling takes place.
b. The individual fan cooling unit has a design cooling capacity of 80,000 Btu/h 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 40,000 Btu/h 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 vivariums, museums, surgical suites, and buildings with refrigerating *systems*, such as supermarkets, refrigerated warehouses, and ice arenas. This exception does not apply to *computer rooms*.
e. At least 75% of the *energy* for *reheating* or for providing warm air in mixing *systems* is provided from a *site-recovered* (including condenser heat) or *site-solar energy source*.
f. *Systems* where the heat added to the airstream is the result of the use of a desiccant *system* and 75% of the heat added by the desiccant *system* is removed by a heat exchanger, either before or after the desiccant *system* with *energy* recovery.

6.5.2.4 Humidification. *Systems* with hydronic cooling and humidification *systems* designed to maintain inside humidity at a dew-point temperature greater than 35°F shall use a *water economizer* if an economizer is required by Section 6.5.1.

6.5.3 Air System Design and Control. Each *HVAC system* having a total *fan system motor nameplate hp* exceeding 5 hp shall meet the provisions of Sections 6.5.3.1 through 6.5.3.4.

6.5.3.1 Fan System Power Limitation

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

Exceptions:

a. Hospital, vivarium, and laboratory *systems* that utilize flow *control devices* on exhaust and/or return to maintain *space* pressure relationships necessary for occupant health and safety or environmental *control* may use variable-volume fan power limitation.
b. Individual exhaust fans with motor *nameplate horsepower* of 1 hp or less.

6.5.3.1.2 Motor Nameplate Horsepower. For each fan, the selected fan motor shall be no larger than the first available motor size greater than the bhp. The fan bhp must be indicated on the design documents to allow for compliance verification by the *code official*.

Exceptions:

a. For fans less than 6 bhp, where the first available motor larger than the bhp has a *nameplate rating* within 50% of the bhp, the next larger nameplate motor size may be selected.
b. For fans 6 bhp and larger, where the first available motor larger than the bhp has a *nameplate rating* within 30% of the bhp, the next larger nameplate motor size may be selected.

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

6.5.3.2.1 Part-Load Fan Power Limitation. Individual VAV fans with motors 10 hp and larger shall meet one of the following:

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

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

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

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

Exceptions to 6.5.3.3:

a. VAV *systems* with zonal transfer fans that recirculate air from other zones without directly mixing it with *outdoor air*, dual-duct dual-fan VAV *systems*, and VAV *systems* with fan-powered *terminal* units.
b. *Systems* required to have the exhaust air *energy* recovery complying with Section 6.5.6.1.
c. *Systems* where total design exhaust airflow is more than 70% of total design *outdoor air* intake flow requirements.

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

Exceptions:

a. Climate zones 1a, 2a, and 3a
b. *Systems* that prevent re-heating, re-cooling, or mixing of heated and cooled supply air.
c. *Systems* in which at least 75 percent of the *energy* for *reheating* (on an annual basis) is from site recovered or site *solar energy sources*.

TABLE 6.5.3.1.1A Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan System Motor Nameplate hp	Allowable Nameplate Motor hp	hp $\le CFM_S \cdot 0.0011$	hp $\le CFM_S \cdot 0.0015$
Option 2: Fan System bhp	Allowable Fan System bhp	bhp $\le CFM_S \cdot 0.00094 + A$	bhp $\le CFM_S \cdot 0.0013 + A$

[a] where
CFM_S = the maximum design supply airflow rate to *conditioned spaces* served by the *system* in cubic feet per minute
hp = the maximum combined motor *nameplate horsepower*
bhp = the maximum combined *fan brake horsepower*
A = sum of $(PD \times CFM_D/4131)$
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1.1B in in. w.c.
L/S = the design airflow through each applicable device from Table 6.5.3.1.1B in cubic feet per minute

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. w.c. (2.15 in. w.c. for laboratory and vivarium systems)
Return and/or exhaust airflow *control devices*	0.5 in. w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate Filtration Credit: MERV 9 through 12	0.5 in. w.c.
Particulate Filtration Credit: MERV 13 through 15	0.9 in. w.c.
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy Recovery Device, other than Coil Runaround Loop	(2.2 × Energy Recovery Effectiveness) – 0.5 in w.c. for each airstream
Coil Runaround Loop	0.6 in. w.c. for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	0.15 in. w.c.
Exhaust system serving fume hoods	0.35 in. w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 in. w.c./100 ft of vertical duct exceeding 75 ft

6.5.4 Hydronic System Design and Control.

6.5.4.1 Hydronic Variable Flow Systems. HVAC pumping *systems* having a total *pump system power* exceeding 10 hp that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual chilled water pumps serving variable flow *systems* having motors exceeding 5 hpshall 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. The differential pressure *setpoint* shall be no more than 110% of that required to achieve design flow through the heat exchanger. Where differential pressure control is used to comply with this section and DDC systems are used the *setpoint* shall be *reset* downward based on valve positions until one valve is nearly wide open.

Exceptions:

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 75 hp 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 300,000 Btu/h supplying chilled or heated water (or both) to comfort conditioning *systems* shall include *controls* that automatically *reset* supply water temperatures by representative building loads (including return water temperature) or by *outdoor air* temperature.

Exceptions:

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

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

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

Exception: Units employing *water economizers*.

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

6.5.4.5 Pipe Sizing. All chilled-water and condenser-water piping shall be designed such that the design flow rate in each pipe segment shall not exceed the values listed in Table 6.5.4.5 for the appropriate total annual hours of operation. Pipe size selections for *systems* that operate under variable flow conditions (e.g., modulating two-way control valves at coils) and that contain variable-speed pump motors are allowed to be made from the "Variable Flow/Variable Speed" columns. All others shall be made from the "Other" columns.

Exceptions:

a. Design flow rates exceeding the values in Table 6.5.4.5 are allowed in specific sections of pipe if the pipe in question is not in the *critical circuit* at *design conditions* and is not predicted to be in the *critical circuit* during more than 30% of operating hours.
b. Piping *systems* that have equivalent or lower total pressure drop than the same *system* constructed with standard weight steel pipe with piping and fittings sized per Table 6.5.4.5.

6.5.5 Heat Rejection Equipment

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

Exception: Heat rejection devices whose *energy* usage is included in the *equipment efficiency* ratings listed in Tables 6.8.1A through 6.8.1D.

6.5.5.2 Fan Speed Control. Each fan powered by a motor of 7.5 hp or larger shall have the capability to operate that fan at two-thirds of full speed or less and shall have *controls* that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device.

Exceptions:

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

TABLE 6.5.4.5 Piping System Design Maximum Flow Rate in GPM

Operating Hours/Year	≤2000 Hours/Year		>2000 and ≤ 4400 Hours/Year		>4400 Hours/Year	
Nominal Pipe Size, in.	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
2 1/2	120	180	85	130	68	110
3	180	270	140	210	110	170
4	350	530	260	400	210	320
5	410	620	310	470	250	370
6	740	1100	570	860	440	680
8	1200	1800	900	1400	700	1100
10	1800	2700	1300	2000	1000	1600
12	2500	3800	1900	2900	1500	2300
Maximum Velocity for Pipes over 12 in. Size	8.5 fps	13.0 fps	6.5 fps	9.5 fps	5.0 fps	7.5 fps

6.5.5.3 Limitation on Centrifugal Fan Open-Circuit Cooling Towers. Centrifugal fan open-circuit cooling towers with a combined rated capacity of 1100 gpm or greater at 95°F condenser water return, 85°F condenser water supply, and 75°F *outdoor air* wet-bulb temperature shall meet the *energy* efficiency requirement for axial fan open-circuit cooling towers listed in Table 6.8.1G.

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

6.5.6 Energy Recovery

6.5.6.1 Exhaust Air Energy Recovery. Each fan *system* shall have an energy recovery *system* when the *system's* supply air flow rate exceeds the value listed in Table 6.5.6.1 based on the climate zone and percentage of *outdoor air* flow rate at *design conditions*.

Energy recovery *systems* required by this section shall have at least 50% *energy* recovery effectiveness. Fifty percent *energy* recovery effectiveness shall mean a change in the enthalpy of the *outdoor air* supply equal to 50% of the difference between the *outdoor air* and return air enthalpies at *design conditions*. Provision shall be made to bypass or control the *energy* recovery *system* to permit *air economizer* operation as required by 6.5.1.1.

Exceptions:

a. Laboratory *systems* meeting 6.5.7.2.
b. *Systems* serving *spaces* that are not cooled and that are heated to less than 60°F.
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 *energy* recovery in climate zones 1 and 2.
g. Cooling *energy* recovery in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8.
h. Where the largest source of air exhausted at a single location at the building exterior is less than 75% of the design *outdoor air* flow rate.
i. *Systems* requiring dehumidification that employ *energy* recovery in series with the cooling coil.
j. *Systems* expected to operate less than 20 hrs per week at the *outdoor air* percentage covered by Table 6.5.6.1

6.5.6.2 Heat Recovery for Service Water Heating

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

a. The facility operates 24 hours a day.
b. The total installed heat rejection capacity of the water-cooled *systems* exceeds 6,000,000 Btu/h of heat rejection.
c. The design *service water heating* load exceeds 1,000,000 Btu/h.

6.5.6.2.2 The required heat recovery *system* shall have the capacity to provide the smaller of:

a. 60% of the peak heat rejection load at *design conditions*, or
b. preheat of the peak *service* hot water draw to 85°F.

Exceptions:

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.

TABLE 6.5.6.1 Exhaust Air Energy Recovery Requirements

Zone	% *Outdoor Air* at Full Design Airflow Rate					
	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000
1B, 2B,5C	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7,8	≥2500	≥1000	>0	>0	>0	>0

NR—Not required

6.5.7 Exhaust Systems

6.5.7.1 Kitchen Exhaust Systems

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

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

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

6.5.7.1.3 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 cfm then each hood shall have an exhaust rate that complies with Table 6.5.7.1.3. If a single hood, or hood section, is installed over appliances with different duty ratings, then the maximum allowable flow rate for the hood or hood section shall not exceed the Table 6.5.7.1.3 values for the highest appliance duty rating under the hood or hood section. Refer to ASHRAE Standard 154 for definitions of hood type, appliance duty, and net exhaust flow rate.

Exception: At least 75% of all the *replacement air* is *transfer air* that would otherwise be exhausted.

6.5.7.1.4 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 cfm then it shall have one of the following:

a. At least 50% of all *replacement air* is *transfer air* that would otherwise be exhausted.
b. Demand *ventilation system(s)* on at least 75% of the exhaust air. Such *systems* shall be capable of at least 50% reduction in exhaust and *replacement air system* airflow rates, including *controls* necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle.
c. Listed *energy* recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.

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

6.5.7.2 Laboratory Exhaust Systems. Buildings with laboratory exhaust *systems* having a total exhaust rate greater than 5000 cfm shall include at least one of the following features:

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

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

Where:

A = Percentage that the exhaust and *makeup air* flow rates can be reduced from *design conditions*.

B = Percentage *sensible recovery effectiveness*.

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

M = *Makeup air* flow rate of the *system* at *design conditions*.

b. VAV laboratory exhaust and room supply *systems* that are required to have minimum circulation rates to comply with code or accreditation standards shall be capable of reducing *zone* exhaust and *makeup air* flow rates to the regulated minimum circulation values, or the minimum required to maintain pressurization relationship requirements. Non regulated *zones* shall be capable of reducing exhaust and *makeup air* flow rates to 50% of the zone design values, or the minimum required to maintain pressurization relationship requirements.

TABLE 6.5.7.1.3 Maximum Net Exhaust Flow Rate, CFM per Linear Foot of Hood Length

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	Not allowed	Not allowed
Backshelf/Pass-over	210	210	280	Not allowed

TABLE 6.5.9 Hot Gas Bypass Limitation

Rated Capacity	Maximum Hot Gas Bypass Capacity (% of Total Capacity)
≤240,000 Btu/h	50%
>240,000 Btu/h	25%

c. Direct makeup (auxiliary) air supply equal to at least 75% of the exhaust air flow rate, heated no warmer than 2°F below room *setpoint*, cooled to no cooler than 3°F above room *setpoint*, no humidification added, and no simultaneous heating and cooling used for dehumidification control.

6.5.8 Radiant Heating Systems

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

Exception: Loading docks equipped with air curtains.

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

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

6.5.9 Hot Gas Bypass Limitation. Cooling *systems* shall not use hot gas bypass or other evaporator pressure control *systems* unless the *system* is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table 6.5.9.

Exception: Unitary packaged *systems* with cooling capacities not greater than 90,000 Btu/h.

6.6 Alternative Compliance Path (Not Used)

6.7 Submittals

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

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

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

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

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

6.7.2.3 System Balancing

6.7.2.3.1 General. *Construction documents* shall require that all *HVAC systems* be balanced in accordance with *generally accepted engineering standards* (see Informative Appendix E). *Construction documents* shall require that a written balance report be provided to the building owner or the designated representative of the building owner for *HVAC systems* serving *zones* with a total conditioned area exceeding 5000 ft^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 1 hp, fan speed shall be adjusted to meet design flow conditions.

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

Exceptions: Impellers need not be trimmed nor pump speed adjusted

a. for pumps with pump motors of 10 hp or less, or
b. when throttling results in no greater than 5% of the *nameplate horsepower* draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed.

6.7.2.4 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 50,000 ft^2 conditioned area, except warehouses and *semiheated spaces*, detailed instructions for commissioning *HVAC systems* (see Informative Appendix E) shall be provided by the designer in plans and specifications.

6.8 Minimum Equipment Efficiency Tables

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

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

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, air cooled	<65,000 Btu/h[c]	All	Split system	13.0 SEER	AHRI 210/240
			Single package	13.0 SEER	
Through-the-wall (air cooled)	≤30,000 Btu/h[c]	All	Split system	12.0 SEER	
			Single package	12.0 SEER	
Air conditioners, air cooled	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.2 EER 11.4 IEER	AHRI 340/360
		All other	Split system and single package	11.0 EER 11.2 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER 11.2 IEER	
		All other	Split system and single package	10.8 EER 11.0 IEER	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	10.0 EER 10.1 IEER	
		All other	Split system and single package	9.8 EER 9.9 IEER	
	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	9.7 EER 9.8 IEER	
		All other	Split system and single package	9.5 EER 9.6 IEER	
Air conditioners, water cooled	<65,000 Btu/h	All	Split system and single package	12.1 EER 12.3 IEER	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.5 EER (before 6/1/2011) 12.1 EER (as of 6/1/2011) 11.7 IEER (before 6/1/2011) 12.3 IEER (as of 6/1/2011)	AHRI 340/360
		All other	Split system and single package	11.3 EER(before 6/1/2011) 11.9 EER(as of 6/1/2011) 11.5 IEER (before 6/1/2011) 12.1 IEER (as of 6/1/2011)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 12.5 EER (as of 6/1/2011) 11.2 IEER (before 6/1/2011) 12.5 IEER (as of 6/1/2011)	
		All other	Split system and single package	10.8 EER (before 6/1/2011) 12.3 EER (before 6/1/2011) 11.0 IEER (before 6/1/2011) 12.5 IEER (before 6/1/2011)	
Air conditioners, water cooled	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 12.4 EER (as of 6/1/2011) 11.1 IEER (before 6/1/2011) 12.6 IEER (as of 6/1/2011)	AHRI 340/360
		All other	Split system and single package	10.8 EER (before 6/1/2011) 12.2 EER (as of 6/1/2011) 10.9 IEER (before 6/1/2011) 12.4 IEER (as of 6/1/2011)	

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

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, water cooled	≥760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER (before 6/1/2011) 12.2 EER (as of 6/1/2011) 11.1 IEER (before 6/1/2011) 12.4 IEER (as of 6/1/2011)	AHRI 340/360
		All other	Split System and Single Package	10.8 EER (before 6/1/2011) 12.0 EER (as of 6/1/2011) 10.9 IEER (before 6/1/2011) 12.2 IEER (as of 6/1/2011)	
Air conditioners, evaporatively cooled	< 65,000 Btu/h	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210/ 240
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER (before 6/1/2011) 12.1 EER (as of 6/1/2011) 11.7 IEER (before 6/1/2011) 12.3 IEER (as of 6/1/2011)	AHRI 340/ 360
		All other	Split System and Single Package	11.3 EER (before 6/1/2011) 11.9 EER (as of 6/1/2011) 11.5 IEER (before 6/1/2011) 12.1 IEER (as of 6/1/2011)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER (before 6/1/2011) 12.0 EER (as of 6/1/2011) 11.2 IEER (before 6/1/2011) 12.2 IERR (as of 6/1/2011)	
		All other	Split System and Single Package	10.8 EER (before 6/1/2011) 11.8 EER (as of 6/1/2011) 11.0 IEER (before 6/1/2011) 12.0 IEER (as of 6/1/2011)	
	≥240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER (before 6/1/2011) 11.9 EER (as of 6/1/2011) 11.1 IEER (before 6/1/2011) 12.1 IEER (as of 6/1/2011)	
		All other	Split System and Single Package	10.8 EER (before 6/1/2011) 12.2 EER (as of 6/1/2011) 10.9 IEER (before 6/1/2011) 11.9 IEER (as of 6/1/2011)	
	≥760,000 Btu/h	Electric Resistance (or None	Split System and Single Package	11.0 EER (before 6/1/2011) 11.7 EER (as of 6/1/2011) 11.1 IEER (before 6/1/2011) 11.9 IEER (as of 6/1/2011)	
		All other	Split System and Single Package	10.8 EER (before 6/1/2011) 11.5 EER (as of 6/1/2011) 10.9 IEER (before 6/1/2011) 11.7 IEER (as of 6/1/2011)	
Condensing units, air cooled	≥135,000 Btu/h	–	–	10.1 EER (before 6/1/2011) 10.5 EER (as of 6/1/2011 11.4 IEER (before 6/1/2011) 11.8 IEER (as of 6/1/2011)	AHRI 365
Condensing units, water cooled	≥135,000 Btu/h	–	–	13.1 EER (before 6/1/2011) 13.5 EER (as of 6/1/2011) 13.6 IEER (before 6/1/2011) 14.0 IEER (as of 6/1/2011)	
Condensing units, evaporatively cooled	≥135,000 Btu/h	–	–	13.1 EER (before 6/1/2011) 13.5 EER (as of 6/1/2011) 13.6 IEER (before 6/1/2011) 14.0 IEER (as of 6/1/2011	

[a]IPLVs and part-load rating conditions are only applicable to *equipment* with capacity modulation.
[b]Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[c]Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER 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	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air cooled (cooling mode)	<65,000 Btu/h[c]	All	Split system	13.0 SEER	AHRI 210/240
			Single packaged	13.0 SEER	
Through-the-wall (air cooled, cooling mode)	≤30,000 Btu/h[c]	All	Split system	12.0 SEER	
			Single package	12.0 SEER	
Air cooled (cooling mode)	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER 11.2 IEER	AHRI 340/360
		All other	Split system and single package	10.8 EER 11.0 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	10.6 EER 10.7 IEER	
		All other	Split system and single package	10.4 EER 10.5 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	Split system and single package	9.5 EER 9.6 IEER	
		All other	Split system and single package	9.3 EER 9.4 IEER	
Water source (cooling mode)	<17,000 Btu/h	All	86°F entering water	11.2 EER	ISO-13256-1
	≥17,000 Btu/h and <65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	86°F entering water	12.0 EER	
Groundwater source (cooling mode)	<135,000 Btu/h	All	59°F entering water	16.2 EER	
Ground source (cooling mode)	<135,000 Btu/h	All	77°F entering water	13.4 EER	
Water source water to water (cooling mode)	<135,000 Btu/h	All	86°F entering water	10.6 EER	ISO-13256-2
Groundwater source water to water (cooling mode)	<135,000 Btu/h	All	59°F entering water	16.3 EER	
Ground source brine to water (cooling mode)	<135,000 Btu/h	All	77°F entering water	12.1 EER	

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

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air cooled (heating mode)	<65,000 Btu/h[c] (cooling capacity)	—	Split system	7.7 HSPF	AHRI 210/240
			Single package	7.7 HSPF	
Through-the-wall (air cooled, heating mode)	≤30,000 Btu/h[c] (cooling capacity)	—	Split system	7.4 HSPF	
			Single package	7.4 HSPF	
Air cooled (heating mode)	≥65,000 Btu/h[c] and <135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.3 COP	AHRI 340/360
			17°F db/15°F wb outdoor air	2.25 COP	
	≥135,000 Btu/h[c] (cooling capacity)	—	47°F db/43°F wb outdoor air	3.2 COP	
			17°F db/15°F wb outdoor air	2.05 COP	
Water source (heating mode)	<135,000 Btu/h (cooling capacity)	—	68°F entering water	4.2 COP	ISO-13256-1
Groundwater source (heating mode)	<135,000 Btu/h (cooling capacity)	—	50°F entering water	3.6 COP	
Ground source (heating mode)	<135,000 Btu/h (cooling capacity)	—	32°F entering water	3.1 COP	
Water source water to water (heating mode)	<135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO-13256-2
Groundwater source water to water (heating mode)	<135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	
Ground source brine to water (heating mode)	<135,000 Btu/h (cooling capacity)	—	32°F entering water	2.5 COP	

[a] IPLVs and part-load rating conditions are only applicable to *equipment* with capacity modulation.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[c] Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1C Water Chilling Packages—Efficiency Requirements[a]

Equipment Type	Size Category	Units	Path A Full Load	Path A IPLV	Path B Full Load	Path B IPLV	Test Procedure[c]
Air-Cooled Chillers	<150 tons	EER	≥9.562	≥12.750	NA[d]	NA[d]	AHRI 550/590
	≥150 tons	EER	≥9.562	≥12.750	NA[d]	NA[d]	
Air-Cooled without Condenser, Electrically Operated	All Capacities	EER	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller *efficiency* requirements.				
Water-Cooled, Electrically Operated, Reciprocating	All Capacities	kW/ton	Reciprocating units must comply with water-cooled positive displacement *efficiency* requirements				
Water-Cooled, Electrically Operated, Positive Displacement	<75 tons	kW/ton	≤0.780	≤0.630	≤0.800	≤0.600	
	≥75 tons and <150 tons	kW/ton	≤0.775	≤0.615	≤0.790	≤0.586	
	≥150 tons and <300 tons	kW/ton	≤0.680	≤0.580	≤0.718	≤0.540	
	≥300 tons	kW/ton	≤0.620	≤0.540	≤0.639	≤0.490	
Water-Cooled, Electrically Operated, Centrifugal	<150 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450	
	≥150 tons and <300 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450	
	≥300 tons and <600 tons	kW/ton	≤0.576	≤0.549	≤0.600	≤0.400	
	≥600 tons	kW/ton	≤0.570	≤0.539	≤0.590	≤0.400	
Air-Cooled Absorption, Single Effect	All Capacities	COP	≥0.600	NR[e]	NA[d]	NA[d]	AHRI 560
Water-Cooled Absorption, Single Effect	All Capacities	COP	≥0.700	NR[e]	NA[d]	NA[d]	
Absorption Double Effect, Indirect Fired	All Capacities	COP	≥1.000	≥1.050	NA[d]	NA[d]	
Absorption Double Effect, Direct Fired	All Capacities	COP	≥1.000	≥1.000	NA[d]	NA[d]	

[a] The centrifugal chiller *equipment* requirements after adjustment per Section 6.4.1.2 do not apply to chillers where the design leaving evaporator temperature is <36°F. The requirements do not apply to positive displacement chillers with design leaving fluid temperatures ≤32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures <40°F.

[b] Compliance with this standard can be obtained by meeting the minimum requirements of Path A or Path B. However, both the full load and *IPLV* must be met to fulfill the requirements of Path A or Path B.

[c] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

[d] *NA* means that this requirement is not applicable and cannot be used for compliance.

[e] *NR* means that there are no minimum requirements for this category.

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) standard size	All capacities	95°F db outdoor air	12.5 – (0.213 × Cap/1000)[c] EER (before 10/08/2012) 13.8 – (0.300 × Cap/1000)[c] EER (as of 10/08/2012)	AHRI 310/380
PTAC (cooling mode) nonstandard size[b]	All capacities	95°F db outdoor air	10.9 – (0.213 × Cap/1000)[c] EER	
PTHP (cooling mode) standard size	All capacities	95°F db outdoor air	12.3 – (0.213 × Cap/1000)[c] EER (before 10/08/2012) 14.0 – (0.300 × Cap/1000)[c] EER (as of 10/08/2012)	
PTHP (cooling mode) nonstandard size[b]	All capacities	95°F db outdoor air	10.8 – (0.213 × Cap/1000)[c] EER	
PTHP (heating mode) standard size	All capacities	—	3.2 – (0.026 × Cap/1000)[c] COP_H (before 10/08/2012) 3.7 – (0.052 × Cap/1000)[c] COP_H (as of 10/08/2012)	
PTHP (heating mode) nonstandard size[b]	All capacities	—	2.9 – (0.026 × Cap/1000)[c] COP_H	
SPVAC (cooling mode)	<65,000 Btu/h	95°F db/75°F wb outdoor air	9.0 EER	AHRI 390
	≥65,000 Btu/h and <135,000 Btu/h	95°F db/75°F wb outdoor air	8.9EER	
	≥135,000 Btu/h and <240,000 Btu/h	95°F db/75°F wb outdoor air	8.6 EER	
SPVHP (cooling mode)	<65,000 Btu/h	95°F db/75°F wb outdoor air	9.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	95°F db/75°F wb outdoor air	8.9EER	
	≥135,000 Btu/h and <240,000 Btu/h	95°F db/75°F wb outdoor air	8.6 EER	
SPVHP (heating mode)	<65,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP	
	≥65,000 Btu/h and <135,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP	
	≥135,000 Btu/h and <240,000 Btu/h	47°F db/43°F wb outdoor air	2.9 COP	
Room air conditioners, with louvered sides	<6000 Btu/h	—	9.7 SEER	ANSI/AHAM RAC-1
	≥6000 Btu/h and <8000 Btu/h		9.7 SEER	
	≥8000 Btu/h and <14,000 Btu/h		9.8 EER	
	≥14,000 Btu/h and <20,000 Btu/h		9.7 SEER	
	≥20,000 Btu/h		8.5 EER	

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 *(continued)*

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[d]
Room air conditioners, without louvered sides	<8000 Btu/h	—	9.0 EER	ANSI/AHAM RAC-1
	≥8000 Btu/h and <20,000 Btu/h		8.5 EER	
	≥20,000 Btu/h		8.5 EER	
Room air-conditioner heat pumps with louvered sides	<20,000 Btu/h	—	9.0 EER	
	≥20,000 Btu/h		8.5 EER	
Room air-conditioner heat pumps without louvered sides	<14,000 Btu/h	—	8.5 EER	
	≥14,000 Btu/h		8.0 EER	
Room air conditioner, casement only	All capacities	—	8.7 EER	
Room air conditioner, casement–slider	All capacities	—	9.5 EER	

[a] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] Nonstandard size units must be factory *labeled* as follows: "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS." Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external *wall* opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area leass than 670 in.^{2}.
[c] *Cap* means the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7000 Btu/h, use 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.
[d] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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	Test Procedure[a]
Warm-Air Furnace, Gas-Fired	<225,000 Btu/h	Maximum capacity[c]	78% AFUE or 80% Et [b,d]	DOE 10 CFR Part 430 or Section 2.39, Thermal Efficiency, ANSI Z21.47
	≥225,000 Btu/h	Maximum capacity[c]	80% Et [d]	Section 2.39, Thermal Efficiency, ANSI Z21.47
Warm-Air Furnace, Oil-Fired	<225,000 Btu/h	Maximum capacity[c]	78% AFUE or 80% Et [b,d]	DOE 10 CFR Part 430 or Section 42, Combustion, UL 727
	≥225,000 Btu/h	Maximum capacity[c]	81% Et [d]	Section 42, Combustion, UL 727
Warm-Air Duct Furnaces, Gas-Fired	All Capacities	Maximum capacity[c]	80% Ec [e]	Section 2.10, Efficiency, ANSI Z83.8
Warm-Air Unit Heaters, Gas-Fired	All capacities	Maximum capacity[c]	80% Ec [e,f]	Section 2.10, Efficiency, ANSI Z83.8
Warm-Air Unit Heaters, Oil-Fired	All capacities	Maximum capacity[c]	80% *Ec* [e,f]	Section 40, Combustion, UL 731

[a] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] Combination units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 19 kW) may comply with either rating.
[c] Compliance of multiple firing rate units shall be at the maximum firing rate.
[d] Et = thermal *efficiency*. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a *flue damper*. A *vent damper* is an acceptable alternative to a *flue damper* for those furnaces where combustion air is drawn from the *conditioned space*.
[e] Ec = combustion *efficiency* (100% less flue losses). See test procedure for detailed discussion.
[f] As of August 8, 2008, according to the Energy Policy Act of 2005, units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an automatic *flue damper*.

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

Equipment Type[a]	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency[b,c]	Efficiency as of 3/2/2010 (Date 3 yrs after ASHRAE Board Approval)	Efficiency as of 3/2/2020 (Date 13 yrs after ASHRAE Board Approval)	Test Procedure
Boilers, hot water	Gas-fired	<300,000 Btu/h	80% AFUE	80% AFUE	80% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	75% E_t	80% E_t	80% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	80% E_c	82% E_c	82% E_c	
	Oil-fired[e]	<300,000 Btu/h	80% AFUE	80% AFUE	80% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	78% E_t	82% E_t	82% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	83% E_c	84% E_c	84% E_c	
Boilers, steam	Gas-fired	<300,000 Btu/h	75% AFUE	75% AFUE	75% AFUE	10 CFR Part 430
	Gas-fired—all, except natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	75% E_t	79% E_t	79% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	80% E_c	79% E_t	79% E_t	
	Gas-fired—natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	75% E_t	77% E_t	79% E_t	
		>2,500,000 Btu/h[a]	80% E_c	77% E_t	79% E_t	
	Oil-fired[e]	<300,000 Btu/h	80% AFUE	80% AFUE	80% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	78% E_t	81% E_t	81% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	83% E_c	81% E_t	81% E_t	

a These requirements apply to *boilers* with rated input of 8,000,000 Btu/h or less that are not *packaged boilers* and to all *packaged boilers*. Minimum *efficiency* requirements for *boilers* cover all capacities of *packaged boilers*.
b Ec = combustion *efficiency* (100% less flue losses). See reference document for detailed information.
c Et = thermal *efficiency*. See reference document for detailed information.
d Maximum capacity – minimum and maximum ratings as provided for and allowed by the unit's *controls*.
e Includes oil-fired (residual).

TABLE 6.8.1G Performance Requirements for Heat Rejection Equipment

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition	Performance Required[a,b,c,d]	Test Procedure[e]
Propeller or axial fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F *entering wb*	≥38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F *entering wb*	≥20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F *entering wb*	≥14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F *entering wb*	≥7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Air-cooled condensers	All	125°F condensing temperature R-22 test fluid 190°F entering gas temperature 15°F subcooling 95°F *entering db*	≥176,000 Btu/h·hp	AHRI 460

[a] For purposes of this table, *open-circuit cooling tower* performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 6.8.1G divided by the fan motor nameplate power.
[b] For purposes of this table, *closed-circuit cooling tower performance* is defined as the process water flow rating of the tower at the thermal rating condition listed in Table 6.8.1G divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.
[c] For purposes of this table, *air-cooled condenser performance* is defined as the heat rejected from the refrigerant divided by the fan motor nameplate power.
[d] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[e] The efficiencies and test procedures for both *open-* and *closed-circuit cooling towers* are not applicable to hybrid cooling towers that contain a combination of separate wet and dry heat exchange sections.

TABLE 6.8.1H Heat Transfer Equipment

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

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

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

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency	Test Procedure
VRF Air Conditioners, Air Cooled	<65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.2 EER 12.5 IEER 13.1 IEER(as of 7/1/2012)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.0 EER 12.3 IEER 12.9 IEER(as of 7/1/2012)	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.0 EER 11.1 IEER 11.6 IEER (as of 7/1/2012)	

TABLE 6.8.1J Electrically Operated Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF Air cooled, (cooling mode)	<65,000 Btu/h	All	VRF Multisplit System	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	VRF Multisplit System	11.0 EER 12.3 IEER 12.9 IEER (as of 7/1/2012)	
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	VRF Multisplit System with Heat Recovery	10.8 EER 12.1 IEER 12.7 IEER (as of 7/1/2012)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multisplit System	10.6 EER 11.8 IEER 12.3 IEER (as of 7/1/2012)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multisplit System with Heat Recovery	10.4 EER 11.6 IEER 12.1 IEER (as of 7/1/2012)	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multisplit System	9.5 EER 10.6 IEER 11.0 IEER (as of 7/1/2012)	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multisplit System with Heat Recovery	9.3 EER 10.4 IEER 10.8 IEER (as of 7/1/2012)	
VRF Water source (cooling mode)	<65,000 Btu/h	All	VRF Multisplit systems 86°F entering water	12.0 EER	AHRI 1230
	<65,000 Btu/h	All	VRF Multisplit systems with Heat Recovery 86°F entering water	11.8 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF Multisplit System 86°F entering water	12.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF Multisplit System with Heat Recovery 86°F entering water	11.8 EER	
	≥135,000 Btu/h	All	VRF Multisplit System 86°F entering water	10.0 EER	
	≥135,000 Btu/h	All	VRF Multisplit System with Heat Recovery 86°F entering water	9.8 EER	
VRF Groundwater source (cooling mode)	<135,000 Btu/h	All	VRF Multisplit System 59°F entering water	16.2 EER	AHRI 1230
	<135,000 Btu/h	All	VRF Multisplit System with Heat Recovery 59°F entering water	16.0 EER	
	≥135,000 Btu/h	All	VRF Multisplit System 59°F entering water	13.8 EER	
	≥135,000 Btu/h	All	VRF Multisplit System with Heat Recovery 59°F entering water	13.6 EER	

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

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF Ground source (cooling mode)	<135,000 Btu/h	All	VRF Multisplit System 77°F entering water	13.4 EER	AHRI 1230
	<135,000 Btu/h	All	VRF Multisplit System with Heat Recovery 77°F entering water	13.2 EER	
	≥135,000 Btu/h	All	VRF Multisplit System 77°F entering water	11.0 EER	
	≥135,000 Btu/h	All	VRF Multisplit System with Heat Recovery 77°F entering water	10.8 EER	
VRF Air cooled (heating mode)	<65,000 Btu/h (cooling capacity)	—	VRF Multisplit System	7.7 HSPF	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	—	VRF Multisplit system 47°F db/43°F wb outdoor air	3.3 COP	
			17°F db/15°F wb outdoor air	2.25 COP	
	≥135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 47°F db/43°F wb outdoor air	3.2 COP	
			17°F db/15°F wb outdoor air	2.05 COP	
VRF Water source (heating mode)	<135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 68°F entering water	4.2 COP	AHRI 1230
	≥135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 68°F entering water	3.9 COP	
VRF Groundwater source (heating mode)	<135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 50°F entering water	3.6 COP	AHRI 1230
	≥135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 50°F entering water	3.3 COP	
VRF Ground source (heating mode)	<135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 32°F entering water	3.1 COP	AHRI 1230
	≥135,000 Btu/h (cooling capacity)	—	VRF Multisplit System 32°F entering water	2.8 COP	

TABLE 6.8.1K Air Conditioners and Condensing Units Serving *Computers Rooms*

Equipment Type	Net Sensible Cooling Capacity[a]	Minimum SCOP-127[b] Efficiency Downflow units / Upflow units	Test Procedure
Air conditioners, air cooled	<65,000 Btu/h	2.20 / 2.09	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.10 / 1.99	
	≥ 240,000 Btu/h	1.90 / 1.79	
Air conditioners, water cooled	<65,000 Btu/h	2.60 / 2.49	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.50 / 2.39	
	≥ 240,000 Btu/h	2.40 /2.29	
Air conditioners, water cooled with fluid economizer	<65,000 Btu/h	2.55 /2.44	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.45 / 2.34	
	≥ 240,000 Btu/h	2.35 / 2.24	
Air conditioners, glycol cooled (rated at 40% propylene glycol)	<65,000 Btu/h	2.50 / 2.39	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.15 / 2.04	
	≥ 240,000 Btu/h	2.10 / 1.99	
Air conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	<65,000 Btu/h	2.45 / 2.34	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.10 / 1.99	
	≥ 240,000 Btu/h	2.05 / 1.94	

a. net sensible cooling capacity: The total gross cooling capacity less the latent cooling less the *energy* to the air movement system. (Total Gross – latent – Fan Power)

b. sensible *coefficient of performance* (SCOP-127): a ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding re-heaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity is the gross sensible capacity minus the *energy* dissipated into the *cooled space* by the fan *system*.

6.8.2 Duct Insulation Tables

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

Climate Zone	Duct Location: Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
				Heating-Only Ducts			
1, 2	none	none	none	none	none	none	none
3	R-3.5	none	none	none	none	none	none
4	R-3.5	none	none	none	none	none	none
5	R-6	R-3.5	none	none	none	none	R-3.5
6	R-6	R-6	R-3.5	none	none	none	R-3.5
7	R-8	R-6	R-6	none	R-3.5	none	R-3.5
8	R-8	R-8	R-6	none	R-6	none	R-6
				Cooling-Only Ducts			
1	R-6	R-6	R-8	R-3.5	R-3.5	none	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
3	R-6	R-6	R-6	R-3.5	R-1.9	none	none
4	R-3.5	R-3.5	R-6	R-1.9	R-1.9	none	none
5, 6	R-3.5	R-1.9	R-3.5	R-1.9	R-1.9	none	none
7, 8	R-1.9	R-1.9	R-1.9	R-1.9	R-1.9	none	none
				Return Ducts			
1 to 8	R-3.5	R-3.5	R-3.5	none	none	none	none

[a] Insulation R-values, measured in (h·ft^2·°F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior *walls* are used as *plenum walls*, *wall* insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a *mean temperature* of 75°F at the installed thickness.
[b] Includes crawlspaces, both ventilated and nonventilated.
[c] Includes return air *plenums* with or without exposed *roofs* above.

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

Climate Zone	Duct Location: Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
				Supply Ducts			
1	R-6	R-6	R-8	R-3.5	R-3.5	none	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
3	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
4	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
5	R-6	R-6	R-6	R-1.9	R-3.5	none	R-3.5
6	R-8	R-6	R-6	R-1.9	R-3.5	none	R-3.5
7	R-8	R-6	R-6	R-1.9	R-3.5	none	R-3.5
8	R-8	R-8	R-8	R-1.9	R-6	none	R-6
				Return Ducts			
1 to 8	R-3.5	R-3.5	R-3.5	none	none	none	none

[a] Insulation R-values, measured in (h·ft^2·°F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior *walls* are used as *plenum walls*, *wall* insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a *mean temperature* of 75°F at the installed thickness.
[b] Includes crawlspaces, both ventilated and nonventilated.
[c] Includes return air *plenums* with or without exposed *roofs* above.

TABLE 6.8.3A Minimum Pipe Insulation Thickness Heating and Hot Water Systems[a,b,c,d] (Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)

Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size (in)				
	Conductivity Btu·in./(h·ft²·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness (in)				
>350 °F	0.32–0.34	250	4.5	5.0	5.0	5.0	5.0
251°F–350°F	0.29–0.32	200	3.0	4.0	4.5	4.5	4.5
201°F–250°F	0.27–0.30	150	2.5	2.5	2.5	3.0	3.0
141°F–200°F	0.25–0.29	125	1.5	1.5	2.0	2.0	2.0
105°F–140°F	0.22–0.28	100	1.0	1.0	1.5	1.5	1.5

a For insulation outside the stated conductivity range, the minimum thickness (*T*) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$ where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in./h·ft2·°F); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

b These thicknesses are based on energy *efficiency* considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

c For piping smaller than 1½" and located in partitions within *conditioned spaces*, reduction of these thicknesses by 1" shall be permitted (before thickness adjustment required in footnote a) but not to thicknesses below 1".

d For direct-buried heating and hot water *system* piping, reduction of these thicknesses by 1.5" shall be permitted (before thickness adjustment required in footnote a) but not to thicknesses below 1".

e The table is based on steel pipe. Non-metallic pipes schedule 80 thickness or less shall use the table values. For other non-metallic pipes having *thermal resistance* greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.

TABLE 6.8.3B Minimum Pipe Insulation Thickness Cooling Systems (Chilled Water, Brine, and Refrigerant)[a,b,c]

Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size (in)				
	Conductivity Btu·in./(h·ft²·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness (in)				
40°F–60°F	0.21–0.27	75	0.5	0.5	1.0	1.0	1.0
<40°F	0.20–0.26	50	0.5	1.0	1.0	1.0	1.5

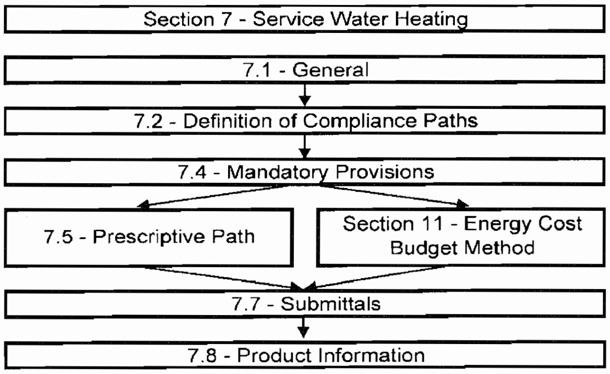
a For insulation outside the stated conductivity range, the minimum thickness (*T*) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$ where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in./h·ft2·°F); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

b These thicknesses are based on *energy efficiency* considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

c For direct-buried cooling *system* piping, insulation is not required.

d The table is based on steel pipe. Non-metallic pipes schedule 80 thickness or less shall use the table values. For other non-metallic pipes having *thermal resistance* greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.

7. SERVICE WATER HEATING



7.1 General

7.1.1 Service Water Heating Scope

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

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

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

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

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

7.2 Compliance Path(s)

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

7.2.2 Projects using the Energy Cost Budget Method (Section 11) for demonstrating compliance with the standard shall meet the requirements of Section 7.4, Mandatory Provisions, in conjunction with Section 11, Energy Cost Budget Method.

7.3 Simplified/Small Building Option (Not Used)

7.4 Mandatory Provisions

7.4.1 Load Calculations. *Service water heating system* design loads for the purpose of sizing *systems* and *equipment* shall be determined in accordance with *manufacturers'* published sizing guidelines or *generally accepted engineering standards* and handbooks acceptable to the *adopting authority* (e.g., *ASHRAE Handbook—HVAC Applications*).

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

Exception: All *water heaters* and *hot-water supply boilers* having more than 140 gal 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-12.5,
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 8 ft 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 120°F or lower to a maximum temperature compatible with the intended use.

Exception: When the *manufacturers'* installation instructions specify a higher minimum *thermostat* setting to minimize condensation and resulting corrosion.

7.4.4.2 Temperature Maintenance Controls. *Systems* designed to maintain usage temperatures in hot-water pipes, such as recirculating hot-water *systems* or *heat trace*, shall be equipped with *automatic* time switches or other *controls* that can be set to switch off the usage temperature maintenance *system* during extended periods when hot water is not required.

7.4.4.3 Outlet Temperature Controls. Temperature controlling means shall be provided to limit the maximum temperature of water delivered from lavatory faucets in *public facility restrooms* to 110°F.

7.4.4.4 Circulating Pump Controls. When used to maintain storage tank water temperature, recirculating pumps shall be equipped with *controls* limiting operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle.

7.4.5 Pools

7.4.5.1 Pool Heaters. *Pool* heaters shall be equipped with a *readily accessible* ON/OFF switch to allow shutting off the heater without adjusting the *thermostat* setting. *Pool* heaters fired by natural gas shall not have continuously burning pilot lights.

7.4.5.2 Pool Covers. Heated *pools* shall be equipped with a vapor retardant *pool* cover on or at the water surface. *Pools* heated to more than 90°F shall have a *pool* cover with a minimum insulation value of R-12.

Exception: *Pools* deriving over 60% of the *energy* for heating from *site-recovered energy* or *solar energy source.*

7.4.5.3 Time Switches. Time switches shall be installed on swimming *pool* heaters and pumps.

Exceptions:

a. Where public health standards require 24-hour pump operation.
b. Where pumps are required to operate solar and waste heat recovery *pool* heating *systems*.

7.4.6 Heat Traps. Vertical pipe risers serving storage *water heaters* and storage tanks not having integral heat traps and serving a *nonrecirculating system* shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank. A heat trap is a means to counteract the natural convection of heated water in a vertical pipe run. The means is either a device specifically designed for the purpose or an arrangement of tubing that forms a loop of 360 degrees or piping that from the point of connection to the *water heater* (inlet or outlet) includes a length of piping directed downward before connection to the vertical piping of the supply water or hot-water *distribution system*, as applicable.

7.5 Prescriptive Path

7.5.1 Space Heating and Water Heating. The use of a gas-fired or oil-fired space-heating *boiler system* otherwise complying with Section 6 to provide the total *space* heating and water heating for a building is allowed when one of the following conditions is met:

a. The single space-heating *boiler*, or the component of a modular or multiple *boiler system* that is heating the *service* water, has a standby loss in Btu/h not exceeding

$$(13.3 \times pmd + 400)/n$$

where *pmd* is the probable maximum *demand* in gal/h, determined in accordance with the procedures described in *generally accepted engineering standards* and handbooks, and *n* is the fraction of the year when the outdoor daily *mean temperature* is greater than 64.9°F.

The standby loss is to be determined for a test period of 24 hours duration while maintaining a *boiler* water temperature of at least 90°F above ambient, with an ambient temperature between 60°F and 90°F. For a *boiler* with a modulating burner, this test shall be conducted at the lowest input.

b. It is demonstrated to the satisfaction of the *authority having jurisdiction* that the use of a single heat source will consume less *energy* than separate units.
c. The *energy* input of the combined *boiler* and *water heater system* is less than 150,000 Btu/h.

7.5.2 Service Water Heating Equipment. *Service water heating equipment* used to provide the additional function of *space* heating as part of a combination (integrated) *system* shall satisfy all stated requirements for the *service water heating equipment.*

7.6 Alternative Compliance Path (Not Used)

7.7 Submittals

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

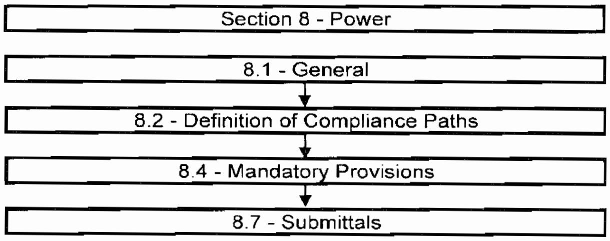
7.8 Product Information

TABLE 7.8 Performance Requirements for Water-Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure[b,c]
Electric table top water heaters	≤12 kW	Resistance ≥20 gal	0.93–0.00132V EF	DOE 10 CFR Part 430
Electric water heaters	≤12 kW	Resistance ≥20 gal	0.97–0.00132V EF	DOE 10 CFR Part 430
	>12 kW	Resistance ≥20 gal	$20 + 35\sqrt{V}$ SL, Btu/h	Section G.2 of 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	≤75,000 Btu/h	≥20 gal	0.67–0.0019V EF	DOE 10 CFR Part 430
	>75,000 Btu/h	<4000 (Btu/h)/gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	Sections G.1 and G.2 of ANSI Z21.10.3
Gas instantaneous water heaters	>50,000 Btu/h and <200,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.62–0.0019V EF	DOE 10 CFR Part 430
	≥200,000 Btu/h[d]	≥4000 (Btu/h)/gal and <10 gal	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
	≥200,000 Btu/h	≥4000 (Btu/h)/gal and ≥10 gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Oil storage water heaters	≤105,000 Btu/h	≥20 gal	0.59–0.0019V EF	DOE 10 CFR Part 430
	>105,000 Btu/h	<4000 (Btu/h)/gal	78% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	Sections G.1 and G.2 of ANSI Z21.10.3
Oil instantaneous water heaters	≤210,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.59–0.0019V EF	DOE 10 CFR Part 430
	>210,000 Btu/h	≥4000 (Btu/h)/gal and <10 gal	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
	>210,000 Btu/h	≥4000 (Btu/h)/gal and ≥10 gal	78% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Hot-water supply boilers, gas and oil	≥300,000 Btu/h and <12,500,000 Btu/h	≥4000 (Btu/h)/gal and <10 gal	80% E_t	Sections G.1 and G.2 of ANSI Z21.10.3
Hot-water supply boilers, gas		≥4000 (Btu/h)/gal and ≥10 gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Hot-water supply boilers, oil		≥4000 (Btu/h)/gal and ≥10 gal	78% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Pool heaters, oil and gas	All		78% E_t	ASHRAE 146
Heat pump pool heaters	All	50.0°F db 44.2°F wb Outdoor air 80.0°F Entering water	4.0 COP	AHRI 1160
Unfired storage tanks	All		R-12.5	(none)

[a] *Energy factor* (EF) and thermal *efficiency* (E_t) are minimum requirements, while standby loss (SL) is maximum Btu/h based on a 70°F 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 Btu/h.
[b] Section 12 contains a complete specification, including the year version, of the referenced test procedure.
[c] Section G.1 is titled "Test Method for Measuring Thermal Efficiency" and Section G.2 is titled "Test Method for Measuring Standby Loss."
[d] Instantaneous *water heaters* with input rates below 200,000 Btu/h must comply with these requirements if the *water heater* is designed to heat water to temperatures of 180°F or higher.

8. POWER



8.1 General

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

8.1.2 Low Voltage Dry-Type Distribution Transformers. Low voltage *dry-type transformers* shall comply with the provisions of the Energy Policy Act of 2005 where applicable, as shown in Table 8.1. *Transformers* that are not included in the scope of the Energy Policy Act of 2005 have no performance requirements in this section, and are listed for ease of reference as exceptions.

Exceptions:

Transformers that meet the Energy Policy Act of 2005 exclusions based on NEMA TP-1 definition:

a. special purpose applications
b. not likely to be used in general purpose applications
c. *transformers* with multiple voltage taps where the highest tap is at least 20% more than the lowest tap.

Products meeting these criteria and exempted from 8.1.2 include the following: drive *transformer*, rectifier *transformer*, auto-*transformer*, uninterruptible power *system transformer*, impedance *transformer*, regulating *transformer*, sealed and nonventilating *transformer*, machine tool *transformer*, welding *transformer*, grounding *transformer*, or testing *transformer*.

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

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

8.1.5 Alterations to Existing Buildings.

Exception: Compliance shall not be required for the relocation or reuse of *existing equipment* at the same site.

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

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

8.2 Compliance Path(s)

8.2.1 Power *distribution systems* in all projects shall comply with the requirements of Section 8.1, General; Section 8.4, Mandatory Provisions; and Section 8.7, Submittals.

8.3 Simplified/Small Building Option (Not Used)

8.4 Mandatory Provisions

8.4.1 Voltage Drop

Exception: *Feeder conductors* and *branch circuits* that are dedicated to emergency *services*.

8.4.1.1 Feeders. *Feeder conductors* shall be sized for a maximum *voltage drop* of 2% at design load.

8.4.1.2 Branch Circuits. *Branch circuit* conductors shall be sized for a maximum *voltage drop* of 3% at design load.

TABLE 8.1 Minimum Nominal Efficiency Levels for NEMA Class I Low-Voltage Dry-Type Distribution Transformers[a]

Single-Phase Transformers		Three-Phase Transformers	
kVA[b]	Efficiency,%[c]	kVA[b]	Efficiency,%[c]
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

a. A low voltage distribution *transformer* is a *transformer* that is air-cooled, does not use oil as a coolant, has an input voltage ≤ 600 Volts, and is rated for operation at a frequency of 60 Hz.

b. kilovolt-ampere rating.

c. Nominal efficiencies shall be established in accordance with the NEMA TP-1 2002 test procedure for low voltage *dry-type transformers*. Class I Low Voltage Dry-Type is a National Electrical Manufacturers Association (NEMA) design class designation.

8.4.2 Automatic Receptacle Control. At least 50% of all 125 volt 15- and 20-Ampere receptacles, including those installed in modular partitions, installed in the following *space* types:

a. Private offices
b. Open offices
c. Computer Classrooms

shall be controlled by an *automatic control device* that shall function on:

a. a scheduled basis using a time-of-day operated *control device* that turns receptacles off at specific programmed times—an independent program schedule shall be provided for areas of no more than 25,000 ft^{22} but not more than one floor, or
b. an *occupant sensor* that shall turn receptacles off within 30 minutes of all occupants leaving a *space*, or
c. a signal from another control or alarm *system* that indicates the area is unoccupied.

Exceptions: Receptacles for the following shall not require an *automatic control device*:

   a. Receptacles specifically designated for *equipment* requiring 24 hour operation.
   b. *Spaces* where an *automatic* shutoff would endanger the safety or security of the room or building occupant(s).

8.5 Prescriptive Path (Not Used)

8.6 Alternative Compliance Path (Not Used)

8.7 Submittals

8.7.1 Drawings. *Construction documents* shall require that within 30 days after the date of *system* acceptance, *record drawings* of the actual installation shall be provided to the building owner, including

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

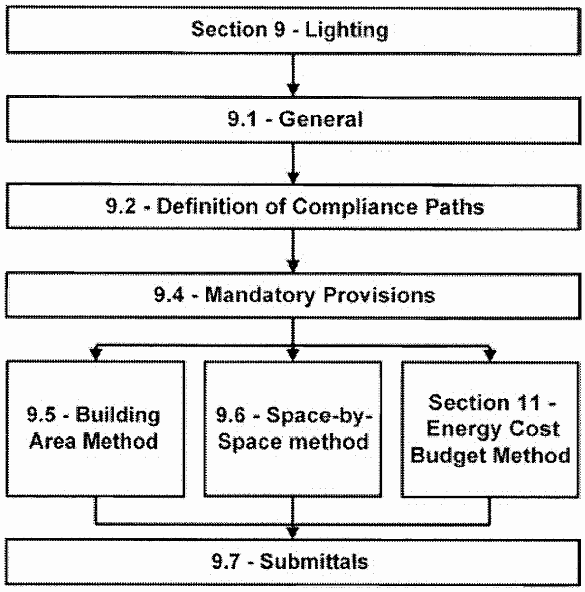
8.7.2 Manuals. *Construction documents* shall require that an operating manual and maintenance manual be provided to the building owner. The manuals shall include, at a minimum, the following:

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

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

8.8 Product Information (Not Used)

9. LIGHTING



9.1 General

9.1.1 Scope. This section shall apply to the following:

a. interior *spaces* of *buildings*
b. exterior building features, including facades, illuminated *roofs*, architectural features, entrances, exits, loading docks, and illuminated canopies
c. exterior *building grounds lighting* provided through the *building's* electrical *service*

Exceptions:

a. emergency lighting that is automatically off during normal *building* operation
b. lighting within *dwelling units*
c. lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation
d. decorative gas *lighting systems*

9.1.2 Lighting Alterations. The *alteration* of *lighting systems* in any building *space* or exterior area shall comply with the *lighting power density (LPD)* requirements of Section 9 applicable to that *space* or area and the *automatic* shutoff requirements of 9.4.1.1. Such *alterations* shall include all *luminaires* that are added, replaced or removed. This requirement shall also be met for *alterations* that involve only the replacement of *lamps* plus *ballasts*. *Alterations* do not include routine maintenance or *repair* situations.

Exception: *Alterations* that involve less than 10% of the connected lighting load in a *space* or area need not comply with these requirements provided that such *alterations* do not increase the installed *LPD*.

9.1.3 Installed Lighting Power. The *luminaire* wattage for all interior and exterior applications shall include all power used by the *luminaires*, including *lamps*, *ballasts*, *transformers*, and *control devices* except as specifically exempted in Section 9.1.1, 9.2.2.3, or 9.4.3.

Exception: If two or more independently operating *lighting systems* in a *space* are capable of being controlled to prevent simultaneous user operation, the *installed interior lighting power* or the *installed exterior lighting power* shall be based solely on the *lighting system* with the highest wattage.

9.1.4 Interior and Exterior Luminaire Wattage. *Luminaire* wattage, when used to calculate either *installed interior lighting power* or *installed exterior lighting power*, shall be determined in accordance with the following criteria:

a. The wattage of line-voltage *luminaires* not containing *permanently installed ballasts*, *transformers*, or similar devices shall be the *manufacturers' labeled* maximum-wattage of the *luminaire*.
b. The wattage of *luminaires* with *permanently installed* or remote *ballasts*, *transformers*, or similar devices shall be the operating input wattage of the maximum *lamp*/auxiliary combination based on values from the auxiliary *manufacturers'* literature or recognized testing laboratories or shall be the maximum *labeled* wattage of the *luminaire*.

Exception: Lighting power calculations for *ballasts* with adjustable *ballast* factors shall be based on the *ballast* factor that will be used in the *space* provided that the *ballast* factor is not user changeable.

c. For line-voltage lighting track and plug-in busway, designed to allow the addition and/or relocation of *luminaires* without altering the wiring of the *system*, the wattage shall be
   1. the specified wattage of the *luminaires* included in the *system* with a minimum of 30 W/lin ft or
   2. the wattage limit of the *system*'s *circuit breaker* or
   3. the wattage limit of other permanent current-limiting device(s) on the *system*.
d. The wattage of low-voltage lighting track, cable conductor, rail conductor, and other flexible *lighting systems* that allow the addition and/or relocation of *luminaires* without altering the wiring of the *system* shall be the specified wattage of the *transformer* supplying the *system*.
e. The wattage of all other miscellaneous lighting *equipment* shall be the specified wattage of the lighting *equipment*.

9.2 Compliance Path(s)

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

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

9.2.2 Prescriptive Requirements

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

9.2.2.2 The Space-by-Space Method, described in Section 9.6, is an alternative approach that allows greater flexibility.

9.2.2.3 Interior Lighting Power. The *interior lighting power allowance* for a *building* or a separately metered or permitted portion of a *building* shall be determined by either the *Building* Area Method described in Section 9.5 or the Space-by-Space Method described in Section 9.6. Trade-offs of *interior lighting power allowance* among portions of the *building* for which a different method of calculation has been used are not permitted. The *installed interior lighting power* identified in accordance with Section 9.1.3 shall not exceed the *interior lighting power allowance* developed in accordance with Section 9.5 or 9.6.

Exceptions: The following *lighting equipment* and applications shall not be considered when determining the *interior lighting power allowance* developed in accordance with Section 9.5 or 9.6, nor shall the wattage for such lighting be included in the *installed interior lighting power* identified in accordance with Section 9.1.3. However, any such lighting shall not be exempt unless it is an addition to *general lighting* and is controlled by an independent *control device*.

a. Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.
b. Lighting that is integral to *equipment* or instrumentation and is installed by its *manufacturer.*
c. Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical *equipment*.
d. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.
e. Lighting integral to food warming and food preparation *equipment*.
f. Lighting for plant growth or maintenance.
g. Lighting in *spaces* specifically designed for use by occupants with special lighting needs including visual impairment and other medical and age-related issues.
h. Lighting in *retail* display windows, provided the display area is enclosed by ceiling-height partitions.
i. Lighting in interior *spaces* that have been specifically designated as a registered interior *historic* landmark.
j. Lighting that is an integral part of advertising or directional signage.
k. Exit signs.
l. Lighting that is for sale or lighting educational demonstration *systems*.
m. Lighting for theatrical purposes, including performance, stage, and film and video production.
n. Lighting for television broadcasting in sporting activity areas.
o. Casino gaming areas.
p. Furniture-mounted supplemental *task lighting* that is controlled by *automatic* shutoff and complies with Section 9.4.1.6(d).
q. Mirror lighting in dressing rooms and accent lighting in religious pulpit and choir areas.
r. Parking garage transition lighting: Lighting for covered vehicle entrances and exits from buildings and parking structures, that comply with section 9.4.1.3 a and c. Each transition zone shall not exceed a depth of 66 ft inside the structure and a width of 50 ft.

9.3 (Not Used)

9.4 Mandatory Provisions

9.4.1 Lighting Control. Building *controls* shall meet the provisions of 9.4.1.1, 9.4.1.2, 9.4.1.3, 9.4.1.4, 9.4.1.5, 9.4.1.6, and 9.4.1.7.

Any *automatic control device* required in sections 9.4.1.1, 9.4.1.2, and 9.4.1.6 shall either be *manual* on or shall be controlled to automatically turn the lighting on to not more than 50% power, except in the following *spaces* where full automatic-on is allowed;

a. public corridors and stairwells,
b. restrooms,
c. primary *building entrance* areas and lobbies, and
d. areas where *manual*-on operation would endanger the safety or security of the room or building occupant(s).

9.4.1.1 Automatic Lighting Shutoff. Interior lighting in buildings 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 25,000 ft^2 but not more than one floor—or
b. an *occupant sensor* that shall turn lighting off within 30 minutes of an occupant leaving a *space*, or
c. a signal from another *control* or alarm *system* that indicates the area is unoccupied.

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

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

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

a. The controlled lighting shall have at least one control step between 30% and 70% (inclusive) of full lighting power in addition to all off.

Exceptions to 9.4.1.2a:

a. Lights in corridors, electrical/mechanical rooms, public lobbies, restrooms, stairways, and storage rooms

b. *Spaces* with only one *luminaire* with rated input power less than 100 W.
c. *Spaces* types with *lighting power allowance* of less than 0.6 W/ft^2 (see Table 9.6.1).

b. An *occupant sensor* or a timer switch shall be installed that automatically turns lighting off within 30 minutes of all occupants leaving a *space* in:

1. classrooms and lecture halls,
2. conference, meeting, and training rooms,
3. employee lunch and break rooms,
4. storage and supply rooms between 50 ft^2 and 1000 ft^2,
5. rooms used for document copying and printing,
6. office *spaces* up to 250 ft^2,
7. restrooms, and
8. dressing, locker, and fitting rooms.

Exceptions to 9.4.1.2b: These *spaces* are not required to be connected to other *automatic* lighting shutoff *controls*:

a. *Spaces* with *multi-scene control systems*,
b. shop and laboratory classrooms,
c. *spaces* where an *automatic* shutoff would endanger the safety or security of the room or building occupant(s), and
d. lighting required for 24-hour operation.

c. For *spaces* not included in 9.4.1.2b, 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 2500 ft^2 area for a *space* 10,000 ft^2 or less and a maximum of 10,000 ft^2 area for a *space* greater than 10,000 ft^2. The occupant shall be able to override any time-of-day scheduled shutoff *control* for no more than two hours.

Exception to 9.4.1.2c: 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 Parking Garage Lighting Control. Lighting for parking garages shall comply with the following requirements:

a. Comply with Section 9.4.1.1.
b. Lighting shall be controlled by one or more devices that automatically reduce lighting power of each *luminaire* by a minimum of 30% when there is no activity detected within a lighting zone for no more than 30 minutes. Lighting zones for this requirement shall be no larger than 3,600 ft^2,
c. Daylight transition zone lighting, as described in Section 9.2.2.3 exception r, shall be separately controlled by a device that automatically turns lighting on during daylight hours and off at sunset.
d. For *luminaires* within 20 ft of any perimeter *wall* structure that has a net opening to *wall* ratio of at least 40% and no exterior obstructions within 20 ft, the power shall be automatically reduced in response to daylight.

Exceptions:

a. Daylight transitions zones and ramps without parking are exempt from sections b and d above.
b. Applications using HID of 150 watts or less or Induction *lamps* are exempt from section b above.

9.4.1.4 Automatic Daylighting Controls for *Primary Sidelighted Areas*. When the combined *primary sidelighted area* in an *enclosed space* equals or exceeds 250 ft^2, the *lamps* for *general lighting* in the *primary sidelighted area* shall be separately controlled by at least one multilevel photocontrol (including continuous dimming devices) having the following characteristics:

a. the light sensor for the photocontrol shall be remote from where calibration adjustments are made;
b. the calibration adjustments shall be *readily accessible*; and
c. the multilevel photocontrol shall reduce electric lighting in response to available daylight with at least one *control* step that is between 50% and 70% of design lighting power and another *control* step that is no greater than 35% (including off) of design power.

Exceptions:

a. *Primary sidelighted areas* where the top of the existing adjacent structures are twice as high above the windows as their distance away from the windows
b. *Primary sidelighted areas* where the *sidelighting effective aperture* is less than 0.1 (10%)
c. retail *spaces*

9.4.1.5 Automatic Daylighting Controls for *Toplighting*. When the total *daylight area under skylights* plus the total *daylight area under rooftop monitors* in an *enclosed space* exceeds 900 ft^2, the *lamps* for *general lighting* in the *daylight area* shall be separately controlled by at least one multilevel photocontrol (including continuous dimming devices) having the following characteristics:

a. the light sensor for the photocontrol shall be remote from where calibration adjustments are made,
b. the calibration adjustments shall be *readily accessible*, and
c. the multilevel photocontrol shall reduce electric lighting in response to available daylight with at least one *control* step that is between 50% and 70% of design lighting power and another *control* step that is no greater than 35% of design power.

Exceptions:

a. *Daylighted areas under skylights* where it is documented that existing adjacent structures or natural objects block direct beam sunlight for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
b. *Daylighted areas* where the *skylight effective aperture* (EA) is less than 0.006 (0.6%).

c. *Buildings* in climate zone 8 with *daylight areas* totaling less than 1,500 ft^2 in an *enclosed space*.

9.4.1.6 Additional Control. Additional *controls* shall meet the following requirements:

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. *Guest Room Lighting*—Guestrooms in hotels, motels, boarding houses or similar buildings shall have one or more *control device(s)* at the entry *door* that collectively control all *permanently installed luminaires* and switched receptacles, except those in the bathroom(s). Suites shall have *control(s)* meeting these requirements at the entry to each room or at the primary entry to the suite. Bathrooms shall have a *control device* installed to automatically turn off the bathroom lighting, except for night lighting not exceeding 5 watts, within 60 minutes of the occupant leaving the *space*."
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*.
g. *Stairwell Lighting*—Lighting in stairwells shall have one or more *control devices* to automatically reduce lighting power in any one controlled zone by at least 50% within 30 minutes of all occupants leaving that controlled zone.

9.4.1.7 Exterior Lighting Control. Lighting for exterior applications not exempted in section 9.1 shall meet the following requirements:

a. Lighting shall be controlled by a device that automatically turns off the lighting when sufficient daylight is available.
b. All building façade and landscape lighting shall be automatically shut off between midnight or business closing, whichever is later, and 6am or business opening, whichever comes first, or between times established by the *authority having jurisdiction*.
c. Lighting not specified in section b above, including advertising signage, shall be controlled by a device that automatically reduces the connected lighting power by at least 30% for at least one of the following conditions

   1. from 12 midnight or within one (1) hour of the end of business operations, whichever is later, until 6 a.m. or business opening, whichever is earlier; or
   2. during any period when no activity has been detected for a time of no longer than 15 minutes.

All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least ten hours.

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

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

9.4.3 Exterior Building Lighting Power. The total *exterior lighting power allowance* for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are designed to be illuminated and are permitted in Table 9.4.3B for the applicable lighting zone. The *installed exterior lighting power* identified in accordance with Section 9.1.3 shall not exceed the *exterior lighting power allowance* developed in accordance with this section. Trade-offs are allowed only among exterior lighting applications listed in the Table 9.4.3B "Tradable Surfaces" section. The lighting zone for the building exterior is determined from Table 9.4.3A unless otherwise specified by the local jurisdiction.

Exceptions: Lighting used for the following exterior applications is exempt when equipped with a *control device* that complies with the requirements of Section 9.4.1.7 and is 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*.

TABLE 9.4.3A Exterior Lighting Zones

Lighting Zone	Description
0	Undeveloped areas within national parks, state parks, forest land, rural areas, and other undeveloped areas as defined by the *authority having jurisdiction*
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of *residential* zoning, neighborhood business districts, light industrial with limited nighttime use and *residential* mixed use areas
3	All other areas
4	High activity commercial districts in major metropolitan areas as designated by the local jurisdiction

TABLE 9.4.3B Individual Lighting Power Allowances for Building Exteriors

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (base allowance may be used in tradable or non-tradable surfaces)					
	No Base Site in Zone 0	500 W	600 W	750 W	1300 W
Tradable Surfaces (*LPD*s for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas may be traded.)					
Uncovered parking areas					
Parking areas and drives	No allowance	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2	0.13 W/ft^2
Building grounds					
Walkways less than 10 ft wide	No allowance	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
Walkways 10 ft wide or greater Plaza areas Special feature areas	No allowance	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.2 W/ft^2
Stairways	No allowance	0.75 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
Pedestrian tunnels	No allowance	0.15 W/ft^2	0.15 W/ft^2	0.2 W/ft^2	0.3 W/ft^2
Landscaping	No allowance	0.04 W/ft^2	0.05 W/ft^2	0.05 W/ft^2	0.05 W/ft^2
Building entrances and exits					
Main entries	No allowance	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
Other doors	No allowance	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
Entry canopies	No allowance	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2	0.4 W/ft^2
Sales Canopies					
Free standing and attached	No allowance	0.6 W/ft^2	0.6 W/ft^2	0.8 W/ft^2	1.0 W/ft^2
Outdoor sales					
Open areas (including vehicle sales lots)	No allowance	0.25 W/ft^2	0.25 W/ft^2	0.5 W/ft^2	0.7 W/ft^2
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Nontradable Surfaces (*LPD* calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)					
Building facades	No allowance	No allowance	0.1 W/ft^2 for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length	0.15 W/ft^2 for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length	0.2 W/ft^2 for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
Automated teller machines and night depositories	No allowance	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location

TABLE 9.4.3B Individual Lighting Power Allowances for Building Exteriors *(continued)*

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Entrances and gatehouse inspection stations at guarded facilities	No allowance	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles	No allowance	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Drive-through windows/doors	No allowance	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
Parking near 24-hour retail entrances	No allowance	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry
Roadway/parking entry, trail head, and toilet facility, or other locations approved by the *authority having jurisdiction.*	A single *luminaire* of 60 watts or less may be installed for each roadway/parking entry, trail head, and toilet facility, or other locations approved by the *authority having jurisdiction*	No allowance	No allowance	No allowance	No allowance

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.*
j. Lighting for hazardous locations.
k. Lighting for swimming *pools* and water features.
l. Searchlights.

9.4.4 Functional Testing. Lighting *control devices* and control *systems* shall be tested to ensure that *control* hardware and software are calibrated, adjusted, programmed, and in proper working condition in accordance with the *construction documents* and *manufacturer's* installation instructions. When *occupant sensors*, time switches, programmable schedule *controls*, or *photosensors* are installed, at a minimum, the following procedures shall be performed:

a. Confirm that the placement, sensitivity and time-out adjustments for *occupant sensors* yield acceptable performance, lights turn off only after *space* is vacated and do not turn on unless *space* is occupied.
b. Confirm that the time switches and programmable schedule *controls* are programmed to turn the lights off.
c. Confirm that *photosensor controls* reduce electric light levels based on the amount of usable daylight in the *space* as specified.

The *construction documents* shall state the party who will conduct and certify the functional testing. The party responsible for the functional testing shall not be directly involved in either the design or *construction* of the project and shall provide documentation certifying that the installed lighting *controls* meet or exceed all documented performance criteria. Certification shall be specific enough to verify conformance.

9.5 Building Area Method Compliance Path

9.5.1 Building Area Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the *interior lighting power allowance* by the Building Area Method:

a. Determine the appropriate building area type from Table 9.5.1 and the allowed *LPD* (watts per unit area) from the "Building Area Method" column. For building area types not listed, selection of a reasonably equivalent type shall be permitted.
b. Determine the *gross lighted floor area* (square feet) of the building area type.
c. Multiply the *gross lighted floor areas* of the building area type(s) times the *LPD.*
d. The *interior lighting power allowance* for the building is the sum of the *lighting power allowances* of all building area

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.82
Convention center	1.08
Courthouse	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire station	0.71
Gymnasium	1.00
Health-care clinic	0.87
Hospital	1.21
Hotel	1.00
Library	1.18
Manufacturing facility	1.11
Motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.06
Office	0.90
Parking garage	0.25
Penitentiary	0.97
Performing arts theater	1.39
Police station	0.96
Post office	0.87
Religious building	1.05
Retail	1.40
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse	0.66
Workshop	1.20

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

types. Trade-offs among building area types are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

9.6 Alternative Compliance Path: Space-by-Space Method

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

a. For each *space* enclosed by partitions that are 80% of the ceiling height or taller, determine the appropriate *space* type from Table 9.6.1. If a *space* has multiple functions, where more than one *space* type is applicable, that *space* shall be broken up into smaller subspaces, each using their own *space* type from Table 9.6.1. Any of these subspaces that are smaller in floor area than 20% of the original *space* and less than 1000 ft^2 need not be broken out separately. Include the floor area of balconies and other projections in this calculation.
b. In calculating the area of each *space* and subspace, the limits of the area are defined by the centerline of interior *walls*, the dividing line between subspaces, and the outside surface of exterior *walls*.
c. Based on the *space* type selected for each *space* or subspace, determine the *lighting power allowance* of each *space* or subspace by multiplying the calculated area of the *space* or subspace by the appropriate LPD determined in 9.6.1(a). For *space* types not listed, selection of a reasonable equivalent category shall be permitted.
d. The *interior lighting power allowance* is the sum of *lighting power allowances* of all *spaces* and subspaces. Trade-offs among *spaces* and subspaces are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance.*

9.6.2 Additional Interior Lighting Power. When using the Space-by-Space Method, an increase in the *interior lighting power allowance* is allowed for specific lighting functions. Additional power shall be allowed only if the specified lighting is installed and automatically controlled, separately from the *general lighting*, to be turned off during nonbusiness hours. This additional power shall be used only for the specified *luminaires* and shall not be used for any other purpose, unless otherwise indicated.

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

a. For *spaces* in which lighting is specified to be installed in addition to the *general lighting* for the purpose of decorative appearance or for highlighting art or exhibits, provided that the additional lighting power shall not exceed 1.0 W/ft^2 of such *spaces*.
b. For lighting *equipment* installed in sales areas and specifically designed and directed to highlight merchandise, calculate the additional lighting power as follows:

$$\text{Additional Interior Lighting Power Allowance} = 1000 \text{ watts} + (\text{Retail Area 1} \times 0.6 \text{ W/ft}^2) + (\text{Retail Area 2} \times 0.6 \text{ W/ft}^2) + (\text{Retail Area 3} \times 1.4 \text{ W/ft}^2) + (\text{Retail Area 4} \times 2.5 \text{ W/ft}^2),$$

where

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

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

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

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

Exception: Other merchandise categories may be included in Retail Areas 2 through 4 above, provided that justification documenting the need for additional lighting power based on visual inspection, contrast, or other critical display is approved by the *authority having jurisdiction.*

c. For *space* types identified in Table 9.6.2, when additional *controls* are used as indicated, provided that all mandatory *controls* are used according to Section 9.4, the additional lighting power, to be used anywhere in the building, is calculated as follows:

Additional Interior Lighting Power Allowance = Lighting Power Under Control × Control Factor;

where

Lighting Power Under Control = the total wattage of all lighting fixtures that are controlled in the given *space* using the control method indicated

Control Factor = the value given in Table 9.6.2 for the corresponding *space* type and control method.

9.6.3 Room Geometry Adjustment. When using the *space* by *space* method, an adjustment of the *space* LPD is allowed for individual *spaces* where:

the *Room Cavity Ratio* (RCR) calculated for the empty room is documented to be greater than the RCR threshold for that *space* type shown in Table 9.6.1.

$$RCR = 2.5 \times \text{Room Cavity Height} \times \text{room perimeter length} / \text{room area}$$

where

Room Cavity Height = Luminaire mounting height – Workplane

For corridor/transition *spaces*, this adjustment is allowed when the corridor is less than 8 ft wide, regardless of the RCR.

The LPD allowance for these *spaces* may be increased by the following amount:

$$\text{LPD increase} = \text{Base space LPD} \times 0.20$$

where

Base space LPD = the applicable LPD from Table 9.6.1.

9.7 Submittals

9.7.1 General. Where required by the *authority having jurisdiction* the submittal of compliance documentation and supplemental information shall be in accordance with section 4.2.2.

9.7.2 Completion requirements. The following requirements are mandatory provisions and are necessary for compliance with this standard.

9.7.2.1 Drawings. *Construction documents* shall require that within 90 days after the date of *system* acceptance, *record drawings* of the actual installation be provided to the building owner or the designated representative of the building owner. *Record drawings* shall include, as a minimum, the location, *luminaire* identifier, *control*, and circuiting for each piece of lighting *equipment*.

9.7.2.2 Manuals. *Construction documents* shall require for all lighting *equipment* and lighting *controls*, an operating and maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of *system* acceptance. These manuals shall include, at a minimum, the following:

a. Submittal data indicating all selected options for each piece of lighting *equipment* and lighting *controls*.

b. Operation and maintenance manuals for each piece of lighting *equipment* and lighting *controls* with routine maintenance clearly identified including, as a minimum, a recommended relamping program and a schedule for inspecting and recalibrating all lighting *controls*.

c. A complete narrative of how each lighting *control system* is intended to operate including recommended settings.

9.8 Product Information (Not Used))

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

Common Space Types[a]	LPD, W/ft^2	RCR Threshold
Atrium		
First 40 ft in height	0.03 per ft (height)	NA
Height above 40 ft	0.02 per ft (height)	NA
Audience/Seating Area—Permanent		
For auditorium	0.79	6
For Performing Arts Theater	2.43	8
For Motion Picture Theater	1.14	4
Classroom/Lecture/Training	1.24	4
Conference/Meeting/Multipurpose	1.23	6
Corridor/Transition	0.66	Width<8 ft
Dining Area	0.65	4
For Bar Lounge/Leisure Dining	1.31	4
For Family Dining	0.89	4
Dressing/Fitting Room for Performing Arts Theater	0.40	6
Electrical/Mechanical	0.95	6
Food Preparation	0.99	6
Laboratory		
For Classrooms	1.28	6
For Medical/Industrial/Research	1.81	6
Lobby	0.90	4
For Elevator	0.64	6
For Performing Arts Theater	2.00	6
For Motion Picture Theater	0.52	4
Locker Room	0.75	6
Lounge/Recreation	0.73	4
Office		
Enclosed	1.11	8
Open Plan	0.98	4
Restrooms	0.98	8
Sales Area (for accent lighting, see Section 9.6.2(b))	1.68	6
Stairway	0.69	10
Storage	0.63	6
Workshop	1.59	6

Building-Specific Space Types	LPD, W/ft^2	RCR Threshold
Automotive		
Service/Repair	0.67	4
Bank/Office		
Banking Activity Area	1.38	6
Convention Center		

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

Building-Specific Space Types	LPD, W/ft^2	RCR Threshold
Audience Seating	0.82	4
Exhibit Space	1.45	4
Courthouse/Police Station/Penitentiary		
Courtroom	1.72	6
Confinement Cells	1.10	6
Judges' Chambers	1.17	8
Penitentiary Audience Seating	0.43	4
Penitentiary Classroom	1.34	4
Penitentiary Dining	1.07	6
Dormitory		
Living Quarters	0.38	8
Fire Stations		
Engine Room	0.56	4
Sleeping Quarters	0.25	6
Gymnasium/Fitness Center		
Fitness Area	0.72	4
Gymnasium Audience Seating	0.43	6
Playing Area	1.20	4
Hospital		
Corridor/Transition	0.89	Width < 8 ft
Emergency	2.26	6
Exam/Treatment	1.66	8
Laundry/Washing	0.60	4
Lounge/Recreation	1.07	6
Medical Supply	1.27	6
Nursery	0.88	6
Nurses' Station	0.87	6
Operating Room	1.89	6
Patient Room	0.62	6
Pharmacy	1.14	6
Physical Therapy	0.91	6
Radiology/Imaging	1.32	6
Recovery	1.15	6
Hotel/Highway Lodging		
Hotel Dining	0.82	4
Hotel Guest Rooms	1.11	6
Hotel Lobby	1.06	4
Highway Lodging Dining	0.88	4
Highway Lodging Guest Rooms	0.75	6
Library		
Card File and Cataloging	0.72	4
Reading Area	0.93	4
Stacks	1.71	4

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

Building-Specific Space Types	LPD, W/ft²	RCR Threshold
Manufacturing		
Corridor/Transition	0.41	Width < 8 ft
Detailed Manufacturing	1.29	4
Equipment Room	0.95	6
Extra High Bay (>50 ft Floor to Ceiling Height)	1.05	4
High Bay (25–50 ft Floor to Ceiling Height)	1.23	4
Low Bay (<25 ft Floor to Ceiling Height)	1.19	4
Museum		
General Exhibition	1.05	6
Restoration	1.02	6
Parking Garage		
Garage Area	0.19	4
Post Office		
Sorting Area	0.94	4
Religious Buildings		
Audience Seating	1.53	4
Fellowship Hall	0.64	4
Worship Pulpit, Choir	1.53	4

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

Building-Specific Space Types	LPD, W/ft²	RCR Threshold
Retail		
Dressing/Fitting Room	0.87	8
Mall Concourse	1.10	4
Sales Area (for accent lighting, see Section 9.6.3(c))	1.68	6
Sports Arena		
Audience Seating	0.43	4
Court Sports Arena—Class 4	0.72	4
Court Sports Arena—Class 3	1.20	4
Court Sports Arena—Class 2	1.92	4
Court Sports Arena—Class 1	3.01	4
Ring Sports Arena	2.68	4
Transportation		
Air/Train/Bus—Baggage Area	0.76	4
Airport—Concourse	0.36	4
Audience Seating	0.54	4
Terminal—Ticket Counter	1.08	4
Warehouse		
Fine Material Storage	0.95	6
Medium/Bulky Material Storage	0.58	4

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

TABLE 9.6.2 Control Factors Used in Calculating Additional Interior Lighting Power Allowance

Additional Control Method (in Addition to Mandatory Requirements).	Space Type				
	Open Office	Private Office	Conference Room, Meeting Room, Classroom (Lecture/ Training)	Retail Sales Area	Lobby, Atrium, Dining Area, Corridors/ Stairways, Gym/ Pool, Mall Concourse, Parking Garage
Manual, continuous dimming control or Programmable multi-level dimming control	0.05	0.05	0.10[1]	0.10	0
Programmable multi-level dimming control using programmable time scheduling	0.05	0.05	0.10[1]	0.10	0.10
Multi-level occupancy sensors	0.05	0.05	0.05	0	0
Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off capabilities.	0.25[2]	0	0	0	0
Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off operation, in combination with personal continuous dimming control of downlight illumination by workstation occupant.	0.30[2,3]	0	0	0	0
Automatic bi-level or multi-level switching in *primary sidelighted areas* when *sidelighting effective aperture* is greater than 0.15	0	0	0	0.10[4]	0
Automatic bi-level or multi-level switching in *primary sidelighted areas* when *sidelighting effective aperture* is greater than 0.15 and when *primary sidelighted area* is less than 250 ft^2	0.10[4]	0.10[4]	0.10[4]	0.10[4]	0.10[4]
Automatic continuous daylight dimming in *primary sidelighted areas* when *sidelighting effective aperture* is greater than 0.15 and when *primary sidelighted area* is less than 250 ft^2	0.20[4]	0.20[4]	0.20[4]	0.20[4]	0.20[4]
Automatic continuous daylight dimming in *primary sidelighted areas* when *sidelighting effective aperture* is greater than 0.15 and when *primary sidelighted area* is greater than 250 ft^2	0.10[4]	0.10[4]	0.10[4]	0.10[4]	0.10[4]
Automatic continuous daylight dimming in *secondary sidelighted areas* when *sidelighting effective aperture* is greater than 0.3	0.10[4]	0.10[4]	0.10[4]	0.10[4]	0.10[4]
Automatic continuous daylight dimming in *daylighted areas under skylights* when the total of those areas is less than 900 ft^2 and when *skylight effective aperture* is greater than 0.01	0.20	0.20	0.20	0.20	0.20
Automatic continuous daylight dimming in *daylighted areas under skylights* when the total of those areas is greater than 900 ft^2 and when *skylight effective aperture* is greater than 0.01	0.10	0.10	0.10	0.10	0.10

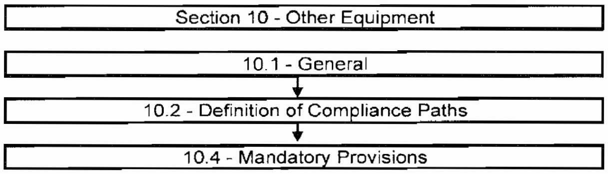
[1] These *control* factors may only be used if the requirements of section 9.4.1.2 are met using an *occupancy sensor*.

[2] *Control* factor is limited to the wattage of workstation-specific *luminaires* in partitioned single occupant workspaces contained within an open office environment (i.e. direct-indirect *luminaires* with separately controlled downlight and uplight components, with the downward component providing illumination to a single occupant in an open plan workstation). Within 30 minutes of the occupant leaving the *space*, the downward component shall continuously dim to off over a minimum of 2 minutes. Upon the occupant entering the *space*, the downward component shall turn on at the minimum level and continuously raise the illumination to a *preset* level over a minimum of 30 seconds. The uplight component of workstation specific luminaire shall comply with section 9.4.1.1 (*automatic* shutoff).

[3] In addition to the requirements described in footnote 2, the *control* shall allow the occupant to select their preferred light level via a personal computer, handheld device, or similarly accessible device located within the workstation.

[4] *Control* factors may not be used if *controls* are used to satisfy exceptions to Section 5.5.4.2.3

10. OTHER EQUIPMENT



10.1 General

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

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

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

10.1.1.3 Alterations to Existing Buildings

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

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

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

10.2 Compliance Path(s)

10.2.1 Compliance with Section 10 shall be achieved by meeting all requirements of Section 10.1, General; Section 10.4, Mandatory Provisions; and Section 10.8, Product Information.

10.2.2 Projects using the Energy Cost Budget Method (Section 11 of this standard) must comply with Section 10.4, the mandatory provisions of this section, as a portion of that compliance path.

10.3 Simplified/Small Building Option (Not Used)

10.4 Mandatory Provisions

10.4.1 Electric Motors. Electric motors manufactured before December 19, 2010 shall comply with the requirements of the Energy Policy Act of 1992 where applicable, as shown in Table 10.8a. Prior to December 19, 2010, motors not included in the scope of the Energy Policy Act of 1992 have no performance requirements in this section, such as but not limited to the following types:

a. Footless designs
b. Two-speed versions
c. 50 Hertz
d. 200/400 and 575 volt
e. Design C and D
f. Close coupled pump motors
g. TEAO motors
h. TENV motors

Electric motors manufactured alone or as a component of another piece of *equipment* on or after December 19, 2010 shall comply with the requirements of the Energy Independence and Security Act of 2007, as shown in Table 10.8B *for general purpose electric motors (subtype I)* and 10.8C *for general purpose electric motors (subtype II)*.

Fire pump motors and NEMA Design B, general purpose electric motors with a power rating of more than 200 hp, but no more than 500 hp, manufactured on or after December 19, 2010, shall have a minimum nominal full load *efficiency* that is not less than as shown in Table 10.8C.

Motors that are not included in the scope of the Energy Independence and Security Act of 2007, Section 313, have no performance requirements in this section.

10.4.2 Service Water Pressure Booster Systems. *Service* water pressure booster *systems* shall be designed such that:

a. One or more pressure sensors shall be used to vary pump speed and/or start and stop pumps. The sensor(s) shall either be located near the critical *fixture(s)* that determine the pressure required, or logic shall be employed that adjusts the *setpoint* to simulate operation of remote sensor(s).
b. No device(s) shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster *system* pump or booster *system*, except for safety devices.
c. No booster *system* pumps shall operate when there is no *service* water flow.

10.4.3 Elevators. Elevator *systems* shall comply with the requirements of this section:

10.4.3.1 Lighting. All cab *lighting systems* shall have *efficacy* of not less than 35 lumens per Watt.

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

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

10.5 Prescriptive Compliance Path (Not Used)

10.6 Alternative Compliance Path (Not Used)

10.7 Submittals (Not Used)

10.8 Product Information

TABLE 10.8A Minimum Nominal Efficiency for General Purpose Design A and Design B Motors Rated 600 Volts or Less[a]

	Minimum Nominal Full-Load Motor Efficiency (%) prior to December 19, 2010					
	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Horsepower						
1	NR	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	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.
NR—No requirement

TABLE 10.8B Minimum Nominal Full-Load Efficiency for 60 HZ NEMA General Purpose Electric Motors (Subtype I) Rated 600 Volts or Less (Random Wound)[a]

Minimum Nominal Full Load Efficiency (%) for Motors Manufactured on or after December 19, 2010

	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Horsepower						
1	77.0	85.5	82.5	77.0	85.5	82.5
1.5	84.0	86.5	86.5	84.0	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	89.5	88.5	89.5	89.5
7.5	88.5	91.0	90.2	89.5	91.7	91.0
10	89.5	91.7	91.7	90.2	91.7	91.0
15	90.2	93.0	91.7	91.0	92.4	91.7

Minimum Nominal Full Load Efficiency (%) for Motors Manufactured on or after December 19, 2010

	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) ⇒	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
20	91.0	93.0	92.4	91.0	93.0	91.7
25	91.7	93.6	93.0	91.7	93.6	93.0
30	91.7	94.1	93.6	91.7	93.6	93.0
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93.0	94.5	94.1	93.0	94.5	94.1
60	93.6	95.0	94.5	93.6	95.0	94.5
75	93.6	95.0	94.5	93.6	95.4	94.5
100	93.6	95.4	95.0	94.1	95.4	95.0
125	94.1	95.4	95.0	95.0	95.4	95.0
150	94.1	95.8	95.4	95.0	95.8	95.8
200	95.0	95.8	95.4	95.4	96.2	95.8
250	95.0	95.8	95.4	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	95.8	96.2	96.2	95.8	96.2	95.8
500	95.8	96.2	96.2	95.8	96.2	95.8

[a] Nominal efficiencies shall be established in accordance with NEMA Standard MG1.

TABLE 10.8C Minimum Nominal Full-Load Efficiency of General Purpose Electric Motors (Subtype II and Design B)[a]

Minimum Nominal Full Load Efficiency (%) for Motors Manufactured on or after December 19, 2010								
	Open Drip-Proof Motors				Totally Enclosed Fan Cooled Motors			
Number of Poles ==>	2	4	6	8	2	4	6	8
Synchronous Speed (RPM)==>	3600	1800	1200	900	3600	1800	1200	900
Motor Horsepower								
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
Minimum Nominal Full Load Efficiency (%) for Motors Manufactured on or after December 19, 2010								
	Open Drip-Proof Motors				Totally Enclosed Fan Cooled Motors			
Number of Poles ==>	2	4	6	8	2	4	6	8
Synchronous Speed (RPM)==>	3600	1800	1200	900	3600	1800	1200	900
Motor Horsepower								
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
350	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
400	95.4	95.4	NR	NR	95.4	95.4	NR	NR
450	95.8	95.8	NR	NR	95.4	95.4	NR	NR
500	95.8	95.8	NR	NR	95.4	95.8	NR	NR

[a] Nominal efficiencies shall be established in accordance with NEMA Standard MG1.

NR—No requirement

11. ENERGY COST BUDGET METHOD

11.1 General

11.1.1 Energy Cost Budget Method Scope. The building Energy Cost Budget Method is an alternative to the prescriptive provisions of this standard. It may be employed for evaluating the compliance of all *proposed designs* except designs with no mechanical *system*.

11.1.2 Trade-Offs Limited to Building Permit. When the building permit being sought applies to less than the whole building, only the calculation parameters related to the *systems* to which the permit applies shall be allowed to vary. Parameters relating to unmodified existing conditions or to future building components shall be identical for both the *energy cost budget* and the *design energy cost* calculations. Future building components shall meet the prescriptive requirements of Sections 5.5, 6.5, 7.5, and either 9.5 or 9.6.

11.1.3 Envelope Limitation. For new buildings or *additions*, the building Energy Cost Budget Method results shall not be submitted for building permit approval to the *authority having jurisdiction* prior to submittal for approval of the building envelope design.

11.1.4 Compliance. Compliance with Section 11 will be achieved if:

a. all requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met;
b. the *design energy cost*, as calculated in Section 11.3, does not exceed the *energy cost budget*, as calculated by the *simulation program* described in Section 11.2; and
c. the *energy efficiency* level of components specified in the building design meet or exceed the *efficiency* levels used to calculate the *design energy cost.*

Informative Note: *The energy cost budget and the design energy cost calculations are applicable only for determining compliance with this standard. They are not predictions of actual energy consumption or costs of the proposed design after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this standard, changes in energy rates between design of the building and occupancy, and precision of the calculation tool.*

11.1.5 Documentation Requirements. Compliance shall be documented and submitted to the *authority having jurisdiction*. The information submitted shall include the following:

a. The *energy cost budget* for the *budget building design* and the *design energy cost* for the *proposed design.*
b. A list of the energy-related features that are included in the design and on which compliance with the provisions of Section 11 is based. This list shall document all *energy* features that differ between the models used in the *energy cost budget* and the *design energy cost* calculations.
c. The input and output report(s) from the *simulation program*, including a breakdown of *energy* usage by at least the following components: lights, internal *equipment* loads, *service water heating equipment*, *space* heating *equipment*, *space* cooling and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of time any loads are not met by the *HVAC system* for both the *proposed design* and *budget building design.*
d. An explanation of any error messages noted in the *simulation program* output.

11.2 Simulation General Requirements

11.2.1 Simulation Program. The *simulation program* shall be a computer-based program for the analysis of *energy* consumption in buildings (a program such as, but not limited to, DOE-2 or BLAST). The *simulation program* shall include calculation methodologies for the building components being modeled.

Note to Adopting Authority: *ASHRAE Standing Standard Project Committee 90.1 recommends that a compliance shell implementing the rules of a compliance supplement that controls inputs to and reports outputs from the required computer analysis program be adopted for the purposes of easier use and simpler compliance.*

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

a. a minimum of 1400 hours per year
b. hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat setpoints*, and *HVAC system* operation, defined separately for each day of the week and holidays
c. thermal mass effects
d. ten or more thermal zones
e. part-load performance curves for mechanical *equipment*
f. capacity and *efficiency* correction curves for *mechanical heating* and cooling *equipment*
g. air-side and water-side economizers with integrated *control*
h. the *budget building design* characteristics specified in Section 11.2.5

11.2.1.2 The *simulation program* shall have the ability to either:

a. directly determine the *design energy cost* and *energy cost budget*, or
b. produce hourly reports of *energy* use by *energy* source suitable for determining *the design energy cost* and *energy cost budget* using a separate calculation engine.

11.2.1.3 The *simulation program* shall be capable of performing design load calculations to determine required HVAC *equipment* capacities and air and water flow rates in accordance with Section 6.4.2 for both the *proposed design* and the *budget building design.*

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

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

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

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

11.2.4 Compliance Calculations. The *design energy cost* and *energy cost budget* shall be calculated using

a. the same *simulation program*,
b. the same weather data, and
c. the same *purchased energy rates*.

11.2.5 Exceptional Calculation Methods. Where no *simulation program* is available that adequately models a design, material, or device, the *authority having jurisdiction* may approve an exceptional calculation method to be used to demonstrate compliance with Section 11. Applications for approval of an exceptional method to include theoretical and empirical information verifying the method's accuracy shall include the following documentation to demonstrate that the exceptional calculation method and results:

a. make no change in any input parameter values specified by this standard and the *adopting authority*;
b. provide input and output documentation that facilitates the enforcement agency's review and meets the formatting and content required by the *adopting authority*; and
c. are supported with instructions for using the method to demonstrate that the *energy cost budget* and *design energy cost* required by Section 11 are met.

11.3 Calculation of Design Energy Cost and Energy Cost Budget

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

TABLE 11.3.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
1. Design Model		
	a. The simulation model of the *proposed building design* shall be consistent with the design documents, including proper accounting of *fenestration* and *opaque* envelope types and area; interior lighting power and *controls*; *HVAC system* types, sizes, and *controls*; and *service water heating systems* and *controls*. b. All *conditioned spaces* in the *proposed building design* shall be simulated as being both heated and cooled even if no cooling or heating *system* is being installed. Temperature and humidity *control setpoints* and schedules, as well as *temperature control throttling range* shall be the same for *proposed* and *baseline building designs*. c. When the *energy cost budget* method is applied to buildings in which energy-related features have not yet been designed (e.g., a *lighting system*), those yet-to-be-designed features shall be described in the *proposed building design* so that they minimally comply with applicable mandatory and prescriptive requirements from Sections 5 through 10. Where the *space* classification for a building is not known, the building shall be categorized as an office building.	The *budget building design* shall be developed by modifying the *proposed design* as described in this table. Except as specifically instructed in this table, all building *systems* and *equipment* shall be modeled identically in the *budget building design* and *proposed building design*.
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 building design*
3. Space Use Classification		
	The building type or *space* type classifications shall be chosen in accordance with Section 9.5.1 or 9.6.1. The user or designer shall specify the *space* use classifications using either the building type or *space* type categories but shall not combine the two types of categories within a single permit application. More than one building type category may be used for a building if it is a mixed-use facility.	Same as *proposed building design*
4. Schedules		
	The schedule types listed in Section 11.2.1.1(b) shall be required input. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *authority having jurisdiction*. Required schedules shall be identical for the *proposed building design* and *budget building design*.	Same as *proposed building design*

TABLE 11.3.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(continued)*

<table>
<tr><th>No.</th><th>Proposed Building Design (Column A)
Design Energy Cost (DEC)</th><th>Budget Building Design (Column B)
Energy Cost Budget (ECB)</th></tr>
<tr><td colspan="3">5. Building Envelope</td></tr>
<tr><td colspan="2">All components of the building envelope in the proposed building design shall be modeled as shown on architectural drawings or as installed for existing building envelopes.
Exceptions: The following building elements are permitted to differ from architectural drawings.
a. Any envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described. If not separately described, the area of an envelope assembly must be added to the area of the adjacent assembly of that same type.
b. Exterior surfaces whose azimuth orientation and tilt differ by no more than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.
c. The exterior roof surface shall be modeled using the aged solar reflectance and thermal emittance determined in accordance with Section 5.5.3.1.1(a). Where aged test data is unavailable, the roof surface shall be modeled with a solar reflectance of 0.30 and a thermal emittance of 0.90.
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.</td><td>The budget building design shall have identical conditioned floor area and identical exterior dimensions and orientations as the proposed building design, except as follows:
a. Opaque assemblies such as roof, floors, doors, and walls shall be modeled as having the same heat capacity as the proposed building design but with the minimum U-factor required in Section 5.5 for new buildings or additions and Section 5.1.3 for alterations.
b. Roof Solar Reflectance and Thermal Emittance. The exterior roof surfaces shall be modeled with a solar reflectance and thermal emittance as required in Section 5.5.3.1.1(a). All other roofs, including roofs exempted from the requirements in Section 5.5.3.1.1, shall be modeled the same as the proposed design.
c. Fenestration—No shading projections are to be modeled; fenestration shall be assumed to be flush with the exterior wall or roof. If the fenestration area for new buildings or additions exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. If the fenestration area facing west or east of the proposed building exceeds the area limit set in Section 5.5.4.5, the area shall be reduced proportionally until the area is the same as the area limit set in Section 5.5.4.5. The area limit is the fenestration area facing south in the northern hemisphere or the fenestration area facing north in the southern hemisphere as defined in Section 5.5.4.5. Fenestration U-factor shall be the minimum required for the climate, and the SHGC shall be the maximum allowed for the climate and orientation. The fenestration model for envelope alterations shall reflect the limitations on area, U-factor, and SHGC as described in Section 5.1.3.

Exception: When trade-offs are made between an addition and an existing building as described in the Exception to Section 4.2.1.2, the envelope assumptions for the existing building in the budget building design shall reflect existing conditions prior to any revisions that are part of this permit.</td></tr>
<tr><td colspan="3">6. Lighting</td></tr>
<tr><td colspan="2">Lighting power in the proposed building design shall be determined as follows:
a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model.
b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4.
c. Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type.
d. Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures).</td><td>Lighting power in the budget building design shall be determined using the same categorization procedure (building area or space-by-space method) and categories as the proposed building design with lighting power set equal to the maximum allowed for the corresponding method and category in either Section 9.5 or 9.6. Power for fixtures not included in the LPD calculation shall be modeled identically in the proposed building design and budget building design. Lighting controls shall be the minimum required.</td></tr>
</table>

TABLE 11.3.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(continued)*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
7. Thermal Blocks—HVAC Zones Designed		
	Where *HVAC zones* are defined on HVAC design drawings, each *HVAC zone* shall be modeled as a separate *thermal block.* **Exception:** Different *HVAC zones* may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied provided all of the following conditions are met: a. The *space* use classification is the same throughout the *thermal block.* b. All *HVAC zones* in the *thermal block* that are adjacent to glazed exterior *walls* face the same *orientation* or their *orientations* are within 45 degrees of each other. c. All of the zones are served by the same *HVAC system* or by the same kind of *HVAC system.*	Same as *proposed building design*
8. Thermal Blocks—HVAC Zones Not Designed		
	Where the *HVAC zone*s and *systems* have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and *space* temperature schedules, and in combination with the following: a. Separate *thermal blocks* shall be assumed for interior and perimeter *spaces*. Interior *spaces* shall be those located more than 15 ft from an exterior *wall*. Perimeter *spaces* shall be those located closer than 15 ft from an exterior *wall*. b. Separate *thermal blocks* shall be assumed for *spaces* adjacent to glazed exterior *walls*; a separate zone shall be provided for each *orientation*, except *orientations* that differ by no more than 45 degrees may be considered to be the same *orientation*. Each zone shall include all floor area that is 15 ft or less from a glazed perimeter *wall*, except that floor area within 15 ft of glazed perimeter *walls* having more than one *orientation* shall be divided proportionately between zones. c. Separate *thermal blocks* shall be assumed for *spaces* having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. d. Separate *thermal blocks* shall be assumed for *spaces* having exterior ceiling or *roof* assemblies from zones that do not share these features.	Same as *proposed building design*
9. Thermal Blocks—Multifamily Residential Buildings		
	Residential spaces shall be modeled using one *thermal block* per *space* except that those facing the same *orientations* may be combined into one *thermal block*. Corner units and units with *roof* or floor loads shall only be combined with units sharing these features.	Same as Proposed Design
10. HVAC Systems		
	The *HVAC system* type and all related performance parameters, such as *equipment* capacities and efficiencies, in the *proposed building design* shall be determined as follows: a. Where a complete *HVAC system* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where an *HVAC system* has been designed, the HVAC model shall be consistent with design documents. Mechanical *equipment* efficiencies shall be adjusted from actual *design conditions* to the standard rating conditions specified in Section 6.4.1, if required by the simulation model. c. Where no heating *system* exists or no heating *system* has been specified, the heating *system* shall be modeled as *fossil fuel*. The *system* characteristics shall be identical to the *system* modeled in the *budget building design.* d. Where no cooling *system* exists or no cooling *system* has been specified, the cooling *system* shall be modeled as an air-cooled *single-zone system*, one unit per *thermal block*. The *system* characteristics shall be identical to the *system* modeled in the *budget building design.*	The *HVAC system* type and related performance parameters for the *budget building design* shall be determined from Figure 11.3.2, the *system* descriptions in Table 11.3.2A and accompanying notes, and in accord with rules specified in Section 11.3.2 (a)–(j).

TABLE 11.3.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(continued)*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
11. Service Hot-Water Systems		
	The *service* hot-water *system* type and all related performance parameters, such as *equipment* capacities and efficiencies, in the *proposed building design* shall be determined as follows: a. Where a complete *service* hot-water *system* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where a *service* hot-water *system* has been designed, the *service* hot-water model shall be consistent with design documents. c. Where no *service* hot-water *system* exists or is specified, no *service* hot-water heating shall be modeled.	The *service* hot-water *system* type in the *budget building design* shall be identical to the proposed building design. The *service* hot-water *system* performance of the *budget building design* shall meet the requirements of Table 7.8. **Exceptions:** a. If the *service* hot water *system* type is not listed in Table 7.8, it shall be identical to the proposed building design. b. Where Section 7.5 applies, the *boiler* shall be split into a separate *space* heating *boiler* and hot-*water heater* with *efficiency* requirements set to the least efficient allowed. c. For 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery *systems* described in Section 6.5.6.2, a *system* meeting the requirements of that section shall be included in the *baseline building design* regardless of the exceptions to Section 6.5.6.2. If a condenser heat recovery *system* meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a *system* in the actual building shall be met as a prescriptive requirement in accordance with Section 6.5.6.2 and no heat-recovery *system* shall be included in the *proposed* or *budget building design*.
12. Miscellaneous Loads		
	Receptacle, motor, and *process loads* shall be modeled and estimated based on the building type or *space* type category and shall be assumed to be identical in the *proposed* and *budget building designs*. These loads shall be included in simulations of the building and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the building shall be modeled, unless specifically excluded by Sections 13 and 14 of Table 11.3.1: including, but not limited to, exhaust fans, parking garage *ventilation* fans, exterior building lighting, swimming *pool* heaters and pumps, elevators and escalators, refrigeration *equipment*, and cooking *equipment*.	Receptacle, motor, and *process loads* shall be modeled and estimated based on the building type or *space* type category and shall be assumed to be identical in the *proposed* and *budget building designs*. These loads shall be included in simulations of the building and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the building shall be modeled, unless specifically excluded by Sections 13 and 14 of Table 11.3.1: including, but not limited to, exhaust fans, parking garage *ventilation* fans, exterior building lighting, swimming *pool* heaters and pumps, elevators and escalators, refrigeration *equipment*, and cooking *equipment*.
13. Modeling Exceptions		
	All elements of the *proposed building design* envelope, HVAC, *service water heating*, lighting, and electrical *systems* shall be modeled in the *proposed building design* in accordance with the requirements of Sections 1 through 12 of Table 11.3.1. **Exceptions:** Components and *systems* in the *proposed building design* may be excluded from the simulation model provided: a. component *energy* usage does not affect the *energy* usage of *systems* and components that are being considered for trade-off; b. the applicable prescriptive requirements of Sections 5.5, 6.5, 7.5, and either 9.5 or 9.6 applying to the excluded components are met.	None

TABLE 11.3.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget *(continued)*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
14. Modeling Limitations to the Simulation Program		
	If the *simulation program* cannot model a component or *system* included in the *proposed building design*, one of the following methods shall be used with the approval of the *authority having jurisdiction*: a. Ignore the component if the *energy* impact on the trade-offs being considered is not significant. b. Model the component substituting a thermodynamically similar component model. c. Model the *HVAC system* components or *systems* using the *budget building design's* HVAC *system* in accordance with Section 10 of Table 11.3.1. Whichever method is selected, the component shall be modeled identically for both the *proposed building design* and *budget building design* models.	Same as *proposed building design*

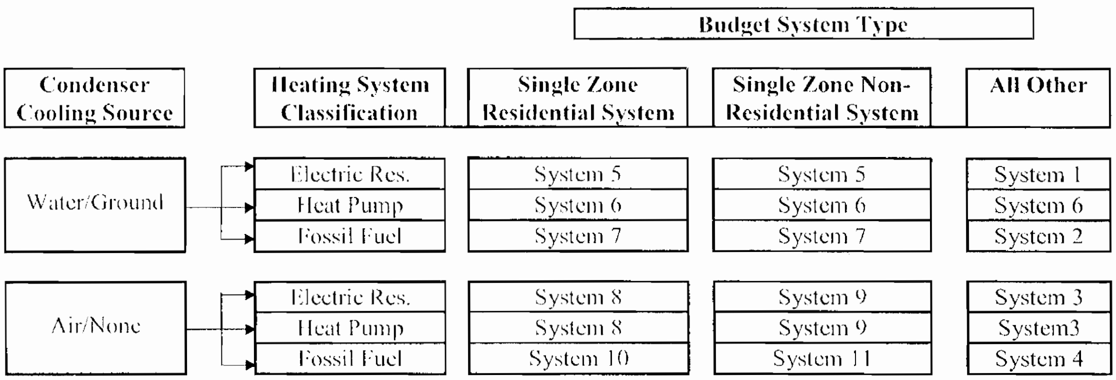


Figure 11.3.2 HVAC systems map.

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

a. Components and parameters not listed in Figure 11.3.2 and Table 11.3.2A or otherwise specifically addressed in this subsection shall be identical to those in the *proposed building design.*

Exception: Where there are specific requirements in Sections 6.4 and 6.5, the component *efficiency* in the *budget building design* shall be adjusted to the lowest *efficiency* level allowed by the requirement for that component type.

b. All HVAC and *service water heating equipment* in the *budget building* shall be modeled at the minimum *efficiency* levels, both part load and full load, in accordance with Sections 6.4 and 7.4.

c. Where *efficiency* ratings, such as IEER and ICOP, include fan *energy*, the descriptor shall be broken down into its components so that supply fan *energy* can be modeled separately. Supply and return/relief *system* fans shall be modeled as operating at least whenever the *spaces* served are occupied except as specifically noted in Table 11.3.2A.

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

e. *Budget building systems* as listed in Table 11.3.2A shall have *outdoor air economizers* or *water economizers*, the same as in the proposed building, in accordance with Section 6.5.1. The high-limit shutoff shall be in accordance with Table 11.3.2D.

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

g. *System* design supply air rates for the *budget building design* shall be based on a supply-air-to-room-air temperature difference of 20°F. If return or relief fans are specified in the *proposed building design*, the *budget building design* shall also be modeled with the same fan type sized for the budget *system* supply fan air quantity less the minimum *outdoor air*, or 90% of the supply fan air quantity, whichever is larger.

h. Fan *system efficiency* (bhp per cfm of supply air including the effect of belt losses but excluding motor and motor drive losses) shall be the same as the *proposed building*

TABLE 11.3.2A Budget System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1	VAV with parallel fan-powered boxes[a]	VAV[d]	Chilled water[e]	Electric resistance
2	VAV with reheat[b]	VAV[d]	Chilled water[e]	Hot-water fossil fuel boiler[f]
3	Packaged VAV with parallel fan-powered boxes[a]	VAV[d]	Direct expansion[c]	Electric resistance
4	Packaged VAV with reheat[b]	VAV[d]	Direct expansion[c]	Hot-water fossil fuel boiler[f]
5	Two-pipe fan-coil	Constant volume[i]	Chilled water[e]	Electric resistance
6	Water-source heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump and boiler[g]
7	Four-pipe fan-coil	Constant volume[i]	Chilled water[e]	Hot-water fossil fuel boiler[f]
8	Packaged terminal heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump[h]
9	Packaged rooftop heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump[h]
10	Packaged terminal air conditioner	Constant volume[i]	Direct expansion	Hot-water fossil fuel boiler[f]
11	Packaged rooftop air conditioner	Constant volume[i]	Direct expansion	Fossil fuel furnace

[a]**VAV with parallel boxes:** Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume *setpoints* for fan-powered boxes shall be equal to the minimum rate for the *space* required for *ventilation* consistent with Section 6.5.2.1 Exception (a) 2. Supply air temperature *setpoint* shall be constant at the design condition [see Section 11.3.2 (h)].

[b]**VAV with reheat:** Minimum volume *setpoints* for VAV reheat boxes shall be 30% of zone peak air flow or the minimum *ventilation* rate, whichever is larger, consistent with Section 6.5.2.1 Exception (a) 1. The supply air temperature for cooling shall be *reset* higher by 5°F under the minimum cooling load conditions.

[c]**Direct expansion:** The *fuel* type for the cooling *system* shall match that of the cooling *system* in the *proposed building design*.

[d]**VAV:** Constant volume can be modeled if the *system* qualifies for Exception (b) to Section 6.5.2.1. When the *proposed building design system* has a supply, return, or relief fan motor 25 hp or larger, the corresponding fan in the VAV *system* of the *budget building design* shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. If the *proposed building design's system* has a DDC *system* at the zone level, static pressure *setpoint reset* based on zone requirements in accordance with Section 6.5.3.2.3 shall be modeled.

[e]**Chilled water:** For *systems* using purchased chilled water, the chillers are not explicitly modeled and chilled water costs shall be based as determined in Section 11.2.3. Otherwise, the *budget building design's* chiller plant shall be modeled with chillers having the number as indicated in Table 11.3.2B as a function of *budget building design* chiller plant load and type as indicated in Table 11.3.2C as a function of individual chiller load. Where chiller *fuel* source is mixed, the *system* in the *budget building design* shall have chillers with the same *fuel* types and with capacities having the same proportional capacity as the *proposed building design's* chillers for each *fuel* type. Chilled-water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. Piping losses shall not be modeled in either building model. Chilled-water supply water temperature shall be *reset* in accordance with Section 6.5.4.3. *Pump system power* for each pumping *system* shall be the same as the *proposed building design*; if the *proposed building design* has no chilled-water pumps, the *budget building design* pump power shall be 22 W/gpm (equal to a pump operating against a 75 ft head, 65% combined impeller and motor *efficiency*). The chilled-water *system* shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled-water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in Section 6.5.4.1. The heat rejection device shall be an axial fan cooling tower with two-speed fans if required in Section 6.5.5 and shall meet the performance requirements of Table 6.8.1G. Condenser water design supply temperature shall be 85°F or 10°F approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F leaving water temperature where weather permits, floating up to leaving water temperature at *design conditions*. *Pump system power* for each pumping *system* shall be the same as the *proposed building design*; if the *proposed building design* has no condenser water pumps, the *budget building design* pump power shall be 19 W/gpm (equal to a pump operating against a 60 ft head, 60% combined impeller and motor *efficiency*). Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller.

[f]**Fossil fuel boiler:** For *systems* using purchased hot water or steam, the *boilers* are not explicitly modeled and hot water or steam costs shall be based on actual utility rates. Otherwise, the *boiler* plant shall use the same *fuel* as the *proposed building design* and shall be natural draft. The *budget building design boiler* plant shall be modeled with a single *boiler* if the *budget building design* plant load is 600,000 Btu/h and less and with two equally sized *boilers* for plant capacities exceeding 600,000 Btu/h. *Boilers* shall be staged as required by the load. Hot-water supply temperature shall be modeled at 180°F design supply temperature and 130°F return temperature. Piping losses shall not be modeled in either building model. Hot-water supply water temperature shall be *reset* in accordance with Section 6.5.4.3. *Pump system power* for each pumping *system* shall be the same as the *proposed building design*; if the *proposed building design* has no hot-water pumps, the *budget building design* pump power shall be 19 W/gpm (equal to a pump operating against a 60 ft head, 60% combined impeller and motor *efficiency*). The hot-water *system* shall be modeled as primary-only with continuous variable flow. Hot-water pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section 6.5.4.1.

[g]**Electric heat pump and boiler:** Water-source heat pumps shall be connected to a common heat pump water loop controlled to maintain temperatures between 60°F and 90°F. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with two-speed fans if required in Section 6.5.5.2. Heat addition to the loop shall be provided by a *boiler* that uses the same *fuel* as the *proposed building design* and shall be natural draft. If no *boilers* exist in the *proposed building design*, the budget building *boilers* shall be *fossil fuel*. The *budget building design boiler* plant shall be modeled with a single *boiler* if the *budget building design* plant load is 600,000 Btu/h or less and with two equally sized *boilers* for plant capacities exceeding 600,000 Btu/h. *Boilers* shall be staged as required by the load. Piping losses shall not be modeled in either building model. *Pump system power* shall be the same as the *proposed building design*; if the *proposed building design* has no pumps, the *budget building design* pump power shall be 22 W/gpm, which is equal to a pump operating against a 75 ft head, with a 65% combined impeller and motor *efficiency*. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles off as required by Section 6.5.4.4. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section 6.5.4.1.

[h]**Electric heat pump:** Electric air-source heat pumps shall be modeled with electric auxiliary heat. The *system* shall be controlled with a multi-stage *space thermostat* and an *outdoor air thermostat* wired to energize auxiliary heat only on the last *thermostat* stage and when *outdoor air* temperature is less than 40°F.

[i]**Constant volume:** Fans shall be controlled in the same manner as in the *proposed building design*; i.e., fan operation whenever the *space* is occupied or fan operation cycled on calls for heating and cooling. If the fan is modeled as cycling and the fan *energy* is included in the *energy efficiency* rating of the *equipment*, fan *energy* shall not be modeled explicitly.

design or up to the limit prescribed in Section 6.5.3.1, whichever is smaller. If this limit is reached, each fan shall be proportionally reduced in brake horsepower until the limit is met. Fan electrical power shall then be determined by adjusting the calculated fan hp by the minimum motor *efficiency* prescribed by Section 10.4 for the appropriate motor size for each fan.

i. The *equipment* capacities for the *budget building design* shall be sized proportionally to the capacities in the *proposed building design* based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the *proposed building design* and *budget building design*. *Unmet load hours* for the *proposed design* or *baseline building designs* shall not exceed 300. The *unmet load hours* for the *proposed design* shall not exceed the *unmet load hours* for the budget building. Alternatively, *unmet load hours* exceeding these limits may be accepted at the discretion of the *rating authority* provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

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

   1. Enter Figure 11.3.2 at "Water" if the *proposed building design system* condenser is water or evaporatively cooled; enter at "Air" if the condenser is air-cooled. Closed-circuit dry-coolers shall be considered air-cooled. *Systems* utilizing district cooling shall be treated as if the condenser water type were "water." If no *mechanical cooling* is specified or the *mechanical cooling system* in the *proposed building design* does not require heat rejection, the *system* shall be treated as if the condenser water type were "Air." For *proposed building designs* with ground-source or groundwater-source heat pumps, the budget *system* shall be water-source heat pump (System 6).

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

   3. Select the *budget building design system* category: The *system* under "Single Zone *Residential* System" shall be selected if the *HVAC system* in the *proposed design* is a *single-zone system* and serves a *residential space*. The *system* under "Single Zone Nonresidential System" shall be selected if the *HVAC system* in the *proposed design* is a *single-zone system* and serves other than *residential spaces*. The *system* under "All Other" shall be selected for all other cases.

k. For kitchens with a total exhaust hood airflow rate greater than 5000 cfm, use a *demand ventilation system* on 75% of the exhaust air. The *system* shall reduce exhaust and *replacement air system* airflow rates by 50% for one half of the kitchen occupied hours in the baseline design. If the *proposed design* uses *demand ventilation* the same air flow rate schedule shall be used. The maximum exhaust flow rate allowed for the hood or hood section shall meet the requirements of Section 6.5.7.1.3 for the numbers and types of hoods and appliances provided in the *proposed design*.

TABLE 11.3.2B Number of Chillers

Total Chiller Plant Capacity	Number of Chillers
≤300 tons	One
>300 tons, <600 tons	Two sized equally
≥600 tons	Two minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

TABLE 11.3.2C Water Chiller Types

Individual Chiller Plant Capacity	Electric Chiller Type	Fossil Fuel Chiller Type
≤100 tons	Reciprocating	Single-effect absorption, direct fired
>100 tons, <300 tons	Screw	Double-effect absorption, direct fired
≥300 tons	Centrifugal	Double-effect absorption, direct fired

TABLE 11.3.2D Economizer High-Limit Shutoff

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

12. NORMATIVE REFERENCES

Reference	Title
Air Conditioning, Heating and Refrigeration Institute, 2111 Wilson Blvd., Suite 500, Arlington, VA 22201	
AHRI 210/240-2008	Unitary Air Conditioning and Air-Source Heat Pump Equipment
AHRI 340/360-2007	Performance Rating of Commercial and Industrial Unitary Air -Conditioning and Heat Pump Equipment
AHRI 310/380-2004	Packaged Terminal Air-Conditioners and Heat Pumps
AHRI 340/360-2007	Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
AHRI 365-2009	Commercial and Industrial Unitary Air-Conditioning Condensing Units
AHRI 390-2003	Performance Rating of Single Packaged Vertical Air-Conditioners and Heat Pumps
AHRI 400-2001 with Addendum 2	Liquid-to-Liquid Heat Exchangers
AHRI 460-2005	Remote Mechanical Draft Air Cooled Refrigerant Condensers
AHRI 550/590-2003	Water-Chilling Packages Using the Vapor Compression Cycle
AHRI 560-2000	Absorption Water Chilling and Water Heating Packages
AHRI 1160-2008	Performance Rating of Heat Pump Pool Heaters
AHRI 1230-2010	Performance Rating of Variable Refrigerant Flow (VRF) Multi-split Air-Conditioning and Heat Pump Equipment
BTS 2000	Testing Standard Method to Determine Efficiency of Commercial Space Heating Boilers
Air Movement and Control Association International, 30 West University Drive, Arlington Heights, IL 60004-1806	
AMCA 500-D-07	Laboratory Methods of Testing Dampers for Rating
American Architectural Manufacturers Association, 1827 Walden Office Square, Suite 550, Schaumburg, IL 60173-4268	
AAMA/WDMA/CSA 101/I.S.2/A440-08	Standard/Specification for Windows, Doors, and Unit Skylights
American National Standards Institute, 11 West 42nd Street, New York, NY 10036	
ANSI Z21.10.3-2004	Gas Water Heater, Volume 3, Storage, with Input Ratings above 75,000 Btu/h, Circulating and Instantaneous Water Heaters
ANSI Z21.47-2006	Gas-Fired Central Furnaces (Except Direct Vent and Separated Combustion System Furnaces)
ANSI Z83.8-2009	Gas Unit Heaters and Duct Furnaces
Association of Home Appliance Manufacturers, 1111 19th Street NW, Suite 402, Washington, DC 20036	
ANSI/AHAM RAC-1-R2008	Room Air Conditioners
American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1791 Tullie Circle, NE, Atlanta, GA 30329	
ANSI/ASHRAE/IESNA Standard 90.1-2007	Energy Standard for Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE/ACCA Standard 183-2007	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings
ANSI/ASHRAE Standard 62.1-2007	Ventilation for Acceptable Indoor Air Quality

Reference	Title
ANSI/ASHRAE Standard 127-2007	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners
ANSI/ASHRAE Standard 140-2004	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
ANSI/ASHRAE 146-2006	Method of Testing for Rating Pool Heaters
ANSI/ASHRAE Standard 154-2003	Ventilation for Commercial Cooking Operations
Briggs, R.S., R.G. Lucas, and Z.T. Taylor. 2003. Climate classification for building energy codes and standards: Part 1—Development process. ASHRAE Transactions 109(1): 109–121.	
American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959	
ASTM C90-03	Standard Specification for Loadbearing Concrete Masonry Units
ASTM C177-97	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM C272-01	Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM C518-04	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus
ASTM C835-01	Standard Test Method for Total Hemispherical Emittance of Surfaces From 20°C to 1400°C
ASTM C1363-97	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM C1371-04	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers
ASTM C1549-04	Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer
ASTM D1003-00	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
ASTM E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
ASTM E408-71 (2002)	Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques
ASTM E903-96	Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
ASTM E972-96 (2002)	Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight
ASTM E1175-87 (2003)	Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere
ASTM E1677-2005	Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls
ASTM E1680-95 (2003)	Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems
ASTM E1918 (2006)	Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-Sloped Surfaces in the Field
ASTM E1980 (2001)	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low Sloped Opaque Surfaces

Reference	Title
ASTM E2178-03	Standard Test Method for Air Permeance of Building Materials
ASTM E2357-05	Standard Test Method for Determining Air Leakage of Air Barrier Assemblies
Canadian Standards Association, 5060 Spectrum Way, Mississauga, Ontario, Canada L4W 5N6	
AAMA/WDMA/CSA 101/I.S.2/A440-08	Standard/Specification for Windows, Doors, and Unit Skylights
Cooling Technology Institute, 2611 FM 1960 West, Suite A-101, Houston, TX 77068-3730; P.O. Box 73383, Houston, TX 77273-3383	
CTI ATC-105 (00)	Acceptance Test Code for Water Cooling Towers
CTI ATC-105S (96)	Acceptance Test Code for Closed-Circuit Cooling Towers
CTI STD-201 (09)	Standard for Thermal Performance Certification of Evaporative Heat Transfer Equipment
Door and Access Systems Manufacturers Association (DASMA), 1300 Sumner Avenue, Cleveland, OH 44115-2851	
ANSI/DASMA 105-92 (R 1998)	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors
International Organization for Standardization, 1, rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland	
ISO 13256-1 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps
ISO 13256-2 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance—Part 2: Water-to-Water and Brine-to-Water Heat Pumps
National Electrical Manufacturers Association, 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209	
ANSI/NEMA MG 1-2006	Motors and Generators
National Fire Protection Association, 1 Battery March Park, P.O. Box 9101, Quincy, MA 02269-9101	
NFPA 70 Article 708-2008	Critical Operations Power Systems (COPS)
NFPA 96-94	Ventilation Control and Fire Protection of Commercial Cooking Operations
National Fenestration Rating Council, 1300 Spring Street, Suite 500, Silver Springs, MD 20910	
NFRC 100-2004	Procedure for Determining Fenestration Product U-Factors
NFRC 200-2004	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence
NFRC 300-2004	Standard Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems
NFRC 400-2004	Procedure for Determining Fenestration Product Air Leakage
Telecommunications Industry Association, 2500 Wilson Boluevard, Arlington, VA 22201	
ANSI/TIA-942-2005	Telecommunication Infrastructure Standard for Data Centers

Reference	Title
Underwriters Laboratories, Inc., **333 Pfingsten Rd., Northbrook, IL 60062**	
UL 181A-2005	Closure Systems for Use with Rigid Air Ducts and Air Connectors
UL 181B-2006	Closure Systems for Use with Flexible Air Ducts and Air Connectors
UL 727-06	UL Standard for Safety—Oil Fired Central Furnaces
UL 731-06	UL Standard for Safety—Oil-Fired Unit Heaters
U.S. Department of Energy **1000 Independence Avenue, SW, Washington, DC 20585**	
10 CFR Part 430, App N	Uniform Test Method for Measuring the Energy Consumption of Furnaces
42 USC 6831, et seq., Public Law 102-486	Energy Policy Act of 1992
U.S. Security and Exchange Commission, **100 F Street, NE, Washington, DC 2-549**	
The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System	The Interagency Paper on Sound Practices to Strengthen the Resilience of the US Financial System, April 7, 2003
Window and Door Manufacturers Association, **2025 M Street, NW, Washington, DC 20036**	
AAMA/WDMA/CSA 101/I.S.2/A440-08	North American Fenestration Standard/Specification for Windows, Doors, and Skylights

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX A

RATED R-VALUE OF INSULATION AND ASSEMBLY U-FACTOR, C-FACTOR, AND F-FACTOR DETERMINATIONS

A1. GENERAL

A1.1 Pre-Calculated Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. The *U-factors*, *C-factors*, *F-factors*, and *heat capacities* for typical *construction* assemblies are included in Sections A2 through A8. These values shall be used for all calculations unless otherwise allowed by Section A1.2. Interpolation between values in a particular table in Normative Appendix A is allowed for *rated R-values of insulation*, including insulated sheathing. Extrapolation beyond values in a table in Normative Appendix A is not allowed.

A1.2 Applicant-Determined Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. If the *building official* determines that the proposed *construction* assembly is not adequately represented in Sections A2 through A8, the applicant shall determine appropriate values for the assembly using the assumptions in Section A9. An assembly is deemed to be adequately represented if:

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

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

A2. ROOFS

A2.1 General. The buffering effect of suspended ceilings or attic *spaces* shall not be included in *U-factor* calculations.

A2.2 Roofs with Insulation Entirely Above Deck

A2.2.1 General. For the purpose of Section A1.2, the base assembly is *continuous insulation* over a structural deck. The *U-factor* includes R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. Added insulation is continuous and uninterrupted by framing. The framing factor is zero.

A2.2.2 Rated R-Value of Insulation. For *roofs with insulation entirely above deck*, the *rated R-value of insulation* is for *continuous insulation.*

Exception: 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	U-1.282
R-1	U-0.562
R-2	U-0.360
R-3	U-0.265
R-4	U-0.209
R-5	U-0.173
R-6	U-0.147
R-7	U-0.129
R-8	U-0.114
R-9	U-0.102
R-10	U-0.093
R-11	U-0.085
R-12	U-0.078
R-13	U-0.073
R-14	U-0.068
R-15	U-0.063
R-16	U-0.060
R-17	U-0.056
R-18	U-0.053
R-19	U-0.051
R-20	U-0.048
R-21	U-0.046
R-22	U-0.044
R-23	U-0.042
R-24	U-0.040
R-25	U-0.039
R-26	U-0.037
R-27	U-0.036
R-28	U-0.035
R-29	U-0.034
R-30	U-0.032
R-35	U-0.028
R-40	U-0.025
R-45	U-0.022
R-50	U-0.020
R-55	U-0.018
R-60	U-0.016

A2.3 Metal Building Roofs

A2.3.1 General. For the purpose of Section A1.2, the base assembly is a *roof* with *thermal spacer blocks* where the insulation is draped over the steel structure (purlins), spaced nominally 5 ft on center and compressed when the metal *roof* panels are attached to the steel structure (purlins).

A2.3.2 Rated R-Value of Insulation

A2.3.2.1 The first *rated R-value of insulation* is for insulation draped over purlins and then compressed when the metal *roof* panels are attached, or for insulation hung between the purlins. A minimum R-3.5 thermal spacer block between the purlins and the metal *roof* panels is required when specified in Table A2.3.

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

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

A2.3.2.4 ***Liner System* (Ls).** A continuous vapor barrier liner is installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the liner between the purlins. For multilayer installations, the first *rated R-Value of insulation* is for unfaced insulation draped over purlins and then compressed when the metal *roof* panels are attached. A minimum R-3.5. thermal spacer block between the purlins and the metal *roof* panels is required when specified in Table A2.3.

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

A2.4 Attic Roofs with Wood Joists

A2.4.1 General. For the purpose of Section A1.2, the base *attic roof* assembly is a *roof* with nominal 4 in. deep wood as the lower chord of a *roof* truss or ceiling joist. The ceiling is attached directly to the lower chord of the truss and the attic *space* above is ventilated. Insulation is located directly on top of the ceiling, first filling the cavities between the wood and then later covering both the wood and cavity areas. No credit is given for roofing materials. The *single-rafter roof* is similar to the base *attic roof*, with the key difference being that there is a single, deep rafter to which both the *roof* and the ceiling are attached. The heat flow path through the rafter is calculated to be the same depth as the insulation. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing. The *U-factors* include R-0.46 for semi-exterior air film, R-0.56 for 0.625 in. gypsum board, and R-0.61 for interior air film heat flow up. *U-factors* are provided for the following configurations:

a. *Attic roof, standard framing:* insulation is tapered around the perimeter with a resultant decrease in *thermal resistance*. Weighting factors are 85% full-depth insulation, 5% half-depth insulation, and 10% joists.
b. *Attic roof, advanced framing:* full and even depth of insulation extending to the outside edge of exterior *walls*. Weighting factors are 90% full-depth insulation and 10% joists.
c. *Single-rafter roof:* an *attic roof* where the *roof* sheathing and ceiling are attached to the same rafter. Weighting factors are 90% full-depth insulation and 10% joists.

A2.4.2 Rated R-Value of Insulation

A2.4.2.1 For *attics and other roofs,* the *rated R-value of insulation* is for insulation installed both inside and outside the *roof* or entirely inside the *roof* cavity.

A2.4.2.2 Occasional interruption by framing members is allowed but requires that the framing members be covered with insulation when the depth of the insulation exceeds the depth of the framing cavity.

A2.4.2.3 Insulation in such *roofs* shall be permitted to be tapered at the eaves where the building structure does not allow full depth.

A2.4.2.4 For *single-rafter roofs*, the requirement is the lesser of the values for *attics and other roofs* and those listed in Table A2.4.2.

A2.4.3 U-factors for Attic Roofs with Wood Joists. *U-factors* for *attic roofs* with wood joists shall be taken from Table A2.4. It is not acceptable to use these *U-factors* if the framing is not wood. For *attic roofs* with *steel joists*, see Section A2.5.

A2.5 Attic Roofs with Steel Joists

A2.5.1 General. For the purpose of Section A1.2, the base assembly is a *roof* supported by *steel joists* with insulation between the joists. The assembly represents a *roof* in many ways similar to a *roof with insulation entirely above deck* and a *metal building roof.* It is distinguished from the *metal building roof* category in that there is no metal exposed to the exterior. It is distinguished from the *roof with insulation entirely above deck* in that the insulation is located below the deck and is interrupted by metal trusses that provide thermal bypasses to the insulation. The *U-factors* include R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. The performance of the insulation/framing layer is calculated using the values in Table A9.2A.

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

A3. ABOVE-GRADE WALLS

A3.1 Mass Wall

A3.1.1 General. For the purpose of Section A1.2, the base assembly is a masonry or concrete *wall. Continuous insulation* is installed on the interior or exterior or within the masonry units, or it is installed on the interior or exterior of

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-5.6	R-11.2	R-16.8	R-22.4	R-28.0	R-33.6
Standing Seam Roofs with Thermal Spacer Blocks									
Single Layer	None	0	**U-1.280**	0.157	0.083	0.057	0.043	0.035	0.029
	R-6	6	**U-0.167**	0.086	0.058	0.044	0.035	0.029	0.025
	R-10	10	**U-0.097**	0.063	0.046	0.037	0.031	0.026	0.023
	R-11	11	**U-0.092**	0.061	0.045	0.036	0.030	0.026	0.022
	R-13	13	**U-0.083**	0.057	0.043	0.035	0.029	0.025	0.022
	R-16	16	**U-0.072**	0.051	0.040	0.033	0.028	0.024	0.021
	R-19	19	**U-0.065**	0.048	0.038	0.031	0.026	0.023	0.020
Double Layer	R-10 + R-10	20	**U-0.063**	0.047	0.037	0.031	0.026	0.023	0.020
	R-10 + R-11	21	**U-0.061**	0.045	0.036	0.030	0.026	0.023	0.020
	R-11 + R-11	22	**U-0.060**	0.045	0.036	0.030	0.026	0.022	0.020
	R-10 + R-13	23	**U-0.058**	0.044	0.035	0.029	0.025	0.022	0.020
	R-11 + R-13	24	**U-0.057**	0.043	0.035	0.029	0.025	0.022	0.020
	R-13 + R-13	26	**U-0.055**	0.042	0.034	0.029	0.025	0.022	0.019
	R-10 + R-19	29	**U-0.052**	0.040	0.033	0.028	0.024	0.021	0.019
	R-11 + R-19	30	**U-0.051**	0.040	0.032	0.027	0.024	0.021	0.019
	R-13 + R-19	32	**U-0.049**	0.038	0.032	0.027	0.023	0.021	0.019
	R-16 + R-19	35	**U-0.047**	0.037	0.031	0.026	0.023	0.020	0.018
	R-19 + R-19	38	**U-0.046**	0.037	0.030	0.026	0.023	0.020	0.018
Liner System	R-11+R-19	30	**U-0.035**						
	R-11+R-25	36	**U-0.031**						
	R-11+R-30	41	**U-0.029**						
	R-11+R-11+R-25	47	**U-0.026**						
Standing Seam Roofs without Thermal Spacer Blocks									
Liner System	R-11+R-19	30	**U-0.040**		0.028	0.024	0.021	0.020	0.017
Filled Cavity with Thermal Spacer Blocks									
	R-19+R-10	29	**U-0.041**	0.033	0.028	0.024	0.021	0.019	0.017
Thru-Fastened without Thermal Spacer Blocks									
	R-10	10	**U-0.153**						
	R-11	11	**U-0.139**						
	R-13	13	**U-0.130**						
	R-16	16	**U-0.106**						
	R-19	19	**U-0.098**						
Liner System	R-11+R-19	30	**U-0.044**						

(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	U-0.613
R-11	U-0.091
R-13	U-0.081
R-19	U-0.053
R-30	U-0.034
R-38	U-0.027
R-49	U-0.021
R-60	U-0.017
R-71	U-0.015
R-82	U-0.013
R-93	U-0.011
R-104	U-0.010
R-115	U-0.009
R-126	U-0.008
Wood-Framed Attic, Advanced Framing	
None	U-0.613
R-11	U-0.088
R-13	U-0.078
R-19	U-0.051
R-30	U-0.032
R-38	U-0.026
R-49	U-0.020
R-60	U-0.016
R-71	U-0.014
R-82	U-0.012
R-93	U-0.011
R-104	U-0.010
R-115	U-0.009
R-126	U-0.008

Wood Joists, Single-rafter Roof

Cavity Insulation R-Value	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing) — Rated R-Value of Continuous Insulation: None	R-5	R-10	R-15
None	U-0.417	U-0.135	U-0.081	U-0.057
R-11	U-0.088	U-0.061	U-0.047	U-0.038
R-13	U-0.078	U-0.056	U-0.044	U-0.036
R-15	U-0.071	U-0.052	U-0.041	U-0.034
R-19	U-0.055	U-0.043	U-0.035	U-0.030
R-21	U-0.052	U-0.041	U-0.034	U-0.029
R-25	U-0.042	U-0.035	U-0.030	U-0.026
R-30	U-0.036	U-0.030	U-0.026	U-0.023
R-38	U-0.029	U-0.025	U-0.022	U-0.020

TABLE A2.4.2 Single-Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d* (Actual)		
	$d \le 8$ in.	$8 < d \le 10$ in.	$10 < d \le 12$ in.
1–7	R-19 U-0.055	R-30 U-0.036	R-38 U-0.028
8	R-21 U-0.052	R-30 U-0.036	R-38 U-0.028

the concrete. The *U-factors* include R-0.17 for exterior air film and R-0.68 for interior air film, vertical surfaces. For insulated *walls*, the *U-factor* also includes R-0.45 for 0.5 in. gypsum board. *U-factors* are provided for the following configurations:

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

A3.1.2 Mass Wall Rated R-Value of Insulation

A3.1.2.1 *Mass wall HC* shall be determined from Table A3.1B or A3.1C.

A3.1.2.2 The *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing other than 20 gauge 1 in. metal clips spaced no closer than 24 in. on center horizontally and 16 in. on center vertically.

A3.1.2.3 Where other framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly *U-factor*.

A3.1.2.4 Where *rated R-value of insulation* is used for concrete sandwich panels, the insulation shall be continuous throughout the entire panel.

A3.1.3 Mass Wall U-Factor

A3.1.3.1 *U-factors* for *mass walls* shall be taken from Table A3.1A or determined by the procedure in this subsection. It is acceptable to use the *U-factors* in Table A3.1A for all *mass walls*, provided that the grouting is equal to or less than that specified. *HC* for *mass walls* shall be taken from Table A3.1B or A3.1C.

Exception: For *mass walls*, where the requirement in Tables 5.5-1 through 5.5-8 is for a maximum assembly U-0.151 followed by footnote "b," ASTM C90 concrete block *walls*, ungrouted or partially grouted at 32 in. or less on center vertically and 48 in. or less on center horizontally, shall have ungrouted cores filled with material having a maximum thermal conductivity of 0.44 Btu·in./h·ft^2·°F. Other *mass walls* with integral insulation shall meet the criteria when their *U-factors* are equal to or less than those for the appropriate thickness and density in the "Partly Grouted Cells Insulated" column of Table A3.1C

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

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

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

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

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

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

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

a. For concrete *walls*, determine the R_u from Table A3.1B based on the concrete density and *wall* thickness. Next, determine the effective R-value for the insulation/framing layer from Table A3.1D based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the *U-factor* by adding the R_u and the effective R-value together and taking the inverse of the total.

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

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 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Partially Grouted (Cores Uninsulated Except Where Specified)
No Framing	**R-0**	**U-0.740**	**U-0.580**	**U-0.480**
	Ungrouted Cores Filled with Loose-Fill Insulation	**N/A**	**N/A**	**U-0.350**
Continuous Metal Framing at 24 in. on Center Horizontally				
3.5 in.	R-11.0	U-0.168	U-0.158	U-0.149
3.5 in.	R-13.0	U-0.161	U-0.152	U-0.144
3.5 in.	R-15.0	U-0.155	U-0.147	U-0.140
4.5 in.	R-17.1	U-0.133	U-0.126	U-0.121
4.5 in.	R-22.5	U-0.124	U-0.119	U-0.114
4.5 in.	R-25.2	U-0.122	U-0.116	U-0.112
5.0 in.	R-19.0	U-0.122	U-0.117	U-0.112
5.0 in.	R-25.0	U-0.115	U-0.110	U-0.106
5.0 in.	R-28.0	U-0.112	U-0.107	U-0.103
5.5 in.	R-19.0	U-0.118	U-0.113	U-0.109
5.5 in.	R-20.9	U-0.114	U-0.109	U-0.105
5.5 in.	R-21.0	U-0.113	U-0.109	U-0.105
5.5 in.	R-27.5	U-0.106	U-0.102	U-0.099
5.5 in.	R-30.8	U-0.104	U-0.100	U-0.096
6.0 in.	R-22.8	U-0.106	U-0.102	U-0.098
6.0 in.	R-30.0	U-0.099	U-0.095	U-0.092
6.0 in.	R-33.6	U-0.096	U-0.093	U-0.090
6.5 in.	R-24.7	U-0.099	U-0.096	U-0.092
7.0 in.	R-26.6	U-0.093	U-0.090	U-0.087
7.5 in.	R-28.5	U-0.088	U-0.085	U-0.083
8.0 in.	R-30.4	U-0.083	U-0.081	U-0.079
1 in. Metal Clips at 24 in. on Center Horizontally and 16 in. Vertically				
1.0 in.	R-3.8	U-0.210	U-0.195	U-0.182
1.0 in.	R-5.0	U-0.184	U-0.172	U-0.162
1.0 in.	R-5.6	U-0.174	U-0.163	U-0.154
1.5 in.	R-5.7	U-0.160	U-0.151	U-0.143

TABLE A3.1A Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls *(continued)*

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Partially Grouted (Cores Uninsulated Except Where Specified)
No Framing	R-0	U-0.740	U-0.580	U-0.480
	Ungrouted Cores Filled with Loose-Fill Insulation	N/A	N/A	U-0.350
1.5 in.	R-7.5	U-0.138	U-0.131	U-0.125
1.5 in.	R-8.4	U-0.129	U-0.123	U-0.118
2.0 in.	R-7.6	U-0.129	U-0.123	U-0.118
2.0 in.	R-10.0	U-0.110	U-0.106	U-0.102
2.0 in.	R-11.2	U-0.103	U-0.099	U-0.096
2.5 in.	R-9.5	U-0.109	U-0.104	U-0.101
2.5 in.	R-12.5	U-0.092	U-0.089	U-0.086
2.5 in.	R-14.0	U-0.086	U-0.083	U-0.080
3.0 in.	R-11.4	U-0.094	U-0.090	U-0.088
3.0 in.	R-15.0	U-0.078	U-0.076	U-0.074
3.0 in.	R-16.8	U-0.073	U-0.071	U-0.069
3.5 in.	R-13.3	U-0.082	U-0.080	U-0.077
3.5 in.	R-17.5	U-0.069	U-0.067	U-0.065
3.5 in.	R-19.6	U-0.064	U-0.062	U-0.061
4.0 in.	R-15.2	U-0.073	U-0.071	U-0.070
4.0 in.	R-20.0	U-0.061	U-0.060	U-0.058
4.0 in.	R-22.4	U-0.057	U-0.056	U-0.054
1 in. Metal Clips at 24 in. on Center Horizontally and 16 in. Vertically *(continued)*				
5.0 in.	R-28.0	U-0.046	U-0.046	U-0.045
6.0 in.	R-33.6	U-0.039	U-0.039	U-0.038
7.0 in.	R-39.2	U-0.034	U-0.034	U-0.033
8.0 in.	R-44.8	U-0.030	U-0.030	U-0.029
9.0 in.	R-50.4	U-0.027	U-0.027	U-0.026
10.0 in.	R-56.0	U-0.024	U-0.024	U-0.024
11.0 in.	R-61.6	U-0.022	U-0.022	U-0.022
Continuous Insulation Uninterrupted by Framing				
No framing	R-1.0	U-0.425	U-0.367	U-0.324
No framing	R-2.0	U-0.298	U-0.269	U-0.245
No framing	R-3.0	U-0.230	U-0.212	U-0.197
No framing	R-4.0	U-0.187	U-0.175	U-0.164
No framing	R-5.0	U-0.157	U-0.149	U-0.141
No framing	R-6.0	U-0.136	U-0.129	U-0.124
No framing	R-7.0	U-0.120	U-0.115	U-0.110
No framing	R-8.0	U-0.107	U-0.103	U-0.099
No framing	R-9.0	U-0.097	U-0.093	U-0.090
No framing	R-10.0	U-0.088	U-0.085	U-0.083
No framing	R-11.0	U-0.081	U-0.079	U-0.076
No framing	R-12.0	U-0.075	U-0.073	U-0.071
No framing	R-13.0	U-0.070	U-0.068	U-0.066
No framing	R-14.0	U-0.065	U-0.064	U-0.062
No framing	R-15.0	U-0.061	U-0.060	U-0.059
No framing	R-16.0	U-0.058	U-0.056	U-0.055
No framing	R-17.0	U-0.054	U-0.053	U-0.052

TABLE A3.1A Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls *(continued)*

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft³ Solid Concrete Walls	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft³ Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft³ Concrete Block Walls: Partially Grouted (Cores Uninsulated Except Where Specified)
No Framing	**R-0**	**U-0.740**	**U-0.580**	**U-0.480**
	Ungrouted Cores Filled with Loose-Fill Insulation	**N/A**	**N/A**	**U-0.350**
No framing	R-18.0	U-0.052	U-0.051	U-0.050
No framing	R-19.0	U-0.049	U-0.048	U-0.047
No framing	R-20.0	U-0.047	U-0.046	U-0.045
No framing	R-21.0	U-0.045	U-0.044	U-0.043
No framing	R-22.0	U-0.043	U-0.042	U-0.042
No framing	R-23.0	U-0.041	U-0.040	U-0.040
No framing	R-24.0	U-0.039	U-0.039	U-0.038
No framing	R-25.0	U-0.038	U-0.037	U-0.037
No framing	R-30.0	U-0.032	U-0.032	U-0.031
No framing	R-35.0	U-0.028	U-0.027	U-0.027
No framing	R-40.0	U-0.024	U-0.024	U-0.024
No framing	R-45.0	U-0.022	U-0.021	U-0.021
No framing	R-50.0	U-0.019	U-0.019	U-0.019
No framing	R-55.0	U-0.018	U-0.018	U-0.018
No framing	R-60.0	U-0.016	U-0.016	U-0.016

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

Density, lb/ft³	Properties	Thickness, in. 3	4	5	6	7	8	9	10	11	12
20	U-factor	0.22	0.17	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06
	C-factor	0.27	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07
	R_u	4.60	5.85	7.10	8.35	9.60	10.85	12.10	13.35	14.60	15.85
	R_c	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	15.00
	HC	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0
30	U-factor	0.28	0.22	0.19	0.16	0.14	0.12	0.11	0.10	0.09	0.09
	C-factor	0.37	0.28	0.22	0.18	0.16	0.14	0.12	0.11	0.10	0.09
	R_u	3.58	4.49	5.40	6.30	7.21	8.12	9.03	9.94	10.85	11.76
	R_c	2.73	3.64	4.55	5.45	6.36	7.27	8.18	9.09	10.00	10.91
	HC	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
40	U-factor	0.33	0.27	0.23	0.19	0.17	0.15	0.14	0.13	0.11	0.11
	C-factor	0.47	0.35	0.28	0.23	0.20	0.18	0.16	0.14	0.13	0.12
	R_u	2.99	3.71	4.42	5.14	5.85	6.56	7.28	7.99	8.71	9.42
	R_c	2.14	2.86	3.57	4.29	5.00	5.71	6.43	7.14	7.86	8.57
	HC	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0
50	U-factor	0.38	0.31	0.26	0.23	0.20	0.18	0.16	0.15	0.14	0.13
	C-factor	0.57	0.43	0.34	0.28	0.24	0.21	0.19	0.17	0.15	0.14
	R_u	2.61	3.20	3.79	4.38	4.97	5.56	6.14	6.73	7.32	7.91
	R_c	1.76	2.35	2.94	3.53	4.12	4.71	5.29	5.88	6.47	7.06
	HC	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0
85	U-factor	0.65	0.56	0.50	0.44	0.40	0.37	0.34	0.31	0.29	0.27
	C-factor	1.43	1.08	0.86	0.71	0.61	0.54	0.48	0.43	0.39	0.36
	R_u	1.55	1.78	2.01	2.25	2.48	2.71	2.94	3.18	3.41	3.64
	R_c	0.70	0.93	1.16	1.40	1.63	1.86	2.09	2.33	2.56	2.79
	HC	4.3	5.7	7.1	8.5	9.9	11.3	12.8	14.2	15.6	17.0

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

Density, lb/ft³	Properties	Thickness, in. 3	4	5	6	7	8	9	10	11	12
95	U-factor	0.72	0.64	0.57	0.52	0.48	0.44	0.41	0.38	0.36	0.33
	C-factor	1.85	1.41	1.12	0.93	0.80	0.70	0.62	0.56	0.51	0.47
	R_u	1.39	1.56	1.74	1.92	2.10	2.28	2.46	2.64	2.81	2.99
	R_c	0.54	0.71	0.89	1.07	1.25	1.43	1.61	1.79	1.96	2.14
	HC	4.8	6.3	7.9	9.5	11.1	12.7	14.3	15.8	17.4	19.0
105	U-factor	0.79	0.71	0.65	0.59	0.54	0.51	0.47	0.44	0.42	0.39
	C-factor	2.38	1.79	1.43	1.18	1.01	0.88	0.79	0.71	0.65	0.59
	R_u	1.27	1.41	1.56	1.70	1.84	1.98	2.12	2.26	2.40	2.54
	R_c	0.42	0.56	0.70	0.85	0.99	1.13	1.27	1.41	1.55	1.69
	HC	5.3	7.0	8.8	10.5	12.3	14.0	15.8	17.5	19.3	21.0
115	U-factor	0.84	0.77	0.70	0.65	0.61	0.57	0.53	0.50	0.48	0.45
	C-factor	2.94	2.22	1.75	1.47	1.25	1.10	0.98	0.88	0.80	0.74
	R_u	1.19	1.30	1.42	1.53	1.65	1.76	1.87	1.99	2.10	2.21
	R_c	0.34	0.45	0.57	0.68	0.80	0.91	1.02	1.14	1.25	1.36
	HC	5.8	7.7	9.6	11.5	13.4	15.3	17.3	19.2	21.1	23.0
125	U-factor	0.88	0.82	0.76	0.71	0.67	0.63	0.60	0.56	0.53	0.51
	C-factor	3.57	2.70	2.17	1.79	1.54	1.35	1.20	1.03	0.98	0.90
	R_u	1.13	1.22	1.31	1.41	1.50	1.59	1.68	1.78	1.87	1.96
	R_c	0.28	0.37	0.46	0.56	0.65	0.74	0.83	0.93	1.02	1.11
	HC	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0
135	U-factor	0.93	0.87	0.82	0.77	0.73	0.69	0.66	0.63	0.60	0.57
	C-factor	4.55	3.33	2.70	2.22	1.92	1.67	1.49	1.33	1.22	1.11
	R_u	1.07	1.15	1.22	1.30	1.37	1.45	1.52	1.60	1.67	1.75
	R_c	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.75	0.82	0.90
	HC	6.8	9.0	11.3	13.5	15.8	18.0	20.3	22.5	24.8	27.0
144	U-factor	0.96	0.91	0.86	0.81	0.78	0.74	0.71	0.68	0.65	0.63
	C-factor	5.26	4.00	3.23	2.63	2.27	2.00	1.79	1.59	1.45	1.33
	R_u	1.04	1.10	1.16	1.23	1.29	1.35	1.41	1.48	1.54	1.60
	R_c	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75
	HC	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0	26.4	28.8

The *U-factors* and R_u include standard air film resistances.
The *C-factors* and R_c are for the same assembly without air film resistances.
Note that the following assemblies do not qualify as a *mass wall* or *mass floor*:
3 in. thick concrete with densities of 85, 95, 125, and 135 lb/ft³.

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

Product Size, in.	Density, lb/ft³	Properties	Concrete Block Grouting and Cell Treatment: Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
6 in. block	85	U-factor	0.57	0.46	0.34	0.40	0.20
		C-factor	1.11	0.75	0.47	0.60	0.23
		R_u	1.75	2.18	2.97	2.52	5.13
		R_c	0.90	1.33	2.12	1.67	4.28
		HC	10.9	6.7	7.0	4.2	4.6
	95	U-factor	0.61	0.49	0.36	0.42	0.22
		C-factor	1.25	0.83	0.53	0.65	0.27
		R_u	1.65	2.06	2.75	2.38	4.61
		R_c	0.80	1.21	1.90	1.53	3.76
		HC	11.4	7.2	7.5	4.7	5.1
	105	U-factor	0.64	0.51	0.39	0.44	0.24
		C-factor	1.38	0.91	0.58	0.71	0.30
		R_u	1.57	1.95	2.56	2.26	4.17
		R_c	0.72	1.10	1.71	1.41	3.32
		HC	11.9	7.7	7.9	5.1	5.6

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

Product Size, in.	Density, lb/ft^3	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
6 in. block	115	U-factor	0.66	0.54	0.41	0.46	0.26
		C-factor	1.52	0.98	0.64	0.76	0.34
		R_u	1.51	1.87	2.41	2.16	3.79
		R_c	0.66	1.02	1.56	1.31	2.94
		HC	12.3	8.1	8.4	5.6	6.0
	125	U-factor	0.70	0.56	0.45	0.49	0.30
		C-factor	1.70	1.08	0.73	0.84	0.40
		R_u	1.44	1.78	2.23	2.04	3.38
		R_c	0.59	0.93	1.38	1.19	2.53
		HC	12.8	8.6	8.8	6.0	6.5
	135	U-factor	0.73	0.60	0.49	0.53	0.35
		C-factor	1.94	1.23	0.85	0.95	0.49
		R_u	1.36	1.67	2.02	1.90	2.89
		R_c	0.51	0.82	1.17	1.05	2.04
		HC	13.2	9.0	9.3	6.5	6.9
8 in. block	85	U-factor	0.49	0.41	0.28	0.37	0.15
		C-factor	0.85	0.63	0.37	0.53	0.17
		R_u	2.03	2.43	3.55	2.72	6.62
		R_c	1.18	1.58	2.70	1.87	5.77
		HC	15.0	9.0	9.4	5.4	6.0
	95	U-factor	0.53	0.44	0.31	0.39	0.17
		C-factor	0.95	0.70	0.41	0.58	0.20
		R_u	1.90	2.29	3.27	2.57	5.92
		R_c	1.05	1.44	2.42	1.72	5.07
		HC	15.5	9.6	10.0	6.0	6.6
	105	U-factor	0.55	0.46	0.33	0.41	0.19
		C-factor	1.05	0.76	0.46	0.63	0.22
		R_u	1.81	2.17	3.04	2.44	5.32
		R_c	0.96	1.32	2.19	1.59	4.47
		HC	16.1	10.2	10.6	6.6	7.2
	115	U-factor	0.58	0.48	0.35	0.43	0.21
		C-factor	1.14	0.82	0.50	0.68	0.25
		R_u	1.72	2.07	2.84	2.33	4.78
		R_c	0.87	1.22	1.99	1.48	3.93
		HC	16.7	10.8	11.2	7.2	7.8
	125	U-factor	0.61	0.51	0.38	0.45	0.24
		C-factor	1.27	0.90	0.57	0.74	0.30
		R_u	1.64	1.96	2.62	2.20	4.20
		R_c	0.79	1.11	1.77	1.35	3.35
		HC	17.3	11.4	11.8	7.8	8.4
	135	U-factor	0.65	0.55	0.42	0.49	0.28
		C-factor	1.44	1.02	0.67	0.83	0.37
		R_u	1.54	1.83	2.35	2.05	3.55
		R_c	0.69	0.98	1.50	1.20	2.70
		HC	17.9	12.0	12.4	8.4	9.0
10 in. block	85	U-factor	0.44	0.38	0.25	0.35	0.13
		C-factor	0.70	0.57	0.31	0.50	0.14
		R_u	2.29	2.61	4.05	2.84	7.87
		R_c	1.44	1.76	3.20	1.99	7.02
		HC	19.0	11.2	11.7	6.5	7.3
	95	U-factor	0.47	0.41	0.27	0.37	0.14
		C-factor	0.77	0.62	0.35	0.55	0.16
		R_u	2.15	2.46	3.73	2.67	6.94
		R_c	1.30	1.61	2.88	1.82	6.09
		HC	19.7	11.9	12.4	7.3	8.1
	105	U-factor	0.49	0.43	0.29	0.39	0.16
		C-factor	0.85	0.68	0.39	0.59	0.19
		R_u	2.03	2.33	3.45	2.54	6.17
		R_c	1.18	1.48	2.60	1.69	5.32
		HC	20.4	12.6	13.1	8.0	8.8

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

Product Size, in.	Density, lb/ft³	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
10 in. block	115	U-factor	0.52	0.45	0.31	0.41	0.18
		C-factor	0.92	0.73	0.42	0.64	0.21
		R_u	1.94	2.22	3.21	2.42	5.52
		R_c	1.09	1.37	2.36	1.57	4.67
		HC	21.1	13.4	13.9	8.7	9.5
	125	U-factor	0.54	0.48	0.34	0.44	0.21
		C-factor	1.01	0.80	0.48	0.70	0.25
		R_u	1.84	2.10	2.95	2.28	4.81
		R_c	0.99	1.25	2.10	1.43	3.96
		HC	21.8	14.1	14.6	9.4	10.2
	135	U-factor	0.58	0.51	0.38	0.47	0.25
		C-factor	1.14	0.90	0.56	0.79	0.32
		R_u	1.72	1.96	2.64	2.12	4.00
		R_c	0.87	1.11	1.79	1.27	3.15
		HC	22.6	14.8	15.3	10.2	11.0
12 in. block	85	U-factor	0.40	0.36	0.22	0.34	0.11
		C-factor	0.59	0.52	0.27	0.48	0.12
		R_u	2.53	2.77	4.59	2.93	9.43
		R_c	1.68	1.92	3.74	2.08	8.58
		HC	23.1	13.3	14.0	7.5	8.5
	95	U-factor	0.42	0.38	0.24	0.36	0.12
		C-factor	0.66	0.57	0.30	0.52	0.13
		R_u	2.30	2.60	4.22	2.76	8.33
		R_c	1.53	1.75	3.37	1.91	7.48
		HC	23.9	14.2	14.8	8.3	9.3
	105	U-factor	0.44	0.41	0.26	0.38	0.14
		C-factor	0.71	0.62	0.33	0.57	0.15
		R_u	2.25	2.47	3.90	2.62	7.35
		R_c	1.40	1.62	3.05	1.77	6.50
		HC	24.7	15.0	15.6	9.1	10.2
	115	U-factor	0.47	0.42	0.28	0.40	0.15
		C-factor	0.77	0.66	0.36	0.61	0.18
		R_u	2.15	2.36	3.63	2.49	6.54
		R_c	1.30	1.51	2.78	1.64	5.69
		HC	25.6	15.8	16.4	10.0	11.0
	125	U-factor	0.49	0.45	0.30	0.42	0.18
		C-factor	0.84	0.72	0.40	0.66	0.21
		R_u	2.04	2.23	3.34	2.36	5.68
		R_c	1.19	1.38	2.49	1.51	4.83
		HC	26.4	16.6	17.3	10.8	11.8
	135	U-factor	0.52	0.48	0.34	0.46	0.21
		C-factor	0.94	0.81	0.47	0.74	0.26
		R_u	1.91	2.08	2.98	2.19	4.67
		R_c	1.06	1.23	2.13	1.34	3.82
		HC	27.2	17.5	18.1	11.6	12.6

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

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

TABLE A3.2 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-5.6	R-11.2	R-16.8	R-22.4	R-28.0	R-33.6
Single Layer of Mineral Fiber									
	None	0	**1.180**	0.161	0.086	0.059	0.045	0.036	0.030
	R-6	6	**0.184**	0.091	0.060	0.045	0.036	0.030	0.026
	R-10	10	**0.134**	0.077	0.054	0.051	0.033	0.028	0.024
	R-11	11	**0.123**	0.073	0.052	0.040	0.033	0.028	0.024
	R-13	13	**0.113**	0.069	0.050	0.039	0.032	0.027	0.024
	R-16	16	**0.093**	0.061	0.046	0.036	0.030	0.026	0.023
	R-19	19	**0.084**	0.057	0.043	0.035	0.029	0.025	0.022
Double Layer of Mineral Fiber									
(Second layer inside of girts)									
(Multiple layers are listed in order from inside to outside)									
	R-6 + R-13	19	**0.070**	N/A	N/A	N/A	N/A	N/A	N/A
	R-10 + R-13	23	**0.061**	N/A	N/A	N/A	N/A	N/A	N/A
	R-13 + R-13	26	**0.057**	N/A	N/A	N/A	N/A	N/A	N/A
	R-19 + R-13	32	**0.048**	N/A	N/A	N/A	N/A	N/A	N/A

A3.2 Metal Building Walls

A3.2.1 General. For the purpose of Section A1.2, the base assembly is a *wall* where the insulation is compressed between metal *wall* panels and the metal structure. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing.

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

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

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

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

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

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

A3.3 Steel-Framed Walls

A3.3.1 General. For the purpose of Section A1.2, the base assembly is a *wall* where the insulation is installed within the cavity of the steel stud framing but where there is not a metal exterior surface spanning member. The steel stud framing is a minimum uncoated thickness of 0.043 in. for 18 gauge or 0.054 in. for 16 gauge. The *U-factors* include R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625 in. gypsum board on the exterior, R-0.56 for 0.625 in. gypsum board on the interior, and R-0.68 for interior vertical surfaces air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2B. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing. *U-factors* are provided for the following configurations:

a. *Standard framing*: steel stud framing at 16 in. on center with cavities filled with 16 in. wide insulation for both 3.5 in. deep and 6.0 in. deep *wall* cavities.
b. *Advanced framing*: steel stud framing at 24 in. on center with cavities filled with 24 in. wide insulation for both 3.5 in. deep and 6.0 in. deep *wall* cavities.

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

A3.3.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between steel studs. It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing.

A3.3.2.2 If there are two values, the second *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.3.2.3 *Opaque* mullions in spandrel glass shall be covered with insulation complying with the *steel-framed wall* requirements.

A3.3.3 U-Factors for Steel-Framed Walls

A3.3.3.1 *U-factors* for *steel-framed walls* shall be taken from Table A3.3.

A3.3.3.2 For *steel-framed walls* with framing at less than 24 in. on center, use the standard framing values as described in Section A3.3.1(a).

A3.3.3.3 For *steel-framed walls* with framing from 24 to 32 in. on center, use the advanced framing values as described in Section A3.3.1(b).

A3.3.3.4 For *steel-framed walls* with framing greater than 32 in. on center, use the *metal building wall* values in Table A3.2.

A3.4 Wood-Framed Walls

A3.4.1 General. For the purpose of Section A1.2, the base assembly is a *wall* where the insulation is installed between 2 in. nominal wood framing. Cavity insulation is full depth, but values are taken from Table A9.4C for R-19 insulation, which is compressed when installed in a 5.5 in. cavity. Headers are double 2 in. nominal wood framing. The *U-factors* include R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625 in. gypsum board on the exterior, R-0.56 for 0.625 in. gypsum board on the interior, and R-0.68 for interior air film, vertical surfaces. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing. *U-factors* are provided for the following configurations:

a. *Standard framing:* wood framing at 16 in. on center with cavities filled with 14.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep *wall* cavities. Double headers leave no cavity. Weighting factors are 75% insulated cavity, 21% studs, plates, and sills, and 4% headers.
b. *Advanced framing:* wood framing at 24 in. on center with cavities filled with 22.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep *wall* cavities. Double headers leave uninsulated cavities. Weighting factors are 78% insulated cavity, 18% studs, plates, and sills, and 4% headers.
c. *Advanced framing with insulated headers:* wood framing at 24 in. on center with cavities filled with 22.5 in. wide insulation for both 3.5 in. deep and 5.5 in. deep *wall* cavities. Double header cavities are insulated. Weighting factors are 78% insulated cavity, 18% studs, plates, and sills, and 4% headers.

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

A3.4.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between wood studs. It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing.

A3.4.2.2 If there are two values, the second *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.4.3 U-Factors for Wood-Framed Walls

A3.4.3.1 *U-factors* for *wood-framed walls* shall be taken from Table A3.4.

A3.4.3.2 For *wood-framed walls* with framing at less than 24 in. on center, use the standard framing values as described in Section A3.4.1(a).

A3.4.3.3 For *wood-framed walls* with framing from 24 to 32 in. on center, use the advanced framing values as described in Section A3.4.1(b) if the headers are uninsulated or the advanced framing with insulated header values as described in Section A3.4.1(c) if the headers are insulated.

A3.4.3.4 For *wood-framed walls* with framing greater than 32 in. on center, *U-factors* shall be determined in accordance with Section A9.

TABLE A3.3 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-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Steel Framing at 16 in. on center																						
	None (0.0)	**0.352**	0.260	0.207	0.171	0.146	0.128	0.113	0.102	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
3.5 in. depth	R-11 (5.5)	**0.132**	0.117	0.105	0.095	0.087	0.080	0.074	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.036	0.031	0.027	0.024	0.021
	R-13 (6.0)	**0.124**	0.111	0.100	0.091	0.083	0.077	0.071	0.066	0.062	0.059	0.055	0.052	0.050	0.048	0.045	0.043	0.036	0.030	0.026	0.023	0.021
	R-15 (6.4)	**0.118**	0.106	0.096	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.035	0.030	0.026	0.023	0.021
6.0 in. depth	R-19 (7.1)	**0.109**	0.099	0.090	0.082	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.034	0.029	0.026	0.023	0.020
	R-21 (7.4)	**0.106**	0.096	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.022	0.020
Steel Framing at 24 in. on center																						
	None (0.0)	**0.338**	0.253	0.202	0.168	0.144	0.126	0.112	0.100	0.091	0.084	0.077	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
3.5 in. depth	R-11 (6.6)	**0.116**	0.104	0.094	0.086	0.079	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.035	0.030	0.026	0.023	0.021
	R-13 (7.2)	**0.108**	0.098	0.089	0.082	0.075	0.070	0.066	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.023	0.020
	R-15 (7.8)	**0.102**	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.034	0.029	0.025	0.022	0.020
6.0 in. depth	R-19 (8.6)	**0.094**	0.086	0.079	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.033	0.028	0.025	0.022	0.020
	R-21 (9.0)	**0.090**	0.083	0.077	0.071	0.066	0.062	0.059	0.055	0.052	0.050	0.048	0.045	0.043	0.042	0.040	0.038	0.032	0.028	0.024	0.022	0.020

TABLE A3.4 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-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
Wood Studs at 16 in. on center																						
3.5 in depth	None (0.0)	**0.292**	0.223	0.181	0.152	0.132	0.116	0.104	0.094	0.086	0.079	0.073	0.068	0.064	0.060	0.056	0.053	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	**0.096**	0.087	0.079	0.073	0.068	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.032	0.028	0.024	0.022	0.020
	R-13 (13.0)	**0.089**	0.080	0.074	0.068	0.063	0.059	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.031	0.027	0.024	0.021	0.019
	R-15 (15.0)	**0.083**	0.075	0.069	0.064	0.060	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.020	0.019
5.5 in. depth	R-19 (18.0)	**0.067**	0.062	0.058	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.027	0.024	0.021	0.019	0.018
	R-21 (21.0)	**0.063**	0.058	0.054	0.051	0.048	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.032	0.031	0.030	0.026	0.023	0.021	0.019	0.017
+ R-10 headers	R-19 (18.0)	**0.063**	0.059	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.031	0.027	0.024	0.021	0.019	0.017
	R-21 (21.0)	**0.059**	0.055	0.051	0.049	0.046	0.044	0.042	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.026	0.023	0.020	0.018	0.017
Wood Studs at 24 in. on center																						
3.5 in. depth	None (0.0)	**0.298**	0.227	0.183	0.154	0.133	0.117	0.105	0.095	0.086	0.079	0.074	0.068	0.064	0.060	0.057	0.054	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	**0.094**	0.085	0.078	0.072	0.067	0.062	0.059	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.032	0.027	0.024	0.022	0.019
	R-13 (13.0)	**0.086**	0.078	0.072	0.067	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.031	0.026	0.023	0.021	0.019
	R-15 (15.0)	**0.080**	0.073	0.067	0.062	0.058	0.055	0.052	0.049	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.029	0.026	0.023	0.020	0.018
5.5 in. depth	R-19 (18.0)	**0.065**	0.060	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.027	0.024	0.021	0.019	0.018
	R-21 (21.0)	**0.060**	0.056	0.052	0.049	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.026	0.023	0.020	0.018	0.017
+ R-10 headers	R-19 (18.0)	**0.062**	0.058	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.034	0.033	0.032	0.031	0.027	0.024	0.021	0.019	0.017
	R-21 (21.0)	**0.057**	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.029	0.025	0.023	0.020	0.018	0.017

A4. BELOW-GRADE WALLS

A4.1 General. For the purpose of Section A1.2, The base assembly is 8 in. medium-weight concrete block with a density of 115 lb/ft^3 and solid grouted cores. *Continuous insulation* is installed on the interior or exterior. In contrast to the *U-factor* for *above-grade walls*, the *C-factor* for *below-grade walls* does not include R-values for exterior or interior air films or for soil. For insulated *walls*, the *C-factor* does include R-0.45 for 0.5 in. gypsum board.

A4.2 C-Factors for Below-Grade Walls

A4.2.1 C-factors for *below-grade walls* shall be taken from Table A4.2 or determined by the procedure described in this subsection.

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

A4.2.3 If not taken from Table A4.2, *below-grade wall C-factors* shall be determined from Tables A3.1B, A3.1C, or A3.1D using the following procedure:

a. If the *below-grade wall* is uninsulated or only the cells are insulated:

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

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

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

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-1.140
Exterior Insulation, Continuous and Uninterrupted by Framing		
No Framing	R-5.0	C-0.170
No Framing	R-7.5	C-0.119
No Framing	R-10.0	C-0.092
No Framing	R-12.5	C-0.075
No Framing	R-15.0	C-0.063
No Framing	R-17.5	C-0.054
No Framing	R-20.0	C-0.048
No Framing	R-25.0	C-0.039
No Framing	R-30.0	C-0.032
No Framing	R-35.0	C-0.028
No Framing	R-40.0	C-0.025
No Framing	R-45.0	C-0.022
No Framing	R-50.0	C-0.020
Continuous Metal Framing at 24 in. on Center Horizontally		
3.5 in.	R-11.0	C-0.182
3.5 in.	R-13.0	C-0.174
3.5 in.	R-15.0	C-0.168
5.5 in.	R-19.0	C-0.125
5.5 in.	R-21.0	C-0.120
1 in. Metal Clips at 24 in. on Center Horizontally and 16 in. Vertically		
1.0 in.	R-3.8	C-0.233
1.0 in.	R-5.0	C-0.201

TABLE A4.2 Assembly C-Factors for Below-Grade Walls *(continued)*

Framing Type and Depth	Rated R-Value of Insulation Alone	Specified C-Factors (Wall Only, without Soil and Air Films)
1.0 in.	R-5.6	C-0.189
1.5 in.	R-5.7	C-0.173
1.5 in.	R-7.5	C-0.147
1.5 in.	R-8.4	C-0.138
2.0 in.	R-7.6	C-0.138
2.0 in.	R-10.0	C-0.116
2.0 in.	R-11.2	C-0.108
2.5 in.	R-9.5	C-0.114
2.5 in.	R-12.5	C-0.096
2.5 in.	R-14.0	C-0.089
3.0 in.	R-11.4	C-0.098
3.0 in.	R-15.0	C-0.082
3.0 in.	R-16.8	C-0.076
3.5 in.	R-13.3	C-0.085
3.5 in.	R-17.5	C-0.071
3.5 in.	R-19.6	C-0.066
4.0 in.	R-15.2	C-0.076
4.0 in.	R-20.0	C-0.063
4.0 in.	R-22.4	C-0.058

A5. FLOORS

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

A5.2 Mass Floors

A5.2.1 General. For the purpose of Section A1.2, the base assembly is *continuous insulation* over or under a solid concrete *floor*. The *U-factors* include R-0.92 for interior air film-heat flow down, R-1.23 for carpet and rubber pad, R-0.50 for 8 in. concrete, and R-0.46 for 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 24 in. and less below the exposed floor.

A5.2.3 U-Factors for Mass Floors

A5.2.3.1 The *U-factors* for *mass walls* shall be taken from Table A5.2.

A5.2.3.2 It is not acceptable to use the *U-factors* in Table A5.2 if the insulation is not continuous.

A5.3 Steel-Joist Floors

A5.3.1 General. For the purpose of Section A1.2, the base assembly is a *floor* where the insulation is either placed between the *steel joists* or is sprayed on the underside of the *floor* and the joists. In both cases, the steel provides a thermal bypass to the insulation. The *U-factors* include R-0.92 for interior air film—heat flow down, R-1.23 for carpet and pad, R-0.25 for 4 in. concrete, R-0 for metal deck, and R-0.46 for semi-exterior air film. The performance of the insulation/ framing layer is calculated using the values in Table A9.2A.

A5.3.2 Rated R-Value of Insulation for Steel-Joist Floors

A5.3.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between *steel joists* or for spray-on insulation.

A5.3.2.2 It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing. All *continuous insulation* shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.3.3 U-Factors for Steel-Joist Floors

A5.3.3.1 The *U-factors* for *steel-joist floors* shall be taken from Table A5.3.

A5.3.3.2 It is acceptable to use these *U-factors* for any *steel-joist floor.*

A5.4 Wood-Framed and Other Floors

A5.4.1 General. For the purpose of Section A1.2, the base assembly is a *floor* attached directly to the top of the wood joist with insulation located directly below the *floor* and ventilated airspace below the insulation. The heat flow path through the joist is calculated to be the same depth as the insulation. The *U-factors* include R-0.92 for interior air film—heat flow down, R-1.23 for carpet and pad, R-0.94 for 0.75 in. wood subfloor, and R-0.46 for semi-exterior air film. The weighting factors are 91% insulated cavity and 9% framing.

A5.4.2 Rated R-Value of Insulation for Wood-Framed and Other Floors

A5.4.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between wood joists.

A5.4.2.2 It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing. All *continuous insulation* shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.4.3 *U-Factors* for *Wood-Framed Floors*

A5.4.3.1 The *U-factors* for *wood-framed floors* shall be taken from Table A5.4.

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

TABLE A5.2 Assembly U-Factors for Mass Floors

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

TABLE A5.3 Assembly U-Factors for Steel-Joist Floors

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

TABLE A5.4 Assembly U-Factors for Wood-Joist Floors

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated (Effective Installed)	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (Uninterrupted by Framing) — Rated R-Value of Continuous Insulation																			
			R-1.00	**R-2.00**	**R-3.00**	**R-4.00**	**R-5.00**	**R-6.00**	**R-7.00**	**R-8.00**	**R-9.00**	**R-10.00**	**R-11.00**	**R-12.00**	**R-13.00**	**R-14.00**	**R-15.00**	**R-20.00**	**R-25.00**	**R-30.00**	**R-35.00**	**R-40.00**
Wood Joists																						
5.5 in.	None (0.0)	**0.282**	0.220	0.180	0.153	0.132	0.117	0.105	0.095	0.087	0.080	0.074	0.069	0.064	0.060	0.057	0.054	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	**0.074**	0.069	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.030	0.026	0.023	0.020	0.019
	R-13 (13.0)	**0.066**	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.028	0.025	0.022	0.020	0.018
	R-15 (15.0)	**0.060**	0.057	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.027	0.024	0.021	0.019	0.017
	R-19 (18.0)	**0.051**	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.025	0.022	0.020	0.018	0.017
	R-21 (21.0)	**0.046**	0.043	0.042	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.023	0.021	0.019	0.017	0.016
7.25 in.	R-25 (25.0)	**0.039**	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.025	0.025	0.024	0.022	0.019	0.018	0.016	0.015
	R-30C (30.0)	**0.034**	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.020	0.018	0.016	0.015	0.014
9.25 in.	R-30 (30.0)	**0.033**	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014
11.25 in.	R-38C (38.0)	**0.027**	0.026	0.025	0.025	0.024	0.024	0.023	0.022	0.022	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.017	0.016	0.015	0.014	0.013
13.25 in.	R-38 (38.0)	**0.026**	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.017	0.016	0.015	0.014	0.013

A6. SLAB-ON-GRADE FLOORS

A6.1 General. For the purpose of Section A1.2, the base assembly is a slab floor of 6 in. concrete poured directly on to the earth, the bottom of the slab is at grade line, and soil conductivity is 0.75 Btu/h·ft·°F. In contrast to the *U-factor* for *floors*, the *F-factor* for *slab-on-grade floors* is expressed per linear foot of building perimeter. *F-factors* are provided for unheated slabs and for heated slabs. *Unheated slab-on-grade floors* do not have heating elements, and *heated slab-on-grade floors* do have heating elements within or beneath the slab. *F-factors* are provided for three insulation configurations:

a. *Horizontal Insulation: continuous insulation* is applied directly to the underside of the slab and extends inward horizontally from the perimeter for the distance specified or *continuous insulation* is applied downward from the top of the slab and then extends horizontally to the interior or the exterior from the perimeter for the distance specified.
b. *Vertical Insulation: continuous insulation* is applied directly to the slab exterior, extending downward from the top of the slab for the distance specified.
c. *Fully Insulated Slab: continuous insulation* extends downward from the top of the slab and along the entire perimeter and completely covers the entire area under the slab.

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

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

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

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

A6.2.3 Insulation installed outside the foundation *wall* shall extend from the top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum of the distance specified. In all climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10 in. thick.

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

A6.3.1 *F-factors* for *slab-on-grade floors* shall be taken from Table A6.3.

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: 1.45
b. Uninsulated double-layer metal *swinging doors* or *non-swinging doors*, including double-layer uninsulated *access hatches* and uninsulated smoke vents: 0.70
c. Insulated metal *swinging doors*, including fire-rated *doors*, insulated *access hatches*, and insulated smoke vents: 0.50
d. Wood *doors*, minimum nominal thickness of 1.75 in., including panel *doors* with minimum panel thickness of 1.125 in., solid core flush *doors*, and hollow core flush *doors*: 0.50
e. Any other wood *door*: 0.60

A8. FENESTRATION

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

A8.1 Unlabeled Skylights. Unlabeled *skylights* shall be assigned the *U-factors* in Table A8.1A and are allowed to use the *SHGC*s and VTs 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 0.25 in.

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

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

Insulation Description	Rated R-Value of Insulation												
	R-0	R-5	R-7.5	R-10	R-15	R-20	R-25	R-30	R-35	R-40	R-45	R-50	R-55
Unheated Slabs													
None	0.73												
12 in. horizontal		0.72	0.71	0.71	0.71								
24 in. horizontal		0.70	0.70	0.70	0.69								
36 in. horizontal		0.68	0.67	0.66	0.66								
48 in. horizontal		0.67	0.65	0.64	0.63								
12 in.vertical		0.61	0.60	0.58	0.57	0.567	0.565	0.564					
24 in. vertical		0.58	0.56	0.54	0.52	0.510	0.505	0.502					
36 in. vertical		0.56	0.53	0.51	0.48	0.472	0.464	0.460					
48 in. vertical		0.54	0.51	0.48	0.45	0.434	0.424	0.419					
Fully insulated slab		0.46	0.41	0.36	0.30	0.261	0.233	0.213	0.198	0.186	0.176	0.168	0.161
Heated Slabs													
None	1.35												
12 in. horizontal		1.31	1.31	1.30	1.30								
24 in. horizontal		1.28	1.27	1.26	1.25								
36 in. horizontal		1.24	1.21	1.20	1.18								
48 in. horizontal		1.20	1.17	1.13	1.11								
12 in. vertical		1.06	1.02	1.00	0.98	0.968	0.964	0.961					
24 in. vertical		0.99	0.95	0.90	0.86	0.843	0.832	0.827					
36 in. vertical		0.95	0.89	0.84	0.79	0.762	0.747	0.740					
48 in. vertical		0.91	0.85	0.78	0.72	0.688	0.671	0.659					
Fully insulated slab		0.74	0.64	0.55	0.44	0.373	0.326	0.296	0.273	0.255	0.239	0.227	0.217

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

Product Type		Sloped Installation						
		Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type							
	Single Glazing							
1	1/8 in. glass	1.98	1.89	1.75	1.47	1.36	1.25	1.25
2	1/4 in. acrylic/polycarb	1.82	1.73	1.60	1.31	1.21	1.10	1.10
3	1/8 in. acrylic/polycarb	1.90	1.81	1.68	1.39	1.29	1.18	1.18
	Double Glazing							
4	1/4 in. airspace	1.31	1.11	1.05	0.84	0.82	0.70	0.66
5	1/2 in. airspace	1.30	1.10	1.04	0.84	0.81	0.69	0.65
6	1/4 in. argon space	1.27	1.07	1.00	0.80	0.77	0.66	0.62
7	1/2 in. argon space	1.27	1.07	1.00	0.80	0.77	0.66	0.62
	Double Glazing, $e = 0.60$ on surface 2 or 3							
8	1/4 in. airspace	1.27	1.08	1.01	0.81	0.78	0.67	0.63
9	1/2 in. airspace	1.27	1.07	1.00	0.80	0.77	0.66	0.62

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

	Product Type	Sloped Installation: Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Sloped Installation: Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
	Frame Type	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type							
10	1/4 in. argon space	1.23	1.03	0.97	0.76	0.74	0.63	0.58
11	1/2 in. argon space	1.23	1.03	0.97	0.76	0.74	0.63	0.58
	Double Glazing, *e* = 0.40 on surface 2 or 3							
12	1/4 in. airspace	1.25	1.05	0.99	0.78	0.76	0.64	0.60
13	1/2 in. airspace	1.24	1.04	0.98	0.77	0.75	0.64	0.59
14	1/4 in. argon space	1.18	0.99	0.92	0.72	0.70	0.58	0.54
15	1/2 in. argon space	1.20	1.00	0.94	0.74	0.71	0.60	0.56
	Double Glazing, *e* = 0.20 on surface 2 or 3							
16	1/4 in. airspace	1.20	1.00	0.94	0.74	0.71	0.60	0.56
17	1/2 in. airspace	1.20	1.00	0.94	0.74	0.71	0.60	0.56
18	1/4 in. argon space	1.14	0.94	0.88	0.68	0.65	0.54	0.50
19	1/2 in. argon space	1.15	0.95	0.89	0.68	0.66	0.55	0.51
	Double Glazing, *e* = 0.10 on surface 2 or 3							
20	1/4 in. airspace	1.18	0.99	0.92	0.72	0.70	0.58	0.54
21	1/2 in. airspace	1.18	0.99	0.92	0.72	0.70	0.58	0.54
22	1/4 in. argon space	1.11	0.91	0.85	0.65	0.63	0.52	0.47
23	1/2 in. argon space	1.13	0.93	0.87	0.67	0.65	0.53	0.49
	Double Glazing, *e* = 0.05 on surface 2 or 3							
24	1/4 in. airspace	1.17	0.97	0.91	0.70	0.68	0.57	0.52
25	1/2 in. airspace	1.17	0.98	0.91	0.71	0.69	0.58	0.53
26	1/4 in. argon space	1.09	0.89	0.83	0.63	0.61	0.50	0.45
27	1/2 in. argon space	1.11	0.91	0.85	0.65	0.63	0.52	0.47
	Triple Glazing							
28	1/4 in. airspaces	1.12	0.89	0.84	0.64	0.64	0.53	0.48
29	1/2 in. airspaces	1.10	0.87	0.81	0.61	0.62	0.51	0.45
30	1/4 in. argon spaces	1.09	0.86	0.80	0.60	0.61	0.50	0.44
31	1/2 in. argon spaces	1.07	0.84	0.79	0.59	0.59	0.48	0.42
	Triple Glazing, *e* = 0.20 on surface 2,3,4, or 5							
32	1/4 in. airspace	1.08	0.85	0.79	0.59	0.60	0.49	0.43
33	1/2 in. airspace	1.05	0.82	0.77	0.57	0.57	0.46	0.41
34	1/4 in. argon space	1.02	0.79	0.74	0.54	0.55	0.44	0.38
35	1/2 in. argon space	1.01	0.78	0.73	0.53	0.54	0.43	0.37
	Triple Glazing, *e* = 0.20 on surfaces 2 or 3 and 4 or 5							
36	1/4 in. airspace	1.03	0.80	0.75	0.55	0.56	0.45	0.39
37	1/2 in. airspace	1.01	0.78	0.73	0.53	0.54	0.43	0.37
38	1/4 in. argon space	0.99	0.75	0.70	0.50	0.51	0.40	0.35
39	1/2 in. argon space	0.97	0.74	0.69	0.49	0.50	0.39	0.33
	Triple Glazing, *e* = 0.10 on surfaces 2 or 3 and 4 or 5							
40	1/4 in. airspace	1.01	0.78	0.73	0.53	0.54	0.43	0.37
41	1/2 in. airspace	0.99	0.76	0.71	0.51	0.52	0.41	0.36

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

Product Type		Sloped Installation						
		Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	**Glazing Type**							
42	1/4 in. argon space	0.96	0.73	0.68	0.48	0.49	0.38	0.32
43	1/2 in. argon space	0.95	0.72	0.67	0.47	0.48	0.37	0.31
Quadruple Glazing, *e* = 0.10 on surfaces 2 or 3 and 4 or 5								
44	1/4 in. airspace	0.97	0.74	0.69	0.49	0.50	0.39	0.33
45	1/2 in. airspace	0.94	0.71	0.66	0.46	0.47	0.36	0.30
46	1/4 in. argon space	0.93	0.70	0.65	0.45	0.46	0.35	0.30
47	1/2 in. argon space	0.91	0.68	0.63	0.43	0.44	0.33	0.28
48	1/4 in. krypton spaces	0.88	0.65	0.60	0.40	0.42	0.31	0.25

TABLE A8.1B Assembly SHGCs and Assembly Visible Transmittances (VTs) for Unlabeled Skylights

Glass Type	Glazing Type: Number of glazing layers Number and emissivity of coatings (Glazing is glass except where noted)	Unlabeled Skylights (Includes glass/plastic, flat/domed, fixed/operable)					
	Frame:	Metal without Thermal Break		Metal with Thermal Break		Wood/Vinyl/ Fiberglass	
	Characteristic:	SHGC	VT	SHGC	VT	SHGC	VT
Clear	Single glazing, 1/8 in. glass	0.82	0.76	0.78	0.76	0.73	0.73
	Single glazing, 1/4 in. glass	0.78	0.75	0.74	0.75	0.69	0.72
	Single glazing, acrylic/polycarbonate	0.83	0.92	0.83	0.92	0.83	0.92
	Double glazing	0.68	0.66	0.64	0.66	0.59	0.64
	Double glazing, E = 0.40 on surface 2 or 3	0.71	0.65	0.67	0.65	0.62	0.63
	Double glazing, E = 0.20 on surface 2 or 3	0.66	0.61	0.62	0.61	0.57	0.59
	Double glazing, E = 0.10 on surface 2 or 3	0.59	0.63	0.55	0.63	0.51	0.61
	Double glazing, acrylic/polycarbonate	0.77	0.89	0.77	0.89	0.77	0.89
	Triple glazing	0.60	0.59	0.56	0.59	0.52	0.57
	Triple glazing, E = 0.40 on surface 2, 3, 4, or 5	0.64	0.60	0.60	0.60	0.56	0.57
	Triple glazing, E = 0.20 on surface 2, 3, 4, or 5	0.59	0.55	0.55	0.55	0.51	0.53
	Triple glazing, E = 0.10 on surface 2, 3, 4, or 5	0.54	0.56	0.50	0.56	0.46	0.54
	Triple glazing, E = 0.40 on surfaces 3 and 5	0.62	0.57	0.58	0.57	0.53	0.55
	Triple glazing, E = 0.20 on surfaces 3 and 5	0.56	0.51	0.52	0.51	0.48	0.49
	Triple glazing, E = 0.10 on surfaces 3 and 5	0.47	0.54	0.43	0.54	0.40	0.52
	Triple glazing, acrylic/polycarbonate	0.71	0.85	0.71	0.85	0.71	0.85
	Quadruple glazing, E = 0.10 on surfaces 3 and 5	0.41	0.48	0.37	0.48	0.33	0.46
	Quadruple glazing, acrylic/polycarbonate	0.65	0.81	0.65	0.81	0.65	0.81

TABLE A8.1B Assembly SHGCs and Assembly Visible Transmittances (VTs) for Unlabeled Skylights *(continued)*

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	
Tinted	Single glazing, 1/8 in. glass	0.70	0.58	0.66	0.58	0.62	0.56
	Single glazing, 1/4 in. glass	0.61	0.45	0.56	0.45	0.52	0.44
	Single glazing, acrylic/polycarbonate	0.46	0.27	0.46	0.27	0.46	0.27
	Double glazing	0.50	0.40	0.46	0.40	0.42	0.39
	Double glazing, E = 0.40 on surface 2 or 3	0.59	0.50	0.55	0.50	0.50	0.48
	Double glazing, E = 0.20 on surface 2 or 3	0.47	0.37	0.43	0.37	0.39	0.36
	Double glazing, E = 0.10 on surface 2 or 3	0.43	0.38	0.39	0.38	0.35	0.37
	Double glazing, acrylic/polycarbonate	0.37	0.25	0.37	0.25	0.37	0.25
	Triple glazing	0.42	0.22	0.37	0.22	0.34	0.21
	Triple glazing, E = 0.40 on surface 2, 3, 4, or 5	0.53	0.45	0.49	0.45	0.45	0.44
	Triple glazing, E = 0.20 on surface 2, 3, 4, or 5	0.42	0.33	0.38	0.33	0.35	0.32
	Triple glazing, E = 0.10 on surface 2, 3, 4, or 5	0.39	0.34	0.35	0.34	0.31	0.33
	Triple glazing, E = 0.40 on surfaces 3 and 5	0.51	0.43	0.47	0.43	0.43	0.42
	Triple glazing, E = 0.20 on surfaces 3 and 5	0.40	0.31	0.36	0.31	0.32	0.29
	Triple glazing, E = 0.10 on surfaces 3 and 5	0.34	0.32	0.30	0.32	0.27	0.31
	Triple glazing, acrylic/polycarbonate	0.30	0.23	0.30	0.23	0.30	0.23
	Quadruple glazing, E = 0.10 on surfaces 3 and 5	0.30	0.29	0.26	0.29	0.23	0.28
	Quadruple glazing, acrylic/polycarbonate	0.27	0.25	0.27	0.25	0.27	0.25

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

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

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

A9.1 General. Component *U-factors* for other *opaque* assemblies shall be determined in accordance with Section A9 only if approved by the *building official* in accordance with Section A1.2. The procedures required for each *class of construction* are specified in Section A9.2. Testing shall be performed in accordance with Section A9.3. Calculations shall be performed in accordance with Section A9.4.

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

a. Roofs:

1. *Roofs with insulation entirely above deck*: testing or series calculation method.
2. *Metal building roofs*: testing.
3. *Attic roofs*, wood joists: testing or parallel path calculation method.
4. *Attic roofs*, *steel joists*: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2A or modified zone calculation method.
5. *Attic roofs*, concrete joists: testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
6. Other *attic roofs* and other *roofs*: testing or two-dimensional calculation method.

b. *Above-Grade Walls:*

1. *Mass walls*: testing or isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
2. *Metal building walls*: testing.
3. *Steel-framed walls*: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2B or the modified zone method.
4. *Wood-framed walls*: testing or parallel path calculation method.
5. Other *walls*: testing or two-dimensional calculation method.

c. *Below-Grade Walls*:

1. *Mass walls*: testing or isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
2. *Other walls*: testing or two-dimensional calculation method

d. Floors:

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

e. Slab-on-Grade Floors:
No testing or calculations allowed.

TABLE A9.2A Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on Center)

Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value	Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value
0.00	1.00	0.00	20.00	0.85	17.00
4.00	0.97	3.88	21.00	0.84	17.64
5.00	0.96	4.80	24.00	0.82	19.68
8.00	0.94	7.52	25.00	0.81	20.25
10.00	0.92	9.20	30.00	0.79	23.70
11.00	0.91	10.01	35.00	0.76	26.60
12.00	0.90	10.80	38.00	0.74	28.12
13.00	0.90	11.70	40.00	0.73	29.20
15.00	0.88	13.20	45.00	0.71	31.95
16.00	0.87	13.92	50.00	0.69	34.50
19.00	0.86	16.34	55.00	0.67	36.85

A9.3 Testing Procedures

A9.3.1 Building Material Thermal Properties. If *building material* R-values or thermal conductivities are determined by testing, one of the following test procedures shall be used:

a. ASTM C177
b. ASTM C518
c. ASTM C1363

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

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

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

A9.4 Calculation Procedures and Assumptions. The following procedures and assumptions shall be used for all calculations. R-values for air films, insulation, and *building materials* shall be taken from Sections A9.4.1 through A9.4.3, respectively. In addition, the appropriate assumptions listed in Sections A2 through A8, including framing factors, shall be used.

A9.4.1 Air Films. Prescribed R-values for air films shall be as follows:

R-Value	Condition
0.17	All exterior surfaces
0.46	All semi-exterior surfaces
0.61	Interior horizontal surfaces, heat flow up
0.92	Interior horizontal surfaces, heat flow down
0.68	Interior vertical surfaces

A9.4.1.1 Exterior surfaces are areas exposed to the wind.

A9.4.1.2 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 0.5 in. The values for 3.5 in. cavities shall be used for cavities of that width and greater.

TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity, in.	Actual Depth of Cavity, in.	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on Center	Effective Framing/Cavity R-Value at 24 in. on Center
Empty Cavity, No Insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

TABLE A9.4A Values for Cavity Air Spaces

Component	Airspace Thickness, in.	R-Value Effective Emissivity 0.03	0.05	0.20	0.50	0.82
Roof	0.50	2.13	2.04	1.54	1.04	0.77
	0.75	2.33	2.22	1.64	1.09	0.80
	1.50	2.53	2.41	1.75	1.13	0.82
	3.50	2.83	2.66	1.88	1.19	0.85
Wall	0.50	2.54	2.43	1.75	1.13	0.82
	0.75	3.58	3.32	2.18	1.30	0.90
	1.50	3.92	3.62	2.30	1.34	0.93
	3.50	3.67	3.40	2.21	1.31	0.91
Floor	0.50	2.55	1.28	1.00	0.69	0.53
	0.75	1.44	1.38	1.06	0.73	0.54
	1.50	2.49	2.38	1.76	1.15	0.85
	3.50	3.08	2.90	2.01	1.26	0.90

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

Surface	Average Emittance *e*	Effective Emittance *e eff* of Air Space One Surface *e*; Other, 0.9	Both Surfaces Emittance *e*
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (>0.7 gr/ft^2)	0.30	0.29	—
Aluminum foil, with condensate clearly visible (>2.9 gr/ft^2)	0.70	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galv., bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

TABLE A9.4C Effective R-Values for Fiberglass

Insulation R-Value at Standard Thickness									
Rated R-Value		38	30	22	21	19	15	13	11
Standard Thickness, in.		12	9.5	6.5	5.5	6	3.5	3.5	3.5
Nominal Lumber Size, in.	Actual Depth of Cavity, in.	Effective Insulation R-Values when Installed in a Confined Cavity							
2 × 12	11.25	37	—	—	—	—	—	—	—
2 × 10	9.25	32	30	—	—	—	—	—	—
2 × 8	7.25	27	26	22	21	19	—	—	—
2 × 6	5.5	—	21	20	21	18	—	—	—
2 × 4	3.5	—	—	14	—	13	15	13	11
	2.5	—	—	—	—	—	—	9.8	—
	1.5	—	—	—	—	—	—	6.3	6

A9.4.2 Insulation R-Values. Insulation R-values shall be determined as follows:

a. For insulation that is not compressed, the *rated R-value of insulation* shall be used.
b. For calculation purposes, the effective R-value for insulation that is uniformly compressed in confined cavities shall be taken from Table A9.4C.
c. For calculation purposes, the effective R-value for insulation installed in cavities in attic *roofs* with *steel joists* shall be taken from Table A9.2A.
d. For calculation purposes, the effective R-value for insulation installed in cavities in *steel-framed walls* shall be taken from Table A9.2B.

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

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

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

TABLE A9.4D R-Values for Building Materials

Material	Nominal Size, in.	Actual Size, in.	R-Value
Carpet and rubber pad	—	–	1.23
Concrete at R-0.0625/in.	—	2	0.13
	—	4	0.25
	—	6	0.38
	—	8	0.5
	—	10	0.63
	—	12	0.75
Flooring, wood subfloor	—	0.75	0.94
Gypsum board	—	0.5	0.45
	—	0.625	0.56
Metal deck	—	—	0
Roofing, built-up	—	0.375	0.33
Sheathing, vegetable fiber board, 0.78 in.	—	0.78	2.06
Soil at R-0.104/in.	—	12	1.25
Steel, mild		1	0.0031807
Stucco	—	0.75	0.08
Wood, 2 × 4 at R-1.25/in.	4	3.5	4.38
Wood, 2 × 4 at R-1.25/in.	6	5.5	6.88
Wood, 2 × 4 at R-1.25/in.	8	7.25	9.06
Wood, 2 × 4 at R-1.25/in.	10	9.25	11.56
Wood, 2 × 4 at R-1.25/in.	12	11.25	14.06
Wood, 2 × 4 at R-1.25/in.	14	13.25	16.56

TABLE A9.4E Thermal Conductivity of Concrete Block Material

Concrete Block Density, lb/ft^3	Thermal Conductivity, Btu·in./h·ft^2·°F
80	3.7
85	4.2
90	4.7
95	5.1
100	5.5
105	6.1
110	6.7
115	7.2
120	7.8
125	8.9
130	10.0
135	11.8
140	13.5

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX B—BUILDING ENVELOPE CLIMATE CRITERIA

B1. GENERAL

This normative appendix provides the information to determine both United States and international climate zones. For US locations, use either Figure B-1 or Table B-1 to determine the climate zone number and letter that are required for determining compliance regarding various sections and tables in this standard. Figure B-1 contains the county-by-county climate zone map for the United States. Table B-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

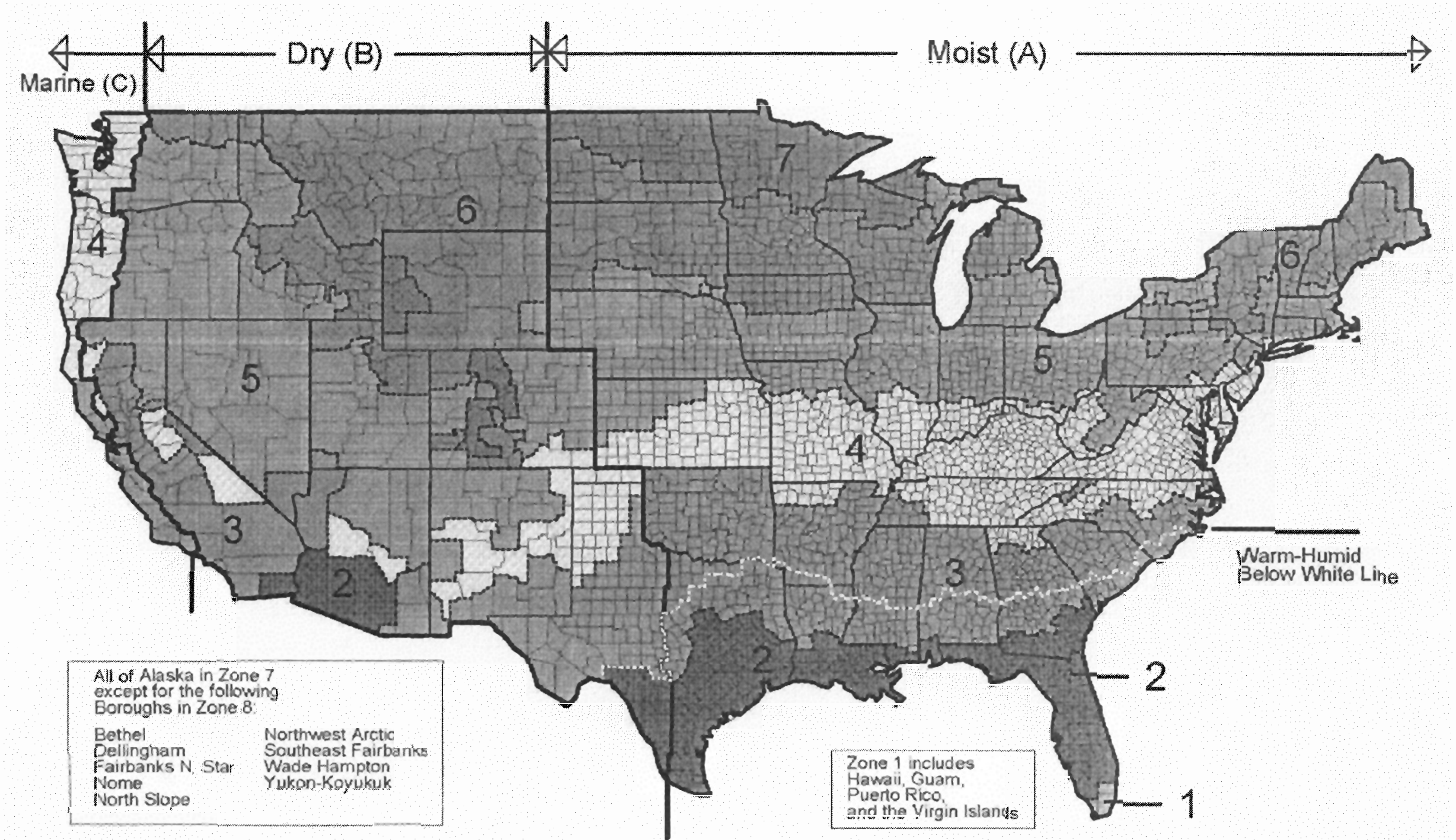


Figure B-1 U.S. map showing DOE climate zones (Briggs et al. 2003).

TABLE B-1 US Climate Zones

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

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

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

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

State / County	Zone
(Kansas cont.)	
Decatur	5A
Ellis	5A
Gove	5A
Graham	5A
Greeley	5A
Hamilton	5A
Jewell	5A
Lane	5A
Logan	5A
Mitchell	5A
Ness	5A
Norton	5A
Osborne	5A
Phillips	5A
Rawlins	5A
Republic	5A
Rooks	5A
Scott	5A
Sheridan	5A
Sherman	5A
Smith	5A
Thomas	5A
Trego	5A
Wallace	5A
Wichita	5A
Kentucky (KY)	
Zone 4A	
Louisiana (LA)	
Zone 2A Except	
Bienville	3A
Bossier	3A
Caddo	3A
Caldwell	3A
Catahoula	3A
Claiborne	3A
Concordia	3A
De Soto	3A
East Carroll	3A
Franklin	3A
Grant	3A

State / County	Zone
(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

State / County	Zone
(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

State / County	Zone
(Minnesota cont.)	
Cass	7
Clay	7
Clearwater	7
Cook	7
Crow Wing	7
Grant	7
Hubbard	7
Itasca	7
Kanabec	7
Kittson	7
Koochiching	7
Lake	7
Lake of the Woods	7
Mahnomen	7
Marshall	7
Mille Lacs	7
Norman	7
Otter Trail	7
Pennington	7
Pine	7
Polk	7
Red Lake	7
Roseau	7
St. Louis	7
Wadena	7
Wilkin	7
Mississippi (MS)	
Zone 3A Except	
Hancock	2A
Harrison	2A
Jackson	2A
Pearl River	2A
Stone	2A
Missouri (MO)	
Zone 4A Except	
Adair	5A
Andrew	5A
Atchison	5A
Buchanan	5A
Caldwell	5A

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

State County	Zone
(Missouri cont.)	
Chariton	5A
Clark	5A
Clinton	5A
Daviess	5A
Gentry	5A
Grundy	5A
Harrison	5A
Holt	5A
Knox	5A
Lewis	5A
Linn	5A
Livingston	5A
Macon	5A
Marion	5A
Mercer	5A
Nodaway	5A
Pike	5A
Putnam	5A
Ralls	5A
Schuyler	5A
Scotland	5A
Shelby	5A
Sullivan	5A
Worth	5A
Montana (MT)	
Zone 6B	
Nebraska (NE)	
Zone 5A	
Nevada (NV)	
Zone 5B Except	
Clark	3B
New Hampshire (NH)	
Zone 6A Except	
Cheshire	5A
Hillsborough	5A
Rockingham	5A
Strafford	5A
New Jersey (NJ)	
Zone 4A Except	
Bergen	5A

State County	Zone
(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

State County	Zone
(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

State County	Zone
(North Carolina cont.)	
Duplin	3A
Edgecombe	3A
Gaston	3A
Greene	3A
Hoke	3A
Hyde	3A
Johnston	3A
Jones	3A
Lenoir	3A
Martin	3A
Mecklenberg	3A
Montgomery	3A
Moore	3A
New Hanover	3A
Onslow	3A
Pamlico	3A
Pasquotank	3A
Pender	3A
Perquimans	3A
Pitt	3A
Randolph	3A
Richmond	3A
Robeson	3A
Rowan	3A
Sampson	3A
Scotland	3A
Stanly	3A
Tyrrell	3A
Union	3A
Washington	3A
Wayne	3A
Wilson	3A
Alleghany	5A
Ashe	5A
Avery	5A
Mitchell	5A
Watauga	5A
Yancey	5A
North Dakota (ND)	
Zone 7 Except	

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

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

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

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

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

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

Table B-2 shows the climate zone numbers for a wide variety of Canadian locations. When the climate zone letter is required to determine compliance with this standard, refer to Table B-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

Table B-3 shows the climate zone numbers for a wide variety of other international locations besides Canada. When the climate zone letter is required to determine compliance with this standard, refer to Table B-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

For all international locations that are not listed either in Table B-2 or B-3, use Table B-4 and the Major Climate Type Definitions in Section B2 to determine both the climate zone letter and number.

Note: CDD50 and HDD65 values may be found in Normative Appendix D.

B2. MAJOR CLIMATE TYPE DEFINITIONS

Use the following information along with Table B-4 to determine climate zone numbers and letters for international climate zones.

Marine (C) definition—Locations meeting all four criteria:

1. *Mean temperature* of coldest month between 27°F and 65°F.
2. Warmest month mean <72°F.
3. At least four months with *mean temperatures* over 50°F.
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

$$P_{in} < 0.44 \times (TF - 19.5),$$

where

P = annual precipitation, in.; and

T = annual *mean temperature*, °F.

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

TABLE B-2 Canadian Climatic Zones

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

TABLE B-3 International Climate Zones

Country / City (Province or Region)	Zone
Argentina	
Buenos Aires/Ezeiza	3
Cordoba	3
Tucuman/Pozo	2
Australia	
Adelaide (SA)	4
Alice Springs (NT)	2
Brisbane (AL)	2
Darwin Airport (NT)	1
Perth/Guildford (WA)	3
Sydney/KSmith (NSW)	3
Azores (Terceira)	
Lajes	3
Bahamas	
Nassau	1
Belgium	
Brussels Airport	5
Bermuda	
St. Georges/Kindley	2
Bolivia	
La Paz/El Alto	5
Brazil	
Belem	1
Brasilia	2
Fortaleza	1
Porto Alegre	2
Recife/Curado	1
Rio de Janeiro	1
Salvador/Ondina	1
Sao Paulo	2
Bulgaria	
Sofia	5
Chile	
Concepcion	4
Punta Arenas/Chabunco	6
Santiago/Pedahuel	4
China	
Shanghai/Hongqiao	3
Cuba	
Guantanamo Bay NAS (Ote.)	1
Cyprus	
Akrotiri	3
Larnaca	3
Paphos	3
Czech Republic	
Prague/Libus	5
Dominican Republic	
Santo Domingo	1
Egypt	
Cairo	2
Luxor	1
Finland	
Helsinki/Seutula	7
France	
Lyon/Satolas	4
Marseille	4
Nantes	4
Nice	4
Paris/Le Bourget	4
Strasbourg	5
Germany	
Berlin/Schoenfeld	5
Hamburg	5
Hannover	5
Mannheim	5
Greece	
Souda (Crete)	3
Thessalonika/Mikra	4
Greenland	
Narssarssuaq	7
Hungary	
Budapest/Lorinc	5
Iceland	
Reykjavik	7
India	
Ahmedabad	1
Bangalore	1
Bombay/Santa Cruz	1
Calcutta/Dum Dum	1
Madras	1
Nagpur Sonegaon	1
New Delhi/Safdarjung	1
Indonesia	
Djakarta/Halimperda (Java)	1
Kupang Penfui (Sunda Island)	1
Makassar (Celebes)	1
Medan (Sumatra)	1
Palembang (Sumatra)	1
Surabaja Perak (Java)	1
Ireland	
Dublin Airport	5
Shannon Airport	4
Israel	
Jerusalem	3
Tel Aviv Port	2
Italy	
Milano/Linate	4
Napoli/Capodichino	4
Roma/Fiumicion	4
Jamaica	
Kingston/Manley	1
Montego Bay/Sangster	1
Japan	
Fukaura	5
Sapporo	5
Tokyo	3
Jordan	
Amman	3
Kenya	
Nairobi Airport	3
Korea	
Pyonggang	5
Seoul	4
Malaysia	
Kuala Lumpur	1
Penang/Bayan Lepas	1
Mexico	
Mexico City (Distrito Federal)	3
Guadalajara (Jalisco)	1
Monterrey (Nuevo Laredo)	3
Tampico (Tamaulipas)	1
Veracruz (Veracruz)	4
Merida (Yucatan)	1
Netherlands	
Amsterdam/Schiphol	5
New Zealand	
Auckland Airport	4
Christchurch	4
Wellington	4
Norway	
Bergen/Florida	5
Oslo/Fornebu	6
Pakistan	
Karachi Airport	1
Papua New Guinea	
Port Moresby	1
Paraguay	
Asuncion/Stroessner	1
Peru	
LimaCallao/Chavez	2
San Juan de Marcona	2
Talara	2
Philippines	
Manila Airport (Luzon)	1
Poland	
Krakow/Balice	5
Romania	
Bucuresti/Bancasa	5
Russia	
Kaliningrad (East Prussia)	5
Krasnoiarsk	7
Moscow Observatory	6
Petropavlovsk	7
(Russia cont.)	
RostovNaDonu	5
Vladivostok	6
Volgograd	6
Saudi Arabia	
Dhahran	1
Riyadh	1
Senegal	
Dakar/Yoff	1
Singapore	
Singapore/Changi	1
South Africa	
Cape Town/D F Malan	4
Johannesburg	4
Pretoria	3
Spain	
Barcelona	4
Madrid	4
Valencia/Manises	3
Sweden	
Stockholm/Arlanda	6
Switzerland	
Zurich	5
Syria	
Damascus Airport	3
Taiwan	
Tainan	1
Taipei	2
Tanzania	
Dar es Salaam	1
Thailand	
Bangkok	1
Tunisia	
Tunis/El Aouina	3
Turkey	
Adana	3
Ankara/Etimesgut	4
Istanbul/Yesilkoy	4
United Kingdom	
Birmingham (England)	5
Edinburgh (Scotland)	5
Glasgow Apt (Scotland)	5
London/Heathrow (England)	4
Uruguay	
Montevideo/Carrasco	3
Venezuela	
Caracas/Maiquetia	1
Vietnam	
Hanoi/Gialam	1
Saigon (Ho Chi Minh)	1

TABLE B-4 International Climate Zone Definitions

Zone Number	Name	Thermal Criteria
1	Very Hot–Humid (1A), Dry (1B)	9000 < CDD50°F
2	Hot–Humid (2A), Dry (2B)	6300 < CDD50°F ≤ 9000
3A and 3B	Warm–Humid (3A), Dry (3B)	4500 < CDD50°F ≤ 6300
3C	Warm–Marine	CDD50°F ≤ 4500 and HDD65°F ≤ 3600
4A and 4B	Mixed–Humid (4A), Dry (4B)	CDD50°F ≤ 4500 and 3600 < HDD65°F ≤ 5400
4C	Mixed–Marine	3600 < HDD65°F ≤ 5400
5A, 5B and 5C	Cool–Humid (5A), Dry (5B), Marine (5C)	5400 < HDD65°F ≤ 7200
6A and 6B	Cold–Humid (6A), Dry (6B)	7200 < HDD65°F ≤ 9000
7	Very Cold	9000 < HDD65°F ≤ 12600
8	Subarctic	12600 < HDD65°F

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX C METHODOLOGY FOR BUILDING ENVELOPE TRADE-OFF OPTION IN SUBSECTION 5.6

C1. MINIMUM INFORMATION

The following minimum information shall be specified for the *proposed design*.

C1.1 At the Building Level. The floor area, broken down by *space-conditioning categories*, shall be specified.

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

C1.3 For Fenestration. The classification, area, *U-factor*, *SHGC*, VT, overhang *PF* for *vertical fenestration*, and width, depth, and height for *skylight wells* shall be specified. (See Figure C1.3 for definition of width, depth, and height for *skylight wells*.) Each *fenestration* element is associated with a surface (defined in Section C1.2) and has the *orientation* of that surface. For *dynamic glazing*, the *SHGC* and *VT* shall be equal to that determined in accordance with C3.5 for the base envelope design.

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

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

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

C2. OUTPUT REQUIREMENTS

Output reports shall contain the following information.

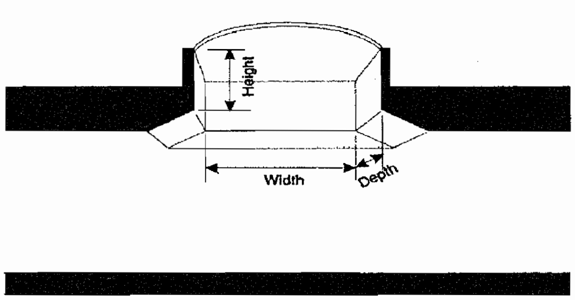


Figure C1.3 Skylight well dimensions.

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

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 AND PROPOSED DESIGN SPECIFICATION

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

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

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

C3.4 For *enclosed spaces* required to comply with Section 5.5.4.2.3, the *skylight area* in the base envelope design shall be 3% of the *roof* area of that *enclosed space*. For *enclosed spaces* required to comply with Section 5.5.4.2.3, the total *daylight area under skylights* in both the base envelope design and the proposed envelope design shall be a minimum of half the floor area. For all other *spaces* the *skylight area* of each *space* category in the base envelope design shall be the same as the proposed envelope design 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, except the *U-factor* for *skylights* in *enclosed spaces* required to comply with Section 5.5.4.2.3 shall be equal to the criteria listed in the Exception to Section 5.5.4.3. The *SHGC* for *fenestration* in the base envelope design shall be equal to the criteria from Tables 5.5-1 through 5.5-8. For portions of those tables where there are no requirements, or for *enclosed spaces* required to comply with Section 5.5.4.2.3, the *SHGC* shall be equal to 0.46 for all *vertical fenestration*, 0.77 for plastic *skylights* on a curb, and 0.72 for all other *skylights* with a curb and without. The VT for *fenestration* in the base envelope design shall be the VT factor from Table C3.5 times the *SHGC* criteria as determined in this subsection. or *enclosed spaces* required to comply with Section 5.5.4.2.3, the VT for *skylights* in that *enclosed space* shall be 0.40.

C3.6 The *roof* of the base envelope design and the *roof* of the proposed envelope design shall both comply with either section 5.5.3.1.1 (a) or (b).

C3.7 *Unconditioned spaces* of the base envelope design and the proposed envelope design shall comply with Section 5.5.4.2.3.

TABLE C3.5 VT Factor for the Base Envelope Design

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

C4. ZONING AND BUILDING GEOMETRY

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

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

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

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

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

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

C5. MODELING ASSUMPTIONS

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

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 70°F for heating and 75°F for cooling, with night *setback* temperatures of 55°F for heating and 99°F 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 50°F for all hours.

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

C5.4 The electrical *systems* shall be the same for both the base envelope design and the *proposed design.* The *LPD* shall be 1.20 W/ft^2 for *nonresidential conditioned spaces*, 1.00 W/ft^2 for *residential conditioned spaces,* and 0.50 W/ft^2 for *semiheated spaces.* The *equipment* power density shall be 0.75 W/ft^2 for *nonresidential conditioned spaces*, 0.25 W/ft^2 for *residential conditioned spaces*, and 0.25 W/ft^2 for *semi-heated spaces. Continuous daylight dimming* shall be assumed in all *spaces* and be activated at 50 fc for *nonresidential conditioned spaces* and *residential conditioned spaces* and 30 fc for *semiheated spaces.*

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

C5.6 The *U-factor* entered for surfaces adjacent to crawlspaces, attics, and parking garages with mechanical or natural *ventilation* shall be adjusted by adding R-2 to the *thermal resistance* to account for the buffering effect.

C5.7 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.*

TABLE C6.1 Input Variables

Variable	Description	I-P Units
$Area_{surface}$	Area of surface	ft^2
$Area_{zone}$	Gross floor area of zone as defined in Section C.5	ft^2
C-factor	C-factor for *below-grade walls*	$Btu/h \cdot ft^2 \cdot °F$
CDD50	CDDs	Base 50°F·day
CDD65	CDDs	Base 65°F·day
CDH80	Cooling degree-hours	Base 80°F·hour
Depth	Depth of bottom of *below-grade wall*	ft
DI	Artificial lighting design illuminance from Section C.5.4	footcandles
DR	Daily range (average outdoor maximum-minimum in hottest month)	°F
EPD	Miscellaneous equipment power density from Section C.5.4	W/ft^2
F-factor	F-factor for slab-on-grade floors	Btu/h·ft·°F
HC	Wall *heat capacity*	$Btu/ft^2 \cdot °F$
HDD50	HDDs	Base 50°F·day
HDD65	HDDs	Base 65°F·day
Length	Length of slab-on-grade floor perimeter	ft
LPD	*LPD* from Section C.5.4	W/ft^2
R-Value	Effective R-value of soil for *below-grade walls*	$h \cdot ft^2 \cdot °F/Btu$
U-factor	U-factor	$Btu/h \cdot ft^2 \cdot °F$
VS	Annual average daily incident solar radiation on vertical surface	$Btu/ft^2 \cdot day$

C6. EQUATIONS FOR ENVELOPE TRADE-OFF CALCULATIONS

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

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

C6.2 Envelope Performance Factor. The *EPF* of a building shall be calculated using Equation C-1 using its actual *orientation*, rotating the entire building 90, 180, and 270 degrees, then averaging the results.

$$EPF = FAF \times [\Sigma HVAC_{surface} + \Sigma Lighting_{zone}] \quad (C\text{-}1)$$

where

$\Sigma HVAC_{surface}$ = sum of HVAC for each surface calculated using Equation C-2

$\Sigma Lighting_{zone}$ = sum of lighting for each zone calculated using Equation C-3

C6.3 HVAC. The HVAC term for each *exterior* or *semi-exterior* surface in the building shall be calculated using Equation C-2.

$$HVAC_{surface} = 0.0939 \times COOL + 1.22 \times HEAT \quad (C\text{-}2)$$

where

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

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

C6.4 Lighting. The lighting term for each zone in the building as defined in Section C4 shall be calculated using Equation C-3.

$$Lighting_{zone} = LPDadj_{zone} \times AREA_{zone} \times 2700 \times 0.939 \quad (C\text{-}3)$$

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.

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

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

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

where

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

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

VT_{vf} = the *visible 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 VA of a *skylight* shall be calculated using Equation C-8.

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

where

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

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

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

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 *LPD*adj.

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

where

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

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

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

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

where

CMC	=	cooling delta load factor
$Area_{mw}$	=	net *opaque area* of this *mass* wall

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

TABLE C6.6 Coefficients for Calculating Kd

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

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

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

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

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	=	$H_9/A_H{}^3 + H_{10}$

TABLE C6.7A Cooling Delta Load Coefficients

	Insulation Position		
Variable	Exterior	Integral	Interior
c_1	220.7245	139.1057	181.6168
c_2	–0.0566	–0.0340	–0.0552
c_3	–118.8354	–10.3267	–34.1590
c_4	–13.6744	–20.8674	–25.5919
c_5	0.2364	0.2839	0.0810
c_6	0.9596	0.3059	1.4190
c_7	–0.2550	0.0226	0.4324
c_8	–905.6780	–307.9438	–1882.9268
c_9	425.1919	80.2096	443.1958
c_{10}	–2.5106	0.0500	0.4302
c_{11}	–43.3880	–5.9895	–28.2851
c_{12}	–259.7234	–11.3961	–63.5623
c_{13}	–33.9755	0.3669	20.8447
c_{14}	20.4882	30.2535	9.8175
c_{15}	–26.2092	8.8337	24.4598
c_{16}	–241.1734	–22.2546	–70.3375
c_{17}	18.8978	29.3297	9.8843
c_{18}	–0.3538	–0.0239	–0.1146
c_{19}	156.3056	63.3228	326.3447
c_{20}	–74.0990	–16.3347	–77.6355
c_{21}	0.4454	–0.0111	–0.0748
c_{22}	7.4967	1.2956	5.2041

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 0.4 Btu/(h·ft^2·°F), then the *U-factor* shall be set to 0.4 Btu/(h·ft^2·°F). If the *U-factor* of the *mass wall* is less than 0.05 Btu/(h·ft^2·°F), then the *U-Factor* shall be set to 0.05 Btu/(h·ft^2·°F). If the *wall HC* of the *mass wall* is greater than 20 Btu/(ft^2·°F), then HC = 20 Btu/(ft^2·°F) shall be used.

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

TABLE C6.7B Heating Delta Load Coefficients

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

northeast is calculated by taking the average of COOL for a north-facing *wall* and COOL for an east-facing *wall*.

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

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

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.

$$COOL = 1000/(1200 \times 12.24) \times [CLU + CLUO + CLXUO + CLM + CLG + CLS + CLC] \quad \text{(C-13)}$$

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

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

where

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

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

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

$$HEAT = 10/(1200 \times 0.608488) \times [HLU + HLUO + HLXUO + HLM + HLG + HLS + HLC] \quad \text{(C-15)}$$

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.

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

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

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

TABLE C6.8.2 Cooling Coefficients for the Exterior Wall Equation

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

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-17 and C-18.

$$HEAT = Area_{sky} \times HDD65 \times (H_2 \times U_{sky} + H_3 \times SHGC/0.86) \quad \text{(C-17)}$$

$$COOL = Area_{sky} \times C_2 \times CDD50 \times SHGC/0.86 \quad \text{(C-18)}$$

where

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

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

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

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

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

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

TABLE C6.8.3 Heating Coefficients for the Exterior Wall Equation

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

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

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.

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

C6.10.3 Calculation of COOL and HEAT. COOL and HEAT shall be calculated for each surface using Equations C-21 and C-22 and coefficients from Table C6.10.2, which depend on surface classification and *space-conditioning category*.

$$COOL = Size \times Factor \times (Ccoef1 \times CDD50 + Ccoef2) \quad (C\text{-}21)$$

$$HEAT = Size \times Hcoef \times Factor \times HDD65 \quad (C\text{-}22)$$

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

TABLE C6.9 Heating and Cooling Coefficients for Skylights

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

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

Depth, ft	R_{soil}, (h·ft²·°F/Btu)
1	0.86
2	1.6
3	2.2
4	2.9
5	3.4
6	4.0
7	4.5
8	5.1
9	5.6
10	6.1

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

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

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX D
CLIMATIC DATA

This normative appendix contains the climatic data necessary to determine *building envelope* and mechanical requirements for various US, Canadian, and international locations. (See Section 5.1.4 for additional information regarding the selection of climatic data.) The following definition applies: N.A. = Not Available.

TABLE D-1 US and US Territory Climatic Data

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	 Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
Alabama (AL)									
Alexander City	32.95 N	85.93 W	640	2910	5102	N.A.	N.A.	N.A.	N.A.
Anniston FAA AP	33.58 N	85.85 W	611	2854	5217	19	93	76	N.A.
Auburn Agronomy Farm	32.60 N	85.50 W	652	2612	5428	N.A.	N.A.	N.A.	N.A.
Birmingham FAA AP	33.57 N	86.75 W	625	2918	5206	18	92	75	760
Dothan	31.32 N	85.45 W	400	1703	6659	28	93	76	N.A.
Gadsden Steam Plant	34.03 N	86.00 W	565	3317	4805	N.A.	N.A.	N.A.	N.A.
Huntsville WSO AP	34.65 N	86.77 W	624	3323	4855	15	92	74	N.A.
Mobile WSO AP	30.68 N	88.25 W	211	1702	6761	26	92	76	774
Montgomery WSO AP	32.30 N	86.40 W	221	2224	5990	24	93	76	734
Selma	32.42 N	87.00 W	147	2249	6080	N.A.	N.A.	N.A.	N.A.
Talladega	33.43 N	86.08 W	555	2790	5097	N.A.	N.A.	N.A.	N.A.
Tuscaloosa FAA AP	33.23 N	87.62 W	169	2661	5624	20	94	77	N.A.
Alaska (AK)									
Anchorage WSCMO AP	61.17 N	150.02 W	114	10,570	688	–14	68	57	521
Barrow WSO AP	71.30 N	156.78 W	31	20,226	0	–41	52	49	N.A.
Fairbanks WSFO AP	64.82 N	147.87 W	436	13,940	1040	–47	77	59	682
Juneau AP	58.37 N	134.58 W	12	8897	559	4	69	58	540
Kodiak WSO AP	57.75 N	152.50 W	111	8817	451	7	65	56	384
Nome WSO AP	64.50 N	165.43 W	13	14,129	274	-31	65	55	210
Arizona (AZ)									
Douglas FAA AP	31.47 N	109.60 W	4098	2767	4786	N.A.	N.A.	N.A.	N.A.
Flagstaff WSO AP	35.13 N	111.67 W	7006	7131	1661	1	83	55	N.A.
Kingman	35.20 N	114.02 W	3539	3212	5040	22	97	63	N.A.
Nogales	31.42 N	110.95 W	3560	2928	4554	N.A.	N.A.	N.A.	N.A.
Phoenix WSFO AP	33.43 N	112.02 W	1110	1350	8425	34	108	70	746

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Arizona cont.)									
Prescott	34.57 N	112.43 W	5205	4995	2875	15	91	60	725
Tucson WSO AP	32.13 N	110.93 W	2584	1678	6921	31	102	65	716
Winslow WSO AP	35.02 N	110.73 W	4890	4776	3681	10	93	60	634
Yuma WSO AP	32.67 N	114.60 W	206	927	8897	40	109	72	697
Arkansas (AR)									
Blytheville AFB	35.97 N	89.95 W	256	3656	5133	12	95	77	N.A.
Camden	33.60 N	92.82 W	116	2953	5309	N.A.	N.A.	N.A.	N.A.
Fayetteville	36.00 N	94.17 W	1250	4040	4452	6	93	75	N.A.
Ft Smith WSO AP	35.33 N	94.37 W	449	3478	5078	13	96	76	547
Hot Springs	34.52 N	93.05 W	680	3181	5243	N.A.	N.A.	N.A.	N.A.
Jonesboro	35.88 N	90.70 W	390	3504	5118	N.A.	N.A.	N.A.	N.A.
Little Rock FAA AP	34.73 N	92.23 W	257	3155	5299	16	95	77	626
Pine Bluff	34.22 N	92.02 W	215	3016	5467	N.A.	N.A.	N.A.	N.A.
Texarkana FAA AP	33.45 N	94.00 W	361	2295	6152	20	95	77	N.A.
California (CA)									
Bakersfield WSO AP	35.42 N	119.05 W	495	2182	6049	32	101	69	848
Blythe FAA Airport	33.62 N	114.72 W	390	1144	8789	N.A.	N.A.	N.A.	N.A.
Burbank Hollywood	34.20 N	118.37 W	774	1204	5849	39	95	69	N.A.
Chico University Farm	39.70 N	121.82 W	185	2953	4454	N.A.	N.A.	N.A.	N.A.
Crescent City	41.77 N	124.20 W	40	4397	1628	N.A.	N.A.	N.A.	N.A.
El Centro	32.77 N	115.57 W	–30	1156	8132	N.A.	N.A.	N.A.	N.A.
Eureka WSO City	40.80 N	124.17 W	60	4496	1529	N.A.	N.A.	N.A.	N.A.
Fairfield/Travis AFB	38.27 N	121.93 W	62	2556	4223	31	94	67	N.A.
Fresno WSO AP	36.77 N	119.72 W	328	2556	5350	30	101	70	785
Laguna Beach	33.55 N	117.78 W	35	2157	3881	N.A.	N.A.	N.A.	N.A.
Livermore	37.67 N	121.77 W	480	2909	3810	N.A.	N.A.	N.A.	N.A.
Lompoc	34.65 N	120.45 W	95	2651	3240	N.A.	N.A.	N.A.	N.A.
Long Beach WSO AP	33.82 N	118.15 W	34	1430	5281	40	88	67	1502
Los Angeles WSO AP	33.93 N	118.38 W	100	1458	4777	43	81	64	1849
Merced/Castle AFB	37.37 N	120.57 W	187	2687	4694	30	97	69	N.A.
Monterey	36.60 N	121.90 W	385	3125	2574	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(California cont.)									
Napa State Hospital	38.28 N	122.27 W	60	2844	3463	N.A.	N.A.	N.A.	N.A.
Needles FAA Airport	34.77 N	114.62 W	914	1309	8645	N.A.	N.A.	N.A.	N.A.
Oakland/Intl	37.73 N	122.20 W	7	2644	3126	N.A.	N.A.	N.A.	1905
Oceanside Marina	33.22 N	117.40 W	10	2010	4069	N.A.	N.A.	N.A.	N.A.
Ontario/Intl	34.05 N	117.62 W	961	1488	5823	35	98	70	N.A.
Oxnard	34.20 N	119.18 W	49	1992	3980	39	79	64	N.A.
Palm Springs	33.83 N	116.50 W	425	985	8555	N.A.	N.A.	N.A.	N.A.
Palmdale	34.58 N	118.10 W	2596	2948	4863	N.A.	N.A.	N.A.	N.A.
Pasadena	34.15 N	118.15 W	864	1453	5476	N.A.	N.A.	N.A.	N.A.
Petaluma Fire Stn 3	38.23 N	122.63 W	27	3050	3188	N.A.	N.A.	N.A.	N.A.
Pomona Cal Poly	34.07 N	117.82 W	740	1713	5145	N.A.	N.A.	N.A.	N.A.
Redding WSO	40.50 N	122.30 W	502	2855	4964	N.A.	N.A.	N.A.	N.A.
Redlands	34.05 N	117.18 W	1318	1875	5435	N.A.	N.A.	N.A.	N.A.
Richmond	37.93 N	122.35 W	55	2574	3285	N.A.	N.A.	N.A.	N.A.
Riverside/March AFB	33.90 N	117.25 W	1535	1861	5295	34	98	68	N.A.
Sacramento FAA AP	38.52 N	121.50 W	18	2749	4474	30	97	68	990
Salinas FAA AP	36.67 N	121.60 W	69	2964	2951	33	78	62	N.A.
San Bernardino/Norton	34.10 N	117.23 W	1155	1821	5450	34	101	70	N.A.
San Diego WSO AP	32.73 N	117.17 W	13	1256	5223	44	81	67	1911
San Francisco WSO AP	37.62 N	122.38 W	8	3016	2883	37	78	62	1796
San Jose	37.35 N	121.90 W	67	2387	3935	35	89	66	N.A.
San Luis Obispo Poly	35.30 N	120.67 W	315	2498	3492	N.A.	N.A.	N.A.	N.A.
Santa Ana Fire Station	33.75 N	117.87 W	135	1238	5430	N.A.	N.A.	N.A.	N.A.
Santa Barbara FAA AP	34.43 N	119.83 W	9	2438	3449	34	80	64	N.A.
Santa Cruz	36.98 N	122.02 W	130	2969	2913	N.A.	N.A.	N.A.	N.A.
Santa Maria WSO AP	34.90 N	120.45 W	254	2984	2918	32	82	62	2016
Santa Monica Pier	34.00 N	118.50 W	14	1819	4145	N.A.	N.A.	N.A.	N.A.
Santa Paula	34.32 N	119.15 W	237	2039	4114	N.A.	N.A.	N.A.	N.A.
Santa Rosa	38.45 N	122.70 W	167	2883	3432	N.A.	N.A.	N.A.	N.A.
Stockton WSO AP	37.90 N	121.25 W	22	2707	4755	30	97	68	N.A.
Ukiah	39.15 N	123.20 W	623	2954	3868	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(California cont.)									
Visalia	36.33 N	119.30 W	325	2511	5186	N.A.	N.A.	N.A.	N.A.
Yreka	41.72 N	122.63 W	2625	5386	2611	N.A.	N.A.	N.A.	N.A.
Colorado (CO)									
Alamosa WSO AP	37.45 N	105.87 W	7536	8749	1374	–17	82	55	N.A.
Boulder	40.03 N	105.28 W	5420	5554	2820	N.A.	N.A.	N.A.	N.A.
Colorado Sprgs WSO AP	38.82 N	104.72 W	6090	6415	2312	–2	87	58	725
Denver WSFO AP	39.77 N	104.87 W	5286	6020	2732	–3	90	59	739
Durango	37.28 N	107.88 W	6600	6911	1942	N.A.	N.A.	N.A.	N.A.
Ft Collins	40.58 N	105.08 W	5004	6368	2411	N.A.	N.A.	N.A.	N.A.
Grand Junction WSO AP	39.10 N	108.55 W	4849	5548	3632	2	94	60	518
Greeley UNC	40.42 N	104.70 W	4715	6306	2698	N.A.	N.A.	N.A.	N.A.
La Junta FAA AP	38.05 N	103.52 W	4190	5265	3795	N.A.	N.A.	N.A.	N.A.
Pueblo WSO AP	38.28 N	104.52 W	4640	5413	3358	–1	94	62	720
Sterling	40.62 N	103.22 W	3938	6541	2809	N.A.	N.A.	N.A.	N.A.
Trinidad FAA AP	37.25 N	104.33 W	5746	5483	2976	–2	90	60	N.A.
Connecticut (CT)									
Bridgeport WSO AP	41.17 N	73.13 W	10	5537	2997	8	84	72	N.A.
Hartford-Brainard Fld	41.73 N	72.65 W	15	6155	2768	2	88	72	598
Norwalk Gas Plant	41.12 N	73.42 W	37	5865	2768	N.A.	N.A.	N.A.	N.A.
Norwich Pub Util Plt	41.53 N	72.07 W	20	5869	2687	N.A.	N.A.	N.A.	N.A.
Delaware (DE)									
Dover	39.15 N	75.52 W	30	4337	3894	14	89	75	N.A.
Wilmington WSO AP	39.67 N	75.60 W	79	4937	3557	10	89	74	617
Florida (FL)									
Belle Glade Exp Stn	26.67 N	80.63 W	16	451	8285	N.A.	N.A.	N.A.	N.A.
Daytona Beach WSO AP	29.18 N	81.05 W	29	909	7567	34	90	77	641
Ft Lauderdale	26.07 N	80.15 W	10	171	9735	46	90	78	N.A.
Ft Myers FAA AP	26.58 N	81.87 W	15	418	8924	42	93	77	N.A.
Ft Pierce	27.47 N	80.35 W	25	490	8448	N.A.	N.A.	N.A.	N.A.
Gainesville Mun AP	29.68 N	82.27 W	138	1267	7009	30	92	77	N.A.
Jacksonville WSO AP	30.50 N	81.70 W	26	1434	6847	29	93	77	674

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Florida cont.)									
Key West WSO AP	24.55 N	81.75 W	4	100	10,174	55	89	79	N.A.
Lakeland	28.02 N	81.92 W	145	588	8472	N.A.	N.A.	N.A.	N.A.
Miami WSCMO AP	25.80 N	80.30 W	12	200	9474	46	90	77	259
Ocala	29.20 N	82.08 W	75	930	7696	N.A.	N.A.	N.A.	N.A.
Orlando WSO Mc Coy	28.43 N	81.33 W	91	686	8227	37	93	76	571
Panama City/Tyndall	30.07 N	85.58 W	16	1216	7023	33	89	79	N.A.
Pensacola FAA AP	30.47 N	87.20 W	112	1617	6816	28	92	78	N.A.
St Augustine WFOY	29.90 N	81.32 W	8	1040	7261	N.A.	N.A.	N.A.	N.A.
St Petersburg	27.77 N	82.63 W	8	603	8537	43	93	79	N.A.
Tallahassee WSO AP	30.38 N	84.37 W	55	1705	6639	25	93	76	747
Tampa WSCMO AP	27.97 N	82.53 W	19	725	8239	36	91	77	592
West Palm Beach WSO AP	26.68 N	80.12 W	18	323	9049	43	90	78	308
Georgia (GA)									
Albany	31.53 N	84.13 W	180	2205	6020	27	95	76	N.A.
Americus	32.05 N	84.25 W	490	2430	5634	N.A.	N.A.	N.A.	N.A.
Athens WSO AP	33.95 N	83.32 W	802	2893	5079	20	92	75	N.A.
Atlanta WSO AP	33.65 N	84.43 W	1010	2991	5038	18	91	74	749
Augusta WSO AP	33.37 N	81.97 W	148	2565	5519	21	94	76	774
Brunswick	31.17 N	81.50 W	13	1578	6729	30	91	79	N.A.
Columbus WSO AP	32.52 N	84.95 W	449	2261	6052	23	93	75	N.A.
Dalton	34.75 N	84.95 W	700	3552	4546	N.A.	N.A.	N.A.	N.A.
Dublin	32.50 N	82.90 W	215	2476	5664	N.A.	N.A.	N.A.	N.A.
Gainesville	34.30 N	83.85 W	1170	3500	4310	N.A.	N.A.	N.A.	N.A.
La Grange	33.05 N	85.02 W	715	2667	5216	N.A.	N.A.	N.A.	N.A.
Macon WSO AP	32.70 N	83.65 W	354	2334	5826	23	94	75	787
Savannah WSO AP	32.13 N	81.20 W	46	1847	6389	26	93	76	N.A.
Valdosta/Moody AFB	30.97 N	83.20 W	233	1552	7216	30	94	77	N.A.
Waycross	31.25 N	82.32 W	145	2025	6172	29	94	76	N.A.
Hawaii (HI)									
Hilo (Hawaii)	19.72 N	155.07 W	36	0	8759	61	84	74	153
Honolulu WSFO AP (Oahu)	21.33 N	157.92 W	7	0	9949	61	88	73	69
Kaneohe Mauka (Oahu)	21.42 N	157.82 W	190	0	8955	67	85	74	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
Idaho (ID)									
Boise WSFO AP	43.57 N	116.22 W	2838	5861	2807	2	94	63	647
Burley FAA AP	42.53 N	113.77 W	4157	6745	2174	–5	90	62	N.A.
Coeur D'Alene R S	47.68 N	116.75 W	2158	6239	2216	N.A.	N.A.	N.A.	N.A.
Idaho Falls FAA AP	43.52 N	112.07 W	4730	8063	1853	–12	89	60	N.A.
Lewiston WSO AP	46.38 N	117.02 W	1436	5270	2964	6	93	64	748
Moscow-Univ of Idaho	46.73 N	116.97 W	2660	6782	1789	N.A.	N.A.	N.A.	N.A.
Mountain Home	43.13 N	115.70 W	3190	6176	2725	0	96	62	N.A.
Pocatello WSO AP	42.92 N	112.60 W	4454	7180	2142	–7	90	60	546
Twin Falls WSO	42.55 N	114.35 W	3960	6769	1995	N.A.	N.A.	N.A.	N.A.
Illinois (IL)									
Aurora	41.75 N	88.35 W	644	6699	2880	N.A.	N.A.	N.A.	N.A.
Belleville/Scott AFB	38.55 N	89.85 W	453	4878	4146	3	93	77	N.A.
Carbondale Sewage Plt	37.73 N	89.17 W	390	4865	3934	N.A.	N.A.	N.A.	N.A.
Champaign	40.03 N	88.28 W	755	5689	3697	N.A.	N.A.	N.A.	N.A.
Chicago Midway AP	41.73 N	87.77 W	620	6176	3251	N.A.	N.A.	N.A.	N.A.
Chicago O'Hare WSO AP	41.98 N	87.90 W	674	6536	2941	–6	88	73	613
Chicago University	41.78 N	87.60 W	594	5753	3391	N.A.	N.A.	N.A.	N.A.
Danville	40.13 N	87.65 W	558	5610	3471	–4	90	77	N.A.
Decatur	39.83 N	89.02 W	620	5522	3652	–2	91	75	N.A.
Dixon	41.83 N	89.52 W	700	6873	2965	N.A.	N.A.	N.A.	N.A.
Freeport Waste Wtr Plt	42.30 N	89.60 W	750	7169	2739	N.A.	N.A.	N.A.	N.A.
Galesburg	40.95 N	90.38 W	771	6314	3249	N.A.	N.A.	N.A.	N.A.
Joliet Brandon Rd Dam	41.50 N	88.10 W	543	6463	3025	N.A.	N.A.	N.A.	N.A.
Moline WSO AP	41.45 N	90.50 W	582	6474	3207	–8	90	74	640
Mt Vernon	38.35 N	88.87 W	490	5189	3818	N.A.	N.A.	N.A.	N.A.
Peoria WSO AP	40.67 N	89.68 W	650	6148	3339	–6	89	74	N.A.
Quincy FAA AP	39.93 N	91.20 W	763	5763	3574	–4	91	75	N.A.
Rantoul	40.32 N	88.17 W	740	6183	3288	N.A.	N.A.	N.A.	N.A.
Rockford WSO AP	42.20 N	89.10 W	724	6969	2852	–10	88	73	N.A.
Springfield WSO AP	39.85 N	89.68 W	594	5688	3635	–4	91	75	600
Waukegan	42.35 N	87.88 W	700	7136	2515	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	 Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
Indiana (IN)									
Anderson Sewage Plant	40.10 N	85.72 W	847	5916	3091	N.A.	N.A.	N.A.	N.A.
Bloomington Indiana U	39.17 N	86.52 W	825	5309	3585	N.A.	N.A.	N.A.	N.A.
Columbus	39.20 N	85.92 W	621	5536	3353	N.A.	N.A.	N.A.	N.A.
Evansville WSO AP	38.05 N	87.53 W	380	4708	4074	3	92	76	611
Ft Wayne WSO AP	41.00 N	85.20 W	797	6273	3077	–4	88	73	601
Goshen College	41.57 N	85.83 W	805	6282	2941	N.A.	N.A.	N.A.	N.A.
Hobart	41.53 N	87.25 W	600	6043	3168	N.A.	N.A.	N.A.	N.A.
Indianapolis WSFO	39.73 N	86.27 W	792	5615	3453	–3	88	74	N.A.
Kokomo	40.42 N	86.05 W	855	6429	2978	N.A.	N.A.	N.A.	N.A.
Lafayette	40.35 N	86.87 W	600	6228	3069	–5	90	75	N.A.
Marion	40.57 N	85.67 W	790	6260	2996	N.A.	N.A.	N.A.	N.A.
Muncie Ball State Univ	40.22 N	85.42 W	940	6027	3196	N.A.	N.A.	N.A.	N.A.
Peru/Grissom AFB	40.65 N	86.15 W	814	5908	3439	–3	89	75	N.A.
Richmond Wtr Wks	39.88 N	84.88 W	1015	5963	3004	N.A.	N.A.	N.A.	N.A.
Shelbyville Sewage Plt	39.52 N	85.78 W	750	5784	3291	N.A.	N.A.	N.A.	N.A.
South Bend WSO AP	41.70 N	86.32 W	773	6331	2920	–2	87	72	635
Terre Haute	39.35 N	87.42 W	555	5581	3490	–3	90	76	N.A.
Valparaiso Waterworks	41.52 N	87.03 W	800	6267	2942	N.A.	N.A.	N.A.	N.A.
Iowa (IA)									
Ames	42.03 N	93.80 W	1099	6776	3079	N.A.	N.A.	N.A.	N.A.
Burlington	40.78 N	91.12 W	597	5943	3601	–4	91	76	649
Cedar Rapids FAA AP	41.88 N	91.70 W	863	6924	3003	–11	89	74	N.A.
Clinton	41.80 N	90.27 W	585	6324	3291	N.A.	N.A.	N.A.	N.A.
Des Moines WSFO AP	41.53 N	93.65 W	938	6497	3371	–9	90	74	667
Dubuque WSO AP	42.40 N	90.70 W	1065	7327	2672	N.A.	N.A.	N.A.	N.A.
Ft Dodge	42.50 N	94.20 W	1115	7261	2902	–13	88	73	N.A.
Iowa City	41.65 N	91.53 W	640	6227	3434	N.A.	N.A.	N.A.	N.A.
Keokuk Lock and Dam	40.40 N	91.37 W	527	5969	3467	N.A.	N.A.	N.A.	N.A.
Marshalltown	42.07 N	92.93 W	870	7170	2813	N.A.	N.A.	N.A.	N.A.
Mason City FAA AP	43.17 N	93.33 W	1194	7837	2653	–15	88	73	610

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Iowa cont.)									
Newton	41.70 N	93.05 W	938	6783	3131	N.A.	N.A.	N.A.	N.A.
Ottumwa Airport	41.10 N	92.45 W	842	6269	3414	–5	92	75	N.A.
Sioux City WSO AP	42.40 N	96.38 W	1103	6893	3149	–11	90	74	602
Waterloo WSO AP	42.55 N	92.40 W	868	7406	2813	–14	88	73	N.A.
Kansas (KS)									
Atchison	39.57 N	95.12 W	945	5184	3940	N.A.	N.A.	N.A.	N.A.
Chanute FAA Airport	37.67 N	95.48 W	978	4650	4226	N.A.	N.A.	N.A.	N.A.
Dodge City WSO AP	37.77 N	99.97 W	2582	5001	4090	0	97	70	637
El Dorado	37.82 N	96.83 W	1340	4587	4317	N.A.	N.A.	N.A.	N.A.
Garden City FAA AP	37.93 N	100.72 W	2882	5216	3936	–3	97	69	N.A.
Goodland WSO AP	39.37 N	101.70 W	3650	5974	3018	–3	94	66	625
Great Bend	38.35 N	98.77 W	1850	4679	4425	N.A.	N.A.	N.A.	N.A.
Hutchinson	37.93 N	98.03 W	1570	5103	4106	N.A.	N.A.	N.A.	N.A.
Liberal	37.05 N	100.92 W	2834	4706	4185	N.A.	N.A.	N.A.	N.A.
Manhattan	39.20 N	96.58 W	1065	5043	4155	N.A.	N.A.	N.A.	N.A.
Parsons	37.37 N	95.28 W	910	4606	4339	N.A.	N.A.	N.A.	N.A.
Russell FAA AP	38.87 N	98.82 W	1864	5338	3939	–4	96	72	N.A.
Salina FAA AP	38.80 N	97.63 W	1257	5101	4167	–3	97	73	N.A.
Topeka WSFO AP	39.07 N	95.63 W	877	5265	3880	–2	93	75	608
Wichita WSO AP	37.65 N	97.43 W	1321	4791	4351	2	97	73	N.A.
Kentucky (KY)									
Ashland	38.45 N	82.62 W	555	5225	3280	N.A.	N.A.	N.A.	N.A.
Bowling Green FAA AP	36.97 N	86.42 W	547	4328	4132	7	91	75	N.A.
Covington WSO AP	39.07 N	84.67 W	869	5248	3488	1	89	73	661
Hopkinsville/Campbell	36.67 N	87.50 W	571	3928	4654	N.A.	N.A.	N.A.	N.A.
Lexington WSO AP	38.03 N	84.60 W	966	4783	3754	4	89	73	618
Louisville WSFO AP	38.18 N	85.73 W	477	4514	4000	6	90	75	636
Madisonville	37.35 N	87.52 W	440	4167	4290	N.A.	N.A.	N.A.	N.A.
Owensboro	37.77 N	87.15 W	405	4334	4222	N.A.	N.A.	N.A.	N.A.
Paducah WSO	37.07 N	88.77 W	410	4279	4317	7	93	76	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
Louisiana (LA)									
Alexandria	31.32 N	92.47 W	87	2003	6407	27	94	78	N.A.
Baton Rouge WSO AP	30.53 N	91.13 W	64	1669	6845	27	92	77	677
Bogalusa	30.78 N	89.87 W	100	1911	6457	N.A.	N.A.	N.A.	N.A.
Houma	29.58 N	90.73 W	15	1429	6974	N.A.	N.A.	N.A.	N.A.
Lafayette FAA AP	30.20 N	91.98 W	38	1587	6877	28	93	78	N.A.
Lake Charles WSO AP	30.12 N	93.22 W	9	1616	6813	29	91	78	668
Minden	32.58 N	93.28 W	185	2533	5823	N.A.	N.A.	N.A.	N.A.
Monroe FAA AP	32.52 N	92.05 W	78	2407	6039	22	94	78	N.A.
Natchitoches	31.77 N	93.08 W	130	2152	6273	N.A.	N.A.	N.A.	N.A.
New Orleans WSCMO AP	29.98 N	90.25 W	4	1513	6910	30	92	78	789
Shreveport WSO AP	32.47 N	93.82 W	254	2,264	6166	22	95	77	697
Maine (ME)									
Augusta FAA AP	44.32 N	69.80 W	350	7550	2093	–3	84	69	N.A.
Bangor FAA AP	44.80 N	68.82 W	163	7930	1916	–7	84	69	669
Caribou WSO AP	46.87 N	68.02 W	624	9651	1470	–14	82	67	692
Lewiston	44.10 N	70.22 W	180	7244	2261	N.A.	N.A.	N.A.	N.A.
Millinocket	45.65 N	68.70 W	360	8902	1708	N.A.	N.A.	N.A.	N.A.
Portland WSMO AP	43.65 N	70.32 W	57	7378	1943	–3	83	70	665
Waterville Pmp Stn	44.55 N	69.65 W	90	7382	2180	N.A.	N.A.	N.A.	N.A.
Maryland (MD)									
Baltimore WSO AP	39.18 N	76.67 W	196	4707	3709	11	91	74	N.A.
Cumberland	39.63 N	78.75 W	730	5036	3432	N.A.	N.A.	N.A.	N.A.
Hagerstown	39.65 N	77.73 W	660	5293	3341	N.A.	N.A.	N.A.	N.A.
Salisbury	38.37 N	75.58 W	10	4027	4002	13	90	76	N.A.
Massachusetts (MA)									
Boston WSO AP	42.37 N	71.03 W	20	5641	2897	7	87	71	713
Clinton	42.40 N	71.68 W	398	6698	2457	N.A.	N.A.	N.A.	N.A.
Framingham	42.28 N	71.42 W	170	6262	2695	N.A.	N.A.	N.A.	N.A.
Lawrence	42.70 N	71.17 W	57	6322	2648	N.A.	N.A.	N.A.	N.A.
Lowell	42.65 N	71.37 W	110	6339	2715	N.A.	N.A.	N.A.	N.A.
New Bedford	41.63 N	70.93 W	120	5426	2973	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Massachusetts cont.)									
Springfield	42.10 N	72.58 W	190	5754	3037	N.A.	N.A.	N.A.	N.A.
Taunton	41.90 N	71.07 W	20	6346	2461	N.A.	N.A.	N.A.	N.A.
Worcester WSO AP	42.27 N	71.87 W	986	6979	2203	0	83	69	N.A.
Michigan (MI)									
Adrian	41.92 N	84.02 W	760	6737	2586	N.A.	N.A.	N.A.	N.A.
Alpena WSO AP	45.07 N	83.57 W	689	8284	1779	–7	84	69	695
Battle Creek/Kellogg	42.30 N	85.23 W	942	6416	3399	N.A.	N.A.	N.A.	N.A.
Benton Harbor AP	42.13 N	86.43 W	649	6303	2829	N.A.	N.A.	N.A.	N.A.
Detroit City Airport	42.42 N	83.02 W	625	6167	3046	0	87	72	N.A.
Escanaba	45.75 N	87.03 W	600	8593	1664	N.A.	N.A.	N.A.	N.A.
Flint WSO AP	42.97 N	83.75 W	766	6979	2451	–2	86	71	634
Grand Rapids WSO AP	42.88 N	85.52 W	707	6973	2537	0	86	71	622
Holland	42.80 N	86.12 W	610	6747	2536	N.A.	N.A.	N.A.	N.A.
Jackson FAA AP	42.27 N	84.45 W	1005	6791	2707	–3	86	73	N.A.
Kalamazoo State Hosp	42.28 N	85.60 W	945	6230	3015	N.A.	N.A.	N.A.	N.A.
Lansing WSO AP	42.77 N	84.60 W	841	7101	2449	–3	86	72	N.A.
Marquette	46.55 N	87.38 W	665	8356	1730	–13	82	67	N.A.
Mt Pleasant University	43.58 N	84.77 W	796	7436	2319	N.A.	N.A.	N.A.	N.A.
Muskegon WSO AP	43.17 N	86.23 W	628	6924	2361	3	83	70	N.A.
Pontiac State Hospital	42.65 N	83.30 W	982	6653	2770	N.A.	N.A.	N.A.	N.A.
Port Huron	42.98 N	82.42 W	590	6898	2541	N.A.	N.A.	N.A.	N.A.
Saginaw FAA AP	43.53 N	84.08 W	660	7139	2476	0	87	72	N.A.
Sault Ste Marie WSO	46.47 N	84.37 W	724	9316	1421	–12	80	68	733
Traverse City FAA AP	44.73 N	85.58 W	623	7749	2127	–3	86	70	679
Ypsilanti East Mich U	42.25 N	83.62 W	779	6466	2878	N.A.	N.A.	N.A.	N.A.
Minnesota (MN)									
Albert Lea	43.62 N	93.42 W	1230	8146	2608	N.A.	N.A.	N.A.	N.A.
Alexandria FAA AP	45.87 N	95.38 W	1416	8999	2316	–20	86	70	N.A.
Bemidji Airport	47.50 N	94.93 W	1377	10200	1781	N.A.	N.A.	N.A.	N.A.
Brainerd	46.37 N	94.20 W	1180	9437	1958	–24	85	68	N.A.
Duluth WSO AP	46.83 N	92.18 W	1428	9818	1536	–21	81	67	650

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature: Dry-Bulb	Cooling Design Temperature: Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Minnesota cont.)									
Faribault	44.30 N	93.27 W	940	8279	2498	N.A.	N.A.	N.A.	N.A.
International Falls WSO AP	48.57 N	93.38 W	1179	10,487	1630	–29	83	67	656
Mankato	44.15 N	94.02 W	836	8005	2691	N.A.	N.A.	N.A.	N.A.
Minneapolis-St Paul WSO AP	44.88 N	93.22 W	834	7981	2680	–16	88	71	566
Rochester WSO AP	43.92 N	92.50 W	1297	8250	2376	–17	85	71	652
St Cloud WSO AP	45.55 N	94.07 W	1037	8928	2149	–20	88	71	N.A.
Virginia	47.50 N	92.55 W	1435	10,024	1583	N.A.	N.A.	N.A.	N.A.
Willmar State Hospital	45.13 N	95.02 W	1128	8637	2465	N.A.	N.A.	N.A.	N.A.
Winona	44.05 N	91.63 W	652	7694	2695	N.A.	N.A.	N.A.	N.A.
Mississippi (MS)									
Biloxi/Keesler AFB	30.42 N	88.92 W	26	1486	6946	31	91	78	N.A.
Clarksdale	34.20 N	90.57 W	173	3188	5357	N.A.	N.A.	N.A.	N.A.
Columbus AFB	33.65 N	88.45 W	220	2769	5565	20	94	78	N.A.
Greenville	33.38 N	91.02 W	132	2778	5661	N.A.	N.A.	N.A.	N.A.
Greenwood FAA AP	33.50 N	90.08 W	155	2698	5760	20	94	78	N.A.
Hattiesburg	31.32 N	89.30 W	161	2180	6085	N.A.	N.A.	N.A.	N.A.
Jackson WSFO AP	32.32 N	90.08 W	330	2467	5900	21	93	76	640
Laurel	31.68 N	89.12 W	225	2327	5893	N.A.	N.A.	N.A.	N.A.
McComb FAA AP	31.23 N	90.47 W	413	2115	6025	23	92	76	N.A.
Meridian WSO AP	32.33 N	88.75 W	294	2444	5804	21	94	76	719
Natchez	31.55 N	91.38 W	195	1903	6378	N.A.	N.A.	N.A.	N.A.
Tupelo WSO AP	34.27 N	88.73 W	361	3079	5224	18	94	76	N.A.
Vicksburg Military Pk	32.35 N	90.85 W	255	2196	6059	N.A.	N.A.	N.A.	N.A.
Missouri (MO)									
Cape Girardeau FAA AP	37.23 N	89.57 W	337	4386	4359	6	94	77	N.A.
Columbia WSO AP	38.82 N	92.22 W	887	5212	3752	–1	92	75	633
Farmington	37.70 N	90.38 W	935	5041	3653	N.A.	N.A.	N.A.	N.A.
Hannibal	39.72 N	91.37 W	712	5628	3685	N.A.	N.A.	N.A.	N.A.
Jefferson City Wtr Plt	38.58 N	92.15 W	670	5302	3705	N.A.	N.A.	N.A.	N.A.
Joplin FAA AP	37.17 N	94.50 W	980	4303	4417	3	94	75	N.A.
Kansas City WSO AP	39.32 N	94.72 W	973	5393	3852	–1	93	75	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Missouri cont.)									
Kirksville Radio KIRX	40.22 N	92.58 W	970	5867	3494	N.A.	N.A.	N.A.	N.A.
Mexico	39.18 N	91.88 W	775	5590	3664	N.A.	N.A.	N.A.	N.A.
Moberly Radio KWIX	39.40 N	92.43 W	840	5204	3948	N.A.	N.A.	N.A.	N.A.
Poplar Bluff R S	36.77 N	90.42 W	380	4328	4368	8	92	76	N.A.
Rolla	38.13 N	91.77 W	1148	4748	4186	N.A.	N.A.	N.A.	N.A.
Rolla Univ of MO	37.95 N	91.77 W	1180	4959	3986	N.A.	N.A.	N.A.	N.A.
St Joseph	39.77 N	94.92 W	811	5590	3783	N.A.	N.A.	N.A.	N.A.
St Louis WSCMO AP	38.75 N	90.37 W	535	4758	4283	2	93	75	N.A.
Montana (MT)									
Billings WSO AP	45.80 N	108.53 W	3567	7164	2466	–13	90	62	617
Bozeman	45.82 N	110.88 W	5950	9908	672	–20	87	60	N.A.
Butte FAA AP	45.95 N	112.50 W	5540	9517	1152	–22	84	56	N.A.
Cut Bank FAA AP	48.60 N	112.37 W	3838	8904	1475	–21	84	59	672
Glasgow WSO AP	48.22 N	106.62 W	2284	8745	2244	–22	90	63	570
Glendive	47.10 N	104.72 W	2076	8178	2619	N.A.	N.A.	N.A.	N.A.
Great Falls WSCMO AP	47.48 N	111.37 W	3663	7741	1993	–19	88	60	641
Havre WSO AP	48.55 N	109.77 W	2584	8447	2132	–25	90	62	N.A.
Helena WSO AP	46.60 N	112.00 W	3893	8031	1922	–18	87	59	651
Kalispell WSO AP	48.30 N	114.27 W	2965	8378	1345	–12	86	61	N.A.
Lewistown FAA AP	47.07 N	109.45 W	4132	8479	1580	–18	86	60	673
Livingston FAA AP	45.70 N	110.45 W	4653	7220	1900	N.A.	N.A.	N.A.	N.A.
Miles City FAA AP	46.43 N	105.87 W	2628	7796	2680	–19	93	65	565
Missoula WSO AP	46.92 N	114.08 W	3190	7792	1679	–9	88	61	658
Nebraska (NE)									
Chadron FAA AP	42.83 N	03.08 W	3312	7020	2692	N.A.	N.A.	N.A.	N.A.
Columbus	41.47 N	97.33 W	1450	6543	3345	N.A.	N.A.	N.A.	N.A.
Fremont	41.43 N	96.48 W	1180	6140	3421	N.A.	N.A.	N.A.	N.A.
Grand Island WSO AP	40.97 N	98.32 W	1841	6421	3243	–8	93	72	611
Hastings	40.58 N	98.35 W	1925	6506	3217	N.A.	N.A.	N.A.	N.A.
Kearney	40.73 N	99.02 W	2130	6548	3090	N.A.	N.A.	N.A.	N.A.
Lincoln WSO AP	40.85 N	96.75 W	1190	6278	3455	–7	94	74	N.A.
Mc Cook	40.22 N	100.58 W	2580	6115	3236	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Nebraska cont.)									
Norfolk WSO AP	41.98 N	97.43 W	1551	6873	3072	–11	92	72	N.A.
North Platte WSO AP	41.13 N	100.68 W	2775	6859	2737	–10	92	69	592
Omaha (Eppley Field)	41.30 N	95.90 W	980	6300	3398	–7	92	75	N.A.
Scottsbluff WSO AP	41.87 N	103.60 W	3945	6729	2680	–11	92	64	620
Sidney	41.23 N	103.00 W	4,320	6966	2409	–8	92	63	N.A.
Nevada (NV)									
Carson City	39.15 N	119.77 W	4651	5691	2312	N.A.	N.A.	N.A.	N.A.
Elko FAA AP	40.83 N	115.78 W	5075	7077	2144	–5	92	59	569
Ely WSO AP	39.28 N	114.85 W	6262	7621	1717	–6	87	56	683
Las Vegas WSO AP	36.08 N	115.17 W	2162	2407	6745	27	106	66	719
Lovelock FAA AP	40.07 N	118.55 W	3900	5869	2886	N.A.	N.A.	N.A.	606
Reno WSFO AP	39.50 N	119.78 W	4404	5674	2504	8	92	60	752
Tonopah AP	38.07 N	117.08 W	5426	5733	2840	7	92	57	660
Winnemucca WSO AP	40.90 N	117.80 W	4297	6315	2379	1	94	60	608
New Hampshire (NH)									
Berlin	44.45 N	71.18 W	930	8645	1718	N.A.	N.A.	N.A.	N.A.
Concord WSO AP	43.20 N	71.50 W	346	7554	2087	–8	87	70	683
Keene	42.92 N	72.27 W	480	6948	2398	N.A.	N.A.	N.A.	N.A.
Portsmouth/Pease AFB	43.08 N	70.82 W	102	6572	2418	4	85	70	N.A.
New Jersey (NJ)									
Atlantic City WSO AP	39.45 N	74.57 W	138	5169	3198	8	88	73	N.A.
Long Branch Oakhurst	40.27 N	74.00 W	30	5253	3057	N.A.	N.A.	N.A.	N.A.
Newark WSO AP	40.70 N	74.17 W	30	4888	3748	10	90	73	644
New Mexico (NM)									
Alamogordo/Holloman	32.85 N	106.10 W	4094	3232	4726	20	96	63	N.A.
Albuquerque WSFO AP	35.05 N	106.62 W	5326	4425	3908	13	93	60	703
Artesia	32.77 N	104.38 W	3320	3527	4583	N.A.	N.A.	N.A.	N.A.
Carlsbad FAA AP	32.33 N	104.27 W	3232	2812	5512	19	98	66	N.A.
Clovis/Cannon AFB	34.38 N	103.32 W	4295	3983	4178	10	93	64	N.A.
Farmington	36.73 N	108.23 W	5502	5464	3307	8	92	60	N.A.
Gallup FAA AP	35.52 N	108.78 W	6468	6244	2355	–1	87	56	N.A.
Grants Airport	35.17 N	107.90 W	6520	5907	2481	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	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. 55 < Tdb < 69
(New Mexico cont.)									
Hobbs	32.70 N	103.13 W	3615	2851	5160	N.A.	N.A.	N.A.	N.A.
Raton Filter Plant	36.92 N	104.43 W	6932	6103	2187	N.A.	N.A.	N.A.	N.A.
Roswell FAA AP	33.30 N	104.53 W	3669	3267	4962	14	96	65	677
Socorro	34.08 N	106.88 W	4585	4074	3845	N.A.	N.A.	N.A.	N.A.
Tucumcari	35.20 N	103.68 W	4086	3912	4196	9	95	65	710
New York (NY)									
Albany WSFO AP	42.75 N	73.80 W	275	6894	2525	–7	86	70	605
Auburn	42.92 N	76.53 W	770	6782	2531	N.A.	N.A.	N.A.	N.A.
Batavia	42.98 N	78.18 W	890	6657	2536	N.A.	N.A.	N.A.	N.A.
Binghamton WSO AP	42.22 N	75.98 W	1600	7273	2193	–2	82	69	662
Buffalo WSCMO AP	42.93 N	78.73 W	705	6747	2468	2	84	69	697
Cortland	42.60 N	76.18 W	1129	7168	2225	N.A.	N.A.	N.A.	N.A.
Elmira/Chemung Co	42.17 N	76.90 W	951	6845	2420	–2	87	71	N.A.
Geneva Research Farm	42.88 N	77.03 W	718	6939	2364	N.A.	N.A.	N.A.	N.A.
Glens Falls FAA AP	43.35 N	73.62 W	321	7635	2182	–10	85	71	N.A.
Gloversville	43.05 N	74.35 W	812	7664	2118	N.A.	N.A.	N.A.	N.A.
Ithaca Cornell Univ	42.45 N	76.45 W	960	7207	2117	N.A.	N.A.	N.A.	N.A.
Lockport	43.18 N	78.65 W	520	6703	2482	N.A.	N.A.	N.A.	N.A.
Massena FAA AP	44.93 N	74.85 W	214	8255	2046	–15	84	71	627
NY Central Pk WSO City	40.78 N	73.97 W	132	4805	3634	N.A.	N.A.	N.A.	790
NY Kennedy WSO AP	40.65 N	73.78 W	16	5027	3342	11	88	72	N.A.
NY La Guardia WSO AP	40.77 N	73.90 W	11	4910	3547	13	89	73	790
Oswego East	43.47 N	76.50 W	350	6733	2431	N.A.	N.A.	N.A.	N.A.
Plattsburgh AFB	44.65 N	73.47 W	165	7837	2175	–9	83	69	N.A.
Poughkeepsie FAA AP	41.63 N	73.88 W	155	6391	2663	2	88	72	N.A.
Rochester WSO AP	43.12 N	77.67 W	547	6734	2406	1	86	71	608
Rome/Griffiss AFB	43.23 N	75.40 W	505	7244	2344	–5	86	70	N.A.
Schenectady	42.83 N	73.92 W	220	6881	2500	N.A.	N.A.	N.A.	N.A.
Syracuse WSO AP	43.12 N	76.12 W	421	6834	2399	–3	85	71	730
Utica	43.10 N	75.28 W	500	7066	2354	N.A.	N.A.	N.A.	N.A.
Watertown	43.97 N	75.87 W	497	7540	2294	–12	83	70	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature: Dry-Bulb	Cooling Design Temperature: Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
North Carolina (NC)									
Asheville WSO AP	35.43 N	82.55 W	2140	4308	3365	11	85	71	915
Charlotte WSO AP	35.22 N	80.93 W	700	3341	4704	18	91	74	777
Durham	36.03 N	78.97 W	406	3867	4159	N.A.	N.A.	N.A.	N.A.
Elizabeth City FAA AP	36.27 N	76.18 W	10	3139	4765	N.A.	N.A.	N.A.	N.A.
Fayetteville/Pope AFB	35.17 N	79.02 W	217	2917	5308	22	94	76	N.A.
Goldsboro	35.33 N	77.97 W	109	3040	5018	22	94	76	N.A.
Greensboro WSO AP	36.08 N	79.95 W	886	3865	4144	15	90	74	718
Greenville	35.62 N	77.38 W	30	3129	4824	N.A.	N.A.	N.A.	N.A.
Henderson	36.37 N	78.42 W	480	4038	4002	N.A.	N.A.	N.A.	N.A.
Hickory FAA AP	35.73 N	81.38 W	1143	3728	4199	18	91	72	N.A.
Jacksonville/New River	34.70 N	77.43 W	26	2456	5678	23	92	78	N.A.
Lumberton	34.70 N	79.07 W	130	3212	4723	N.A.	N.A.	N.A.	N.A.
New Bern FAA AP	35.07 N	77.05 W	18	2742	5262	22	92	78	N.A.
Raleigh-Durham WSFO AP	35.87 N	78.78 W	376	3457	4499	16	90	75	740
Rocky Mount	35.90 N	77.72 W	110	3321	4586	N.A.	N.A.	N.A.	N.A.
Wilmington WSO AP	34.27 N	77.90 W	72	2470	5557	23	91	78	N.A.
North Dakota (ND)									
Bismarck WSFO AP	46.77 N	100.77 W	1647	8968	2144	–21	90	67	556
Devils Lake KDLR	48.12 N	98.87 W	1464	9950	1973	–23	87	67	N.A.
Dickinson FAA AP	46.78 N	102.80 W	2581	8657	2152	N.A.	N.A.	N.A.	N.A.
Fargo WSO AP	46.90 N	96.80 W	900	9254	2289	–22	88	70	546
Grand Forks FAA AP	47.95 N	97.17 W	847	9733	2084	–20	88	69	N.A.
Jamestown FAA AP	46.92 N	98.68 W	1492	9168	2262	N.A.	N.A.	N.A.	N.A.
Minot FAA AP	48.27 N	101.28 W	1715	9193	2135	–20	88	66	581
Ohio (OH)									
Akron-Canton WSO AP	40.92 N	81.43 W	1208	6160	2779	0	85	71	680
Ashtabula	41.85 N	80.80 W	690	6429	2604	N.A.	N.A.	N.A.	N.A.
Bowling Green	41.38 N	83.62 W	675	6482	2876	N.A.	N.A.	N.A.	N.A.
Cambridge	40.02 N	81.58 W	800	5488	3118	N.A.	N.A.	N.A.	N.A.
Cincinnati-Abbe WSO	39.15 N	84.52 W	760	4988	3733	5	90	75	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Ohio cont.)									
Cleveland WSFO AP	41.42 N	81.87 W	770	6201	2755	1	86	72	N.A.
Columbus WSO AP	40.00 N	82.88 W	812	5708	3119	1	88	73	708
Dayton WSCMO AP	39.90 N	84.20 W	995	5708	3249	–1	88	73	611
Defiance	41.28 N	84.38 W	700	6628	2810	N.A.	N.A.	N.A.	N.A.
Findlay FAA AP	41.02 N	83.67 W	797	6302	2907	–2	87	72	N.A.
Fremont	41.33 N	83.12 W	600	6439	2823	N.A.	N.A.	N.A.	N.A.
Lancaster	39.73 N	82.63 W	860	5988	2935	N.A.	N.A.	N.A.	N.A.
Lima Sewage Plant	40.72 N	84.13 W	850	6253	3050	N.A.	N.A.	N.A.	N.A.
Mansfield WSO AP	40.82 N	82.52 W	1295	6258	2818	–1	85	72	N.A.
Marion	40.62 N	83.13 W	965	6407	2836	N.A.	N.A.	N.A.	N.A.
Newark Water Works	40.08 N	82.42 W	835	5657	3107	N.A.	N.A.	N.A.	N.A.
Norwalk	41.27 N	82.62 W	670	6434	2715	N.A.	N.A.	N.A.	N.A.
Portsmouth	38.75 N	82.88 W	540	4913	3581	N.A.	N.A.	N.A.	N.A.
Sandusky	41.45 N	82.72 W	584	6131	2986	N.A.	N.A.	N.A.	N.A.
Springfield New Wtr Wk	39.97 N	83.82 W	930	6254	2790	N.A.	N.A.	N.A.	N.A.
Steubenville	40.38 N	80.63 W	992	5700	3054	N.A.	N.A.	N.A.	N.A.
Toledo Express WSO AP	41.58 N	83.80 W	669	6579	2720	–2	87	72	652
Warren	41.20 N	80.82 W	900	6402	2546	N.A.	N.A.	N.A.	N.A.
Wooster Exp Station	40.78 N	81.92 W	1020	6379	2570	N.A.	N.A.	N.A.	N.A.
Youngstown WSO AP	41.25 N	80.67 W	1178	6544	2536	–1	85	70	679
Zanesville FAA AP	39.95 N	81.90 W	881	5714	3013	2	88	73	N.A.
Oklahoma (OK)									
Ada	34.78 N	96.68 W	1015	3182	5317	N.A.	N.A.	N.A.	N.A.
Altus AFB	34.65 N	99.27 W	1378	3151	5708	13	100	73	N.A.
Ardmore	34.20 N	97.15 W	860	2702	5978	N.A.	N.A.	N.A.	N.A.
Bartlesville	36.75 N	96.00 W	715	3777	4976	N.A.	N.A.	N.A.	N.A.
Chickasha Exp Station	35.05 N	97.92 W	1085	3366	5298	N.A.	N.A.	N.A.	N.A.
Enid	36.42 N	97.87 W	1245	3788	5119	5	98	74	N.A.
Lawton	34.62 N	98.45 W	1150	3457	5268	12	97	73	N.A.
McAlester FAA AP	34.88 N	95.78 W	760	3354	5233	10	96	76	N.A.
Muskogee	35.77 N	95.33 W	583	3413	5185	N.A.	N.A.	N.A.	N.A.
Norman	35.18 N	97.45 W	1109	3,295	5272	N.A.	N.A.	N.A.	N.A.
Oklahoma City WSFO AP	35.40 N	97.60 W	1280	3659	4972	9	96	74	733

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Oklahoma cont.)									
Ponca City FAA AP	36.73 N	97.10 W	999	4226	4791	N.A.	N.A.	N.A.	N.A.
Seminole	35.23 N	96.67 W	865	3097	5552	N.A.	N.A.	N.A.	N.A.
Stillwater	36.12 N	97.10 W	895	4028	4718	N.A.	N.A.	N.A.	N.A.
Tulsa WSO AP	36.18 N	95.90 W	668	3691	5150	9	97	76	591
Woodward	36.45 N	99.38 W	1900	3900	4884	N.A.	N.A.	N.A.	N.A.
Oregon (OR)									
Astoria WSO AP	46.15 N	123.88 W	8	5158	1437	25	72	62	1236
Baker FAA AP	44.83 N	117.82 W	3368	7155	1741	N.A.	N.A.	N.A.	N.A.
Bend	44.07 N	121.28 W	3660	6926	1405	N.A.	N.A.	N.A.	N.A.
Corvallis State Univ	44.63 N	123.20 W	225	4923	2051	N.A.	N.A.	N.A.	N.A.
Eugene WSO AP	44.12 N	123.22 W	364	4546	2354	21	87	65	N.A.
Grants Pass	42.42 N	123.33 W	960	4219	2986	N.A.	N.A.	N.A.	N.A.
Klamath Falls	42.20 N	121.78 W	4098	6634	1954	4	87	62	N.A.
Medford WSO AP	42.38 N	122.88 W	1300	4611	2989	21	95	66	749
Pendleton WSO AP	45.68 N	118.85 W	1492	5294	2787	3	93	63	N.A.
Portland WSFO AP	45.60 N	122.60 W	21	4522	2517	22	86	66	1060
Roseburg KQEN	43.20 N	123.35 W	465	4312	2607	N.A.	N.A.	N.A.	N.A.
Salem WSO AP	44.92 N	123.02 W	195	4927	2100	20	87	66	916
Pennsylvania (PA)									
Allentown WSO AP	40.65 N	75.43 W	388	5785	3028	5	88	72	710
Altoona FAA AP	40.30 N	78.32 W	1476	6140	2719	5	86	70	N.A.
Chambersburg	39.93 N	77.63 W	640	5574	3060	N.A.	N.A.	N.A.	N.A.
Erie WSO AP	42.08 N	80.18 W	732	6279	2652	2	83	70	716
Harrisburg FAA AP	40.22 N	76.85 W	338	5347	3358	9	89	73	648
Johnstown	40.33 N	78.92 W	1214	5649	3028	N.A.	N.A.	N.A.	N.A.
Lancaster	40.05 N	76.28 W	270	5584	3079	N.A.	N.A.	N.A.	N.A.
Meadville	41.63 N	80.17 W	1065	6934	2209	N.A.	N.A.	N.A.	N.A.
New Castle	41.02 N	80.37 W	825	6542	2502	N.A.	N.A.	N.A.	N.A.
Philadelphia WSCMO AP	39.88 N	75.23 W	10	4954	3623	11	89	74	646
Pittsburgh WSCMO2 AP	40.50 N	80.22 W	1150	5968	2836	2	86	70	700
Reading	40.37 N	75.93 W	270	5796	3021	N.A.	N.A.	N.A.	N.A.
State College	40.80 N	77.87 W	1170	6364	2629	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Pennsylvania cont.)									
Uniontown	39.92 N	79.72 W	956	5684	2913	N.A.	N.A.	N.A.	N.A.
Warren	41.85 N	79.15 W	1210	6890	2334	N.A.	N.A.	N.A.	N.A.
West Chester	39.97 N	75.63 W	450	5283	3288	N.A.	N.A.	N.A.	N.A.
Williamsport WSO AP	41.25 N	76.92 W	524	6087	2796	2	87	71	N.A.
York Pump Station 22	39.92 N	76.75 W	390	5256	3274	N.A.	N.A.	N.A.	N.A.
Rhode Island (RI)									
Newport	41.52 N	71.32 W	20	5659	2548	N.A.	N.A.	N.A.	N.A.
Providence WSO AP	41.73 N	71.43 W	51	5884	2743	5	86	71	684
South Carolina (SC)									
Anderson	34.53 N	82.67 W	800	2965	4900	N.A.	N.A.	N.A.	N.A.
Charleston WSO AP	32.90 N	80.03 W	41	2013	6188	N.A.	N.A.	N.A.	N.A.
Charleston WSO City	32.78 N	79.93 W	10	1866	6303	25	92	77	N.A.
Columbia WSFO AP	33.95 N	81.12 W	213	2649	5508	21	94	75	705
Florence FAA AP	34.18 N	79.72 W	146	2585	5597	23	94	76	N.A.
Georgetown	33.35 N	79.25 W	10	2081	5947	N.A.	N.A.	N.A.	N.A.
Greenville-Spartanburg WSO AP	34.90 N	82.22 W	973	3272	4625	19	91	74	851
Greenwood	34.17 N	82.20 W	615	3288	4673	N.A.	N.A.	N.A.	N.A.
Orangeburg	33.50 N	80.87 W	160	2534	5477	N.A.	N.A.	N.A.	N.A.
Spartanburg	34.98 N	81.88 W	840	2887	5046	N.A.	N.A.	N.A.	N.A.
Sumter/Shaw AFB	33.97 N	80.48 W	240	2506	5453	24	93	75	N.A.
South Dakota (SD)									
Aberdeen WSO AP	45.45 N	98.43 W	1296	8446	2497	N.A.	N.A.	N.A.	N.A.
Brookings	44.32 N	96.77 W	1642	8653	2228	N.A.	N.A.	N.A.	N.A.
Huron WSO AP	44.38 N	98.22 W	1282	7923	2709	–17	91	71	545
Mitchell	43.72 N	98.00 W	1274	7558	2925	N.A.	N.A.	N.A.	N.A.
Pierre FAA AP	44.38 N	100.28 W	1726	7411	2938	–14	95	69	557
Rapid City WSO AP	44.05 N	103.07 W	3162	7301	2412	–11	91	65	572
Sioux Falls WSFO AP	43.57 N	96.73 W	1418	7809	2735	–16	90	72	599
(South Dakota, cont.)									
Watertown FAA AP	44.92 N	97.15 W	1746	8375	2499	N.A.	N.A.	N.A.	N.A.
Yankton	42.88 N	97.35 W	1180	7304	2935	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	 Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
Tennessee (TN)									
Athens	35.43 N	84.58 W	940	4054	4040	N.A.	N.A.	N.A.	N.A.
Bristol WSO AP	36.48 N	82.40 W	1525	4406	3621	9	87	72	N.A.
Chattanooga WSO AP	35.03 N	85.20 W	692	3587	4609	15	92	75	684
Clarksville Sew Plt	36.55 N	87.37 W	382	4159	4241	N.A.	N.A.	N.A.	N.A.
Columbia	35.63 N	87.08 W	650	4206	4047	N.A.	N.A.	N.A.	N.A.
Dyersburg FAA AP	36.02 N	89.40 W	337	3536	5010	N.A.	N.A.	N.A.	N.A.
Greeneville Exp Stn	36.10 N	82.85 W	1320	4392	3710	N.A.	N.A.	N.A.	N.A.
Jackson FAA AP	35.60 N	88.92 W	433	3540	4915	12	93	76	N.A.
Knoxville WSO AP	35.80 N	84.00 W	949	3937	4164	13	90	74	703
Memphis FAA-AP	35.05 N	90.00 W	265	3082	5467	16	94	77	851
Murfreesboro	35.92 N	86.37 W	550	3992	4270	N.A.	N.A.	N.A.	N.A.
Nashville WSO AP	36.12 N	86.68 W	580	3729	4689	10	92	75	749
Tullahoma	35.35 N	86.20 W	1048	3630	4422	N.A.	N.A.	N.A.	N.A.
Texas (TX)									
Abilene WSO AP	32.42 N	99.68 W	1784	2584	6050	16	97	71	648
Alice	27.73 N	98.07 W	201	1062	8121	N.A.	N.A.	N.A.	N.A.
Amarillo WSO AP	35.23 N	101.70 W	3590	4258	4128	6	94	66	680
Austin WSO AP	30.30 N	97.70 W	597	1688	7171	25	96	74	664
Bay City Waterworks	28.98 N	95.98 W	52	1370	7211	N.A.	N.A.	N.A.	N.A.
Beaumont Research Ctr	30.07 N	94.28 W	27	1677	6703	29	92	79	N.A.
Beeville	28.45 N	97.70 W	255	1372	7393	28	98	77	N.A.
Big Spring	32.25 N	101.45 W	2500	2772	5621	N.A.	N.A.	N.A.	N.A.
Brownsville WSO AP	25.90 N	97.43 W	19	635	8777	36	94	77	422
Brownwood	31.72 N	99.00 W	1385	2199	6479	N.A.	N.A.	N.A.	N.A.
Corpus Christi WSO AP	27.77 N	97.50 W	44	1016	8023	32	94	78	543
Corsicana	32.08 N	96.47 W	425	2396	6133	N.A.	N.A.	N.A.	N.A.
Dallas FAA AP	32.85 N	96.85 W	440	2259	6587	17	98	74	N.A.
Del Rio/Laughlin AFB	29.37 N	100.78 W	1079	1565	7207	28	98	73	732
Denton	33.20 N	97.10 W	630	2665	5816	N.A.	N.A.	N.A.	N.A.
Eagle Pass	28.70 N	100.48 W	805	1441	7682	N.A.	N.A.	N.A.	N.A.
El Paso WSO AP	31.80 N	106.40 W	3918	2708	5488	21	98	64	735

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Texas cont.)									
Ft Worth/Meacham	32.82 N	97.35 W	692	2304	6557	19	98	74	N.A.
Galveston WSO City	29.30 N	94.80 W	7	1263	7378	N.A.	N.A.	N.A.	N.A.
Greenville	33.20 N	96.22 W	610	2953	5527	N.A.	N.A.	N.A.	N.A.
Harlingen	26.20 N	97.67 W	38	813	8405	N.A.	N.A.	N.A.	N.A.
Houston /Hobby	29.65 N	95.28 W	50	1371	7357	29	93	77	N.A.
Houston-Bush Intercontinental Airport	29.97 N	95.35 W	96	1599	6876	27	94	77	N.A.
Huntsville	30.72 N	95.55 W	494	1862	6697	N.A.	N.A.	N.A.	N.A.
Killeen/Robert-Gray	31.07 N	97.83 W	1014	2127	6477	20	96	73	N.A.
Lamesa	32.70 N	101.93 W	2965	3159	5107	N.A.	N.A.	N.A.	N.A.
Laredo	27.57 N	99.50 W	430	1025	8495	32	101	74	598
Longview	32.47 N	94.73 W	330	2433	5920	N.A.	N.A.	N.A.	N.A.
Lubbock WSFO AP	33.65 N	101.82 W	3254	3431	4833	11	95	67	743
Lufkin FAA AP	31.23 N	94.75 W	281	1951	6527	23	95	77	681
McAllen	26.20 N	98.22 W	122	778	8597	34	98	76	N.A.
Midland/Odessa WSO AP	31.95 N	102.18 W	2857	2751	5588	17	97	67	729
Mineral Wells FAA AP	32.78 N	98.07 W	934	2625	6015	N.A.	N.A.	N.A.	N.A.
Palestine	31.78 N	95.60 W	465	2005	6454	N.A.	N.A.	N.A.	N.A.
Pampa No 2	35.53 N	100.98 W	3250	4358	4131	N.A.	N.A.	N.A.	N.A.
Pecos	31.42 N	103.50 W	2610	2505	5992	N.A.	N.A.	N.A.	N.A.
Plainview	34.18 N	101.70 W	3370	3717	4462	N.A.	N.A.	N.A.	N.A.
Port Arthur WSO AP	29.95 N	94.02 W	16	1499	6994	N.A.	N.A.	N.A.	697
San Angelo WSO AP	31.37 N	100.50 W	1903	2414	6070	20	97	70	619
San Antonio WSFO	29.53 N	98.47 W	794	1644	7142	26	96	73	N.A.
Sherman	33.63 N	96.62 W	720	2890	5682	N.A.	N.A.	N.A.	721
Snyder	32.72 N	100.92 W	2335	3185	5178	N.A.	N.A.	N.A.	N.A.
Temple	31.08 N	97.37 W	700	2153	6487	N.A.	N.A.	N.A.	N.A.
Tyler	32.35 N	95.40 W	545	2194	6562	N.A.	N.A.	N.A.	N.A.
Vernon	34.08 N	99.30 W	1202	3186	5605	N.A.	N.A.	N.A.	N.A.
Victoria WSO AP	28.85 N	96.92 W	104	1296	7507	29	94	76	N.A.
Waco WSO AP	31.62 N	97.22 W	500	2179	6668	22	99	75	622
Wichita Falls WSO AP	33.97 N	98.48 W	994	3042	5717	N.A.	N.A.	N.A.	723

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
Utah (UT)									
Cedar City FAA AP	37.70 N	113.10 W	5610	5962	2770	2	91	59	629
Logan Utah State Univ	41.75 N	111.80 W	4790	6854	2541	N.A.	N.A.	N.A.	N.A.
Moab	38.60 N	109.60 W	3965	4494	4356	N.A.	N.A.	N.A.	N.A.
Ogden Sugar Factory	41.23 N	112.03 W	4280	5950	3053	N.A.	N.A.	N.A.	N.A.
Richfield Radio KSVC	38.77 N	112.08 W	5270	6367	2300	N.A.	N.A.	N.A.	N.A.
Saint George	37.10 N	113.57 W	2760	3215	5424	N.A.	N.A.	N.A.	N.A.
Salt Lake City NWSFO	40.78 N	111.95 W	4222	5765	3276	6	94	62	586
Vernal Airport	40.45 N	109.52 W	5260	7562	2334	N.A.	N.A.	N.A.	N.A.
Vermont (VT)									
Burlington WSO AP	44.47 N	73.15 W	332	7771	2228	–11	84	69	637
Rutland	43.60 N	72.97 W	620	7066	2345	N.A.	N.A.	N.A.	N.A.
Virginia (VA)									
Charlottesville	38.03 N	78.52 W	870	4224	3902	N.A.	N.A.	N.A.	N.A.
Danville-Bridge St	36.58 N	79.38 W	410	3944	4236	N.A.	N.A.	N.A.	N.A.
Fredericksburg Natl Pk	38.32 N	77.45 W	90	4554	3754	N.A.	N.A.	N.A.	N.A.
Lynchburg WSO AP	37.33 N	79.20 W	916	4340	3728	12	90	74	N.A.
Norfolk WSO AP	36.90 N	76.20 W	22	3495	4478	20	91	76	685
Richmond WSO AP	37.50 N	77.33 W	164	3963	4223	14	92	75	716
Roanoke WSO AP	37.32 N	79.97 W	1149	4360	3715	12	89	72	713
Staunton Sewage Plant	38.15 N	79.03 W	1385	5273	3004	N.A.	N.A.	N.A.	N.A.
Winchester	39.18 N	78.12 W	680	5269	3215	N.A.	N.A.	N.A.	N.A.
Washington (WA)									
Aberdeen	46.97 N	123.82 W	10	5285	1488	N.A.	N.A.	N.A.	N.A.
Bellingham FAA AP	48.80 N	122.53 W	149	5609	1508	15	76	64	N.A.
Bremerton	47.57 N	122.67 W	162	5119	1839	N.A.	N.A.	N.A.	N.A.
Ellensburg	46.97 N	120.55 W	1480	6770	1999	N.A.	N.A.	N.A.	N.A.
Everett	47.98 N	122.18 W	60	5311	1660	N.A.	N.A.	N.A.	N.A.
Kennewick	46.22 N	119.10 W	390	4895	3195	N.A.	N.A.	N.A.	N.A.
Longview	46.15 N	122.92 W	12	5094	1858	N.A.	N.A.	N.A.	N.A.
Olympia WSO AP	46.97 N	122.90 W	192	5655	1558	18	83	65	985
Port Angeles	48.12 N	123.40 W	40	5695	1257	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Washington cont.)									
Seattle EMSU WSO	47.65 N	122.30 W	20	4611	2120	N.A.	N.A.	N.A.	N.A.
Seattle-Tacoma WSCMO AP	47.45 N	122.30 W	450	4908	2021	23	81	64	982
Spokane WSO AP	47.63 N	117.53 W	2356	6842	2032	N.A.	N.A.	N.A.	640
Tacoma/McChord AFB	47.15 N	122.48 W	322	5155	1820	18	82	63	N.A.
Walla Walla FAA AP	46.10 N	118.28 W	1166	4958	3161	4	95	65	N.A.
Wenatchee	47.42 N	120.32 W	640	5579	2956	3	92	65	N.A.
Yakima WSO AP	46.57 N	120.53 W	1064	5967	2348	4	92	64	703
West Virginia (WV)									
Beckley WSO AP	37.78 N	81.12 W	2504	5558	2690	N.A.	N.A.	N.A.	N.A.
Bluefield FAA AP	37.30 N	81.22 W	2870	5230	2907	5	83	69	N.A.
Charleston WSFO AP	38.37 N	81.60 W	1015	4646	3655	6	88	73	704
Clarksburg	39.27 N	80.35 W	945	5512	3014	N.A.	N.A.	N.A.	N.A.
Elkins WSO AP	38.88 N	79.85 W	1992	6120	2360	–2	83	70	N.A.
Huntington WSO AP	38.37 N	82.55 W	827	4665	3615	6	89	73	N.A.
Martinsburg FAA AP	39.40 N	77.98 W	531	5192	3368	8	91	73	N.A.
Morgantown FAA AP	39.65 N	79.92 W	1240	5363	3155	4	87	71	N.A.
Parkersburg	39.27 N	81.57 W	615	5094	3507	4	88	72	N.A.
Wisconsin (WI)									
Appleton	44.25 N	88.37 W	750	7693	2513	N.A.	N.A.	N.A.	N.A.
Ashland Exp Farm	46.57 N	90.97 W	650	8960	1811	N.A.	N.A.	N.A.	N.A.
Beloit	42.50 N	89.03 W	780	7161	2737	N.A.	N.A.	N.A.	N.A.
Eau Claire FAA AP	44.87 N	91.48 W	888	8330	2407	–18	87	71	661
Fond du Lac	43.80 N	88.45 W	760	7541	2573	N.A.	N.A.	N.A.	N.A.
Green Bay WSO AP	44.48 N	88.13 W	682	8089	2177	–13	85	72	651
La Crosse FAA AP	43.87 N	91.25 W	651	7491	2790	–14	88	73	644
Madison WSO AP	43.13 N	89.33 W	858	767	2389	–11	87	72	658
Manitowoc	44.10 N	87.68 W	660	7597	2193	N.A.	N.A.	N.A.	N.A.
Marinette	45.10 N	87.63 W	605	8059	2272	N.A.	N.A.	N.A.	N.A.
Milwaukee WSO AP	42.95 N	87.90 W	672	7324	2388	–7	86	72	618
Racine	42.70 N	87.77 W	595	7167	2459	N.A.	N.A.	N.A.	N.A.
Sheboygan	43.75 N	87.72 W	648	7087	2390	N.A.	N.A.	N.A.	N.A.

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

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb	No. Hrs. 8 a.m.–4 p.m.
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Wisconsin cont.)									
Stevens Point	44.50 N	89.57 W	1079	8009	2325	N.A.	N.A.	N.A.	N.A.
Waukesha	43.02 N	88.23 W	860	7117	2658	N.A.	N.A.	N.A.	N.A.
Wausau FAA AP	44.92 N	89.62 W	1196	8427	2182	–15	85	70	N.A.
Wyoming (WY)									
Casper WSO AP	42.92 N	106.47 W	5338	7682	2082	–13	89	58	535
Cheyenne WSFO AP	41.15 N	104.82 W	6120	7326	1886	–7	85	57	608
Cody	44.52 N	109.07 W	5050	7431	2057	–14	87	58	N.A.
Evanston	41.27 N	110.95 W	6810	8846	1285	N.A.	N.A.	N.A.	N.A.
Lander WSO AP	42.82 N	108.73 W	5370	7889	2184	–14	87	58	N.A.
Laramie FAA AP	41.32 N	105.68 W	7266	9008	1237	N.A.	N.A.	N.A.	N.A.
Newcastle	43.85 N	104.22 W	4410	7267	2518	N.A.	N.A.	N.A.	N.A.
Rawlins FAA AP	41.80 N	107.20 W	6736	8475	1605	N.A.	N.A.	N.A.	N.A.
Rock Springs FAA AP	41.60 N	109.07 W	6741	8365	1734	–9	84	54	552
Sheridan WSO AP	44.77 N	106.97 W	3964	7804	2023	–14	90	61	574
Torrington Exp Farm	42.08 N	104.22 W	4098	6879	2429	N.A.	N.A.	N.A.	N.A.
District of Columbia (DC)									
R. Reagan Nat'l. Airport	38.85 N	77.03 W	66	4047	4391	15	92	76	657
Puerto Rico (PR)									
San Juan/Isla Verde WSFO	18.43 N	66.00 W	10	0	11,406	69	90	78	N.A.
Pacific Islands (PI)									
Guam (GU) - Andersen AFB	13.58 N	144.93 E	361	0	10,690	74	87	79	N.A.
Marshall Island (MH) - Kwajalein Atoll	8.73 N	167.73 E	26	0	11,670	76	88	79	N.A.
Midway Island (MH) - Midway Island NAF	28.22 N	177.37 W	13	134	8323	59	86	75	N.A.
Samoa (WS) - Pago Pago WSO Airport	14.33 S	170.72 W	9	0	11,018	72	88	80	N.A.
Wake Island - Wake Island WSO Airport	19.28 N	166.65 E	12	0	11,097	71	89	79	N.A.
Philippines									
Philippines (PH) - Angeles, Clark AFB	15.18 N	120.55 E	475	0	11,280	68	95	77	N.A.

TABLE D-2 Canadian Climatic Data

Province City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
						99.6%	1.0%	1.0%
Alberta (AB)								
Calgary International A	51.12 N	114.02 W	3533	9885	1167	–22	80	59
Edmonton International A	53.30 N	113.58 W	2345	11,023	1069	–28.1	78	62
Grande Prairie A	55.18 N	118.88 W	2185	11,240	1031	–32	78	60
Jasper	52.88 N	118.07 W	3480	10,244	848	N.A.	N.A.	N.A.
Lethbridge A	49.63 N	112.80 W	3047	8783	1730	–22	84	61
Medicine Hat A	50.02 N	110.72 W	2352	8988	1981	–24	87	62
Red Deer A	52.18 N	113.90 W	2969	10,765	1095	–27	79	61
British Columbia (BC)								
Dawson Creek A	55.73 N	120.18 W	2148	11,435	890	N.A.	N.A.	N.A.
Ft Nelson A	58.83 N	122.58 W	1253	12,941	1013	–33	78	60
Kamloops	50.67 N	120.33 W	1243	6779	2335	–8	88	63
Nanaimo A	49.05 N	123.87 W	98	6054	1469	N.A.	N.A.	N.A.
New Westminster BC Pen	49.22 N	122.90 W	59	5520	1691	N.A.	N.A.	N.A.
Penticton A	49.47 N	119.60 W	1128	6500	2002	5	87	64
Prince George	53.88 N	122.67 W	2267	9495	906	–25	78	59
Prince Rupert A	54.30 N	130.43 W	111	7650	572	7	63	57
Vancouver International A	49.18 N	123.17 W	9	5682	1536	18	74	64
Victoria Gonzales Hts	48.42 N	123.32 W	229	5494	1286	23	75	62
Manitoba (MB)								
Brandon CDA	49.87 N	99.98 W	1190	10,969	1661	–29	84	66
Churchill A	58.73 N	94.07 W	91	16,719	275	–36	72	60
Dauphin A	51.10 N	100.05 W	1000	11,242	1520	–28	84	66
Flin Flon	54.77 N	101.85 W	1099	12,307	1352	N.A.	N.A.	N.A.
Portage La Prairie A	49.90 N	98.27 W	885	10,594	1807	–25	85	67
The Pas A	53.97 N	101.10 W	889	12,490	1231	–32	79	64
Winnipeg International A	49.90 N	97.23 W	784	10,858	1784	–27	84	67
New Brunswick (NB)								
Chatham A	47.02 N	65.45 W	111	9028	1531	–12	83	67
Fredericton A	45.87 N	66.53 W	55	8666	1631	–12	83	68
Moncton A	46.12 N	64.68 W	232	8731	1427	–10	80	67
Saint John A	45.33 N	65.88 W	337	8776	1179	–9	75	64
Newfoundland (NF)								
Corner Brook	48.95 N	57.95 W	16	8756	1075	N.A.	N.A.	N.A.

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

Province City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
						99.6%	1.0%	1.0%
(Newfoundland cont.)								
Gander International A	48.95 N	54.57 W	495	9354	956	–4	76	63
Goose A	53.32 N	60.42 W	150	12,017	758	–23	77	61
St John's A	47.62 N	52.73 W	439	8888	848	3	73	64
Stephenville A	48.53 N	58.55 W	26	8869	952	–2	71	64
Northwest Territories (NW)								
Ft Smith A	60.02 N	111.95 W	666	14,192	932	–34	78	61
Inuvik A	68.30 N	133.48 W	193	18,409	489	–43	75	59
Yellowknife A	62.47 N	114.45 W	672	15,555	851	–39	74	59
Nova Scotia (NS)								
Halifax International A	44.88 N	63.52 W	416	8133	1464	–2	78	66
Kentville CDA	45.07 N	64.48 W	160	7683	1665	N.A.	N.A.	N.A.
Sydney A	46.17 N	60.05 W	183	8364	1287	–1	78	67
Truro	45.37 N	63.27 W	131	8596	1295	–9	77	67
Yarmouth A	43.83 N	66.08 W	141	7515	1180	7	71	64
Nunavut								
Resolute A	74.72 N	94.98 W	219	22,864	0	–42	48	43
Ontario (ON)								
Belleville	44.15 N	77.40 W	249	7556	2252	N.A.	N.A.	N.A.
Cornwall	45.02 N	74.75 W	209	8062	2187	N.A.	N.A.	N.A.
Hamilton RBG	43.28 N	79.88 W	334	6872	2450	N.A.	N.A.	N.A.
Kapuskasing A	49.42 N	82.47 W	744	11,742	1108	–30	80	65
Kenora A	49.78 N	94.37 W	1335	10,884	1626	–27	81	65
Kingston A	44.22 N	76.60 W	305	7826	1960	N.A.	N.A.	N.A.
London A	43.03 N	81.15 W	912	7565	2126	–3	83	70
North Bay A	46.35 N	79.43 W	1174	9794	1509	–18	78	66
Oshawa WPCP	43.87 N	78.83 W	275	7253	2106	N.A.	N.A.	N.A.
Ottawa International A	45.32 N	75.67 W	380	8571	2045	–13	83	69
Owen Sound MOE	44.58 N	80.93 W	587	7730	1896	N.A.	N.A.	N.A.
Peterborough	44.28 N	78.32 W	636	8037	1975	N.A.	N.A.	N.A.
St Catharines	43.20 N	79.25 W	298	6700	2564	N.A.	N.A.	N.A.
Sudbury A	46.62 N	80.80 W	1141	9990	1557	–19	81	66
Thunder Bay A	48.37 N	89.32 W	652	10,562	1198	–22	80	66
Timmins A	48.57 N	81.37 W	967	11,374	1225	–28	81	65

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

Province City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
						99.6%	1.0%	1.0%
(Ontario cont.)								
Toronto Downsview A	43.75 N	79.48 W	649	7306	2370	–4	84	70
Windsor A	42.27 N	82.97 W	623	6619	2679	2	86	71
Prince Edward Island (PE)								
Charlottetown A	46.28 N	63.13 W	157	8598	1400	–6	77	67
Summerside A	46.43 N	63.83 W	78	8411	1536	–5	77	66
Québec (PQ)								
Bagotville A	48.33 N	71.00 W	521	10,603	1300	–23	80	65
Drummondville	45.88 N	72.48 W	269	8601	2024	N.A.	N.A.	N.A.
Granby	45.38 N	72.70 W	551	8367	1984	N.A.	N.A.	N.A.
Montreal Dorval International A	45.47 N	73.75 W	101	8285	2146	–12	83	70
Québec City A	46.80 N	71.38 W	229	9449	1571	–16	80	68
Rimouski	48.45 N	68.52 W	118	9665	1215	N.A.	N.A.	N.A.
Sept-Iles A	50.22 N	66.27 W	180	11,287	690	–20	69	59
Shawinigan	46.57 N	72.75 W	400	9246	1720	N.A.	N.A.	N.A.
Sherbrooke A	45.43 N	71.68 W	780	9464	1372	–20	80	68
St Jean de Cherbourg	48.88 N	67.12 W	1151	11,277	801	N.A.	N.A.	N.A.
St Jerome	45.80 N	74.05 W	557	9171	1771	N.A.	N.A.	N.A.
Thetford Mines	46.10 N	71.35 W	1250	9687	1425	N.A.	N.A.	N.A.
Trois Rivieres	46.37 N	72.60 W	173	9124	1766	N.A.	N.A.	N.A.
Val d'Or A	48.07 N	77.78 W	1105	11,256	1193	–27	80	65
Valleyfield	45.28 N	74.10 W	150	8083	2268	N.A.	N.A.	N.A.
Saskatchewan (SK)								
Estevan A	49.22 N	102.97 W	1876	10,092	1793	–25	86	65
Moose Jaw A	50.33 N	105.55 W	1893	9989	1812	–27	87	64
North Battleford A	52.77 N	108.25 W	1797	11,127	1473	–31	82	63
Prince Albert A	53.22 N	105.68 W	1404	12,009	1252	–34	81	64
Regina A	50.43 N	104.67 W	1893	10,773	1620	–29	85	64
Saskatoon A	52.17 N	106.68 W	1643	11,118	1537	–31	84	63
Swift Current A	50.28 N	107.68 W	2683	10,128	1541	–25	84	62
Yorkton A	51.27 N	102.47 W	1633	11,431	1476	–30	82	64
Yukon Territory (YT)								
Whitehorse A	60.72 N	135.07 W	2306	12,797	611	–34	73	55

TABLE D-3 International Climatic Data

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
Argentina									
Buenos Aires/Ezeiza		34.82 S	58.53 W	66	2211	4693	31	90	72
Cordoba		31.32 S	64.22 W	1555	1816	5182	31	91	72
Tucuman/Pozo		26.85 S	65.10 W	1444	1416	6622	N.A.	N.A.	N.A.
Australia									
Adelaide	SA	34.95 S	138.53 E	20	2082	4381	39	92	64
Alice Springs	NT	23.80 S	133.90 E	1782	1142	7777	34	102	64
Brisbane	QL	27.43 S	153.08 E	7	545	7009	44	86	72
Darwin Airport	NT	12.43 S	130.87 E	95	0	11,736	64	92	76
Perth/Guildford	WA	31.92 S	115.97 E	56	1507	5353	41	95	66
Sydney/K Smith	NSW	33.95 S	151.18 E	20	1351	5259	42	85	67
Azores									
Lajes	Terceira	38.75 N	27.08 W	180	1279	4892	46	78	71
Bahamas									
Nassau		25.05 N	77.47 W	10	29	9775	57	90	78
Belgium									
Brussels Airport		50.90 N	4.47 E	128	5460	1862	15	79	66
Bermuda									
St Georges/Kindley		32.37 N	64.68 W	20	170	8365	N.A.	N.A.	N.A.
Bolivia									
La Paz/El Alto		16.50 S	68.18 W	13,287	7189	237	25	62	44
Brazil									
Belem		1.43 S	48.48 W	79	0	11,552	72	90	78
Brasilia		15.77 S	47.93 W	3809	58	7943	48	88	65
Fortaleza		3.72 S	38.55 W	62	1	11,748	72	90	78
Porto Alegre		30.08 S	51.18 W	23	902	7076	40	92	75
Recife/Curado		8.13 S	34.92 W	36	2	10,951	70	91	78
Rio de Janeiro		22.90 S	43.17 W	16	14	9688	59	99	77
Salvador/Ondina		13.00 S	38.52 W	167	0	10,785	68	88	78
Sao Paulo		23.50 S	46.62 W	2608	447	7219	48	88	69
Bulgaria									
Sofia		42.82 N	23.38 E	1952	5629	2508	10	85	65
Chile									
Concepcion		36.77 S	73.05 W	39	3559	2283	35	74	62
Punta Arenas/Chabunco		53.03 S	70.85 W	108	7807	395	23	61	53

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(Chile cont.)									
Santiago/Pedahuel		33.38 S	70.88 W	1575	2820	3471	29	88	65
China									
Beijing/Peking	Municipalities	39.93 N	116.28 E	180	5252	4115	12	92	72
Hong Kong Intl Arpt	Special Admin. Region	22.33 N	114.18 E	79	543	7894	48	91	79
Shanghai	Municipalities	31.40 N	121.47 E	13	3182	5124	29	92	80
Shanghai/Hongqiao	Municipalities	31.17 N	121.43 E	23	3184	5127	26	92	82
Tianjin/Tientsin	Municipalities	39.10 N	117.17 E	16	4948	4450	14	91	74
Anqing	Anhui	30.53 N	117.05 E	66	3093	5476	28	94	80
Bengbu	Anhui	32.95 N	117.37 E	72	3,44	5053	23	93	79
Fuyang	Anhui	32.93 N	115.83 E	128	3639	5004	23	93	79
Hefei/Luogang	Anhui	31.87 N	117.23 E	118	3468	5110	25	93	80
Huang Shan (Mtns)	Anhui	30.13 N	118.15 E	6024	6723	1647	9	70	65
Huoshan	Anhui	31.40 N	116.33 E	223	3516	4907	24	94	80
Changting	Fujian	25.85 N	116.37 E	1020	1902	6289	30	91	77
Fuding	Fujian	27.33 N	120.20 E	125	1868	6277	34	92	80
Fuzhou	Fujian	26.08 N	119.28 E	279	1396	7047	40	94	80
Jiuxian Shan	Fujian	25.72 N	118.10 E	5417	3923	2763	23	74	67
Longyan	Fujian	25.10 N	117.02 E	1119	1120	7248	37	93	75
Nanping	Fujian	26.65 N	118.17 E	420	1551	6986	35	95	78
Pingtan	Fujian	25.52 N	119.78 E	102	1478	6550	43	87	79
Pucheng	Fujian	27.92 N	118.53 E	902	2325	5940	29	93	78
Shaowu	Fujian	27.33 N	117.43 E	630	2075	6232	29	94	78
Xiamen	Fujian	24.48 N	118.08 E	456	1014	7,26	43	91	79
Yong'An	Fujian	25.97 N	117.35 E	669	1570	6917	33	95	77
Dunhuang	Gansu	40.15 N	94.68 E	3740	6531	3272	1	93	64
Hezuo	Gansu	35.00 N	102.90 E	9547	9760	491	–5	70	54
Huajialing	Gansu	35.38 N	105.00 E	8038	9275	871	4	70	56
Jiuquan/Suzhou	Gansu	39.77 N	98.48 E	4849	7316	2473	–2	86	62
Lanzhou	Gansu	36.05 N	103.88 E	4980	5849	2954	11	87	63
Mazong Shan (Mount)	Gansu	41.80 N	97.03 E	5807	9187	1748	–9	84	55
Minqin	Gansu	38.63 N	103.08 E	4485	7045	2830	0	89	61

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
(China cont.)									
Pingliang	Gansu	35.55 N	106.67 E	4423	6248	2407	9	84	64
Ruo'ergai	Gansu	33.58 N	102.97 E	11,289	10,826	232	–8	65	52
Tianshui	Gansu	34.58 N	105.75 E	3750	5192	3073	17	87	67
Wudu	Gansu	33.40 N	104.92 E	3540	3419	4250	28	90	68
Wushaoling (Pass)	Gansu	37.20 N	102.87 E	9987	11,697	263	–5	64	50
Xifengzhen	Gansu	35.73 N	107.63 E	4669	6471	2388	10	82	63
Yumenzhen	Gansu	40.27 N	97.03 E	5010	7614	2367	–3	86	60
Zhangye	Gansu	38.93 N	100.43 E	4865	7288	2439	–2	88	62
Fogang	Guangdong	23.87 N	113.53 E	223	1063	7709	39	92	79
Gaoyao	Guangdong	23.05 N	112.47 E	39	720	8493	44	93	80
Guangzhou/Baiyun	Guangdong	23.13 N	113.32 E	26	737	8352	42	93	80
Heyuan	Guangdong	23.73 N	114.68 E	135	902	8079	40	93	79
Lian Xian	Guangdong	24.78 N	112.38 E	322	1660	7018	35	94	79
Lianping	Guangdong	24.37 N	114.48 E	702	1301	7189	36	92	78
Meixian	Guangdong	24.30 N	116.12 E	276	937	8016	39	94	79
Shangchuan Island	Guangdong	21.73 N	112.77 E	59	514	8621	46	89	81
Shantou	Guangdong	23.40 N	116.68 E	10	779	7743	45	90	80
Shanwei	Guangdong	22.78 N	115.37 E	16	528	8272	46	89	79
Shaoguan	Guangdong	24.80 N	113.58 E	223	1370	7565	37	94	79
Shenzhen	Guangdong	22.55 N	114.10 E	59	531	8597	44	92	80
Xinyi	Guangdong	22.35 N	110.93 E	276	570	8763	43	93	79
Yangjiang	Guangdong	21.87 N	111.97 E	72	547	8470	45	90	80
Zhangjiang	Guangdong	21.22 N	110.40 E	92	423	9002	46	92	80
Beihai	Guangxi	21.48 N	109.10 E	52	621	8826	44	91	80
Bose	Guangxi	23.90 N	106.60 E	794	716	8488	43	96	79
Guilin	Guangxi	25.33 N	110.30 E	545	1971	6549	35	92	78
Guiping	Guangxi	23.40 N	110.08 E	144	957	8084	42	93	80
Hechi/Jnchengjiang	Guangxi	24.70 N	108.05 E	702	1229	7489	40	93	78
Lingling	Guangxi	26.23 N	111.62 E	571	2608	5993	31	94	78
Liuzhou	Guangxi	24.35 N	109.40 E	318	1370	7604	38	94	78
Longzhou	Guangxi	22.37 N	106.75 E	423	681	8596	43	94	80
Mengshan	Guangxi	24.20 N	110.52 E	476	1485	7125	36	92	79

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)									
Nanning/Wuxu	Guangxi	22.82 N	108.35 E	240	857	8315	42	93	79
Napo	Guangxi	23.30 N	105.95 E	2605	1283	6469	37	87	74
Qinzhou	Guangxi	21.95 N	108.62 E	20	769	8415	43	91	80
Wuzhou	Guangxi	23.48 N	111.30 E	394	1074	7934	39	94	80
Bijie	Guizhou	27.30 N	105.23 E	4957	3837	3496	27	83	68
Dushan	Guizhou	25.83 N	107.55 E	3340	3021	4530	27	83	71
Guiyang	Guizhou	26.58 N	106.72 E	3524	2879	4689	28	85	70
Luodian	Guizhou	25.43 N	106.77 E	1447	1351	7066	38	93	77
Rongjiang/Guzhou	Guizhou	25.97 N	108.53 E	942	1967	6362	34	93	78
Sansui	Guizhou	26.97 N	108.67 E	2005	3322	4659	28	88	75
Sinan	Guizhou	27.95 N	108.25 E	1371	2494	5719	34	93	76
Weining	Guizhou	26.87 N	104.28 E	7336	4632	2342	21	75	60
Xingren	Guizhou	25.43 N	105.18 E	4524	2595	4527	30	83	68
Zunyi	Guizhou	27.70 N	106.88 E	2772	3091	4673	30	88	73
Danxian/Nada	Hainan	19.52 N	109.58 E	554	245	9606	48	94	78
Dongfang/Basuo	Hainan	19.10 N	108.62 E	26	107	10,168	53	91	81
Haikou	Hainan	20.03 N	110.35 E	49	211	9659	51	93	81
Qionghai/Jiaji	Hainan	19.23 N	110.47 E	82	133	9882	52	93	81
Sanhu Island	Hainan	16.53 N	111.62 E	16	0	11,282	69	90	83
Xisha Island	Hainan	16.83 N	112.33 E	16	0	11,221	69	89	82
Yaxian/Sanya	Hainan	18.23 N	109.52 E	23	7	10,735	60	90	80
Baoding	Hebei	38.85 N	115.57 E	62	4949	4411	14	93	73
Cangzhou	Hebei	38.33 N	116.83 E	36	4888	4504	14	92	74
Chengde	Hebei	40.97 N	117.93 E	1227	6778	3356	0	89	69
Fengning/Dagezhen	Hebei	41.22 N	116.63 E	2169	7891	2574	–5	86	66
Huailai/Shacheng	Hebei	40.40 N	115.50 E	1765	6490	3403	5	89	67
Leting	Hebei	39.43 N	118.90 E	39	5918	3562	8	87	74
Qinglong	Hebei	40.40 N	118.95 E	748	6611	3261	0	88	71
Shijiazhuang	Hebei	38.03 N	114.42 E	266	4695	4469	15	93	73
Tangshan	Hebei	39.67 N	118.15 E	95	5675	3867	8	89	74
Weichang/Zhuizishan	Hebei	41.93 N	117.75 E	2769	8600	2201	–6	83	65
Xingtai	Hebei	37.07 N	114.50 E	256	4506	4626	18	93	73
Yu Xian	Hebei	39.83 N	114.57 E	2986	7948	2545	–9	86	65

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)									
Zhangjiakou	Hebei	40.78 N	114.88 E	2382	6823	3202	2	88	65
Aihui	Heilongjiang	50.25 N	127.45 E	545	11,840	1840	–28	83	68
Anda	Heilongjiang	46.38 N	125.32 E	492	10,066	2482	–20	86	69
Baoqing	Heilongjiang	46.32 N	132.18 E	272	9731	2379	–17	85	69
Fujin	Heilongjiang	47.23 N	131.98 E	213	10,265	2356	–18	85	70
Hailun	Heilongjiang	47.43 N	126.97 E	787	11,017	2137	–24	83	68
Harbin	Heilongjiang	45.75 N	126.77 E	469	9830	2482	–20	85	69
Hulin	Heilongjiang	45.77 N	132.97 E	338	9977	2228	–17	82	70
Huma	Heilongjiang	51.72 N	126.65 E	587	12,658	1760	–36	84	67
Jixi	Heilongjiang	45.28 N	130.95 E	768	9518	2318	–14	84	69
Keshan	Heilongjiang	48.05 N	125.88 E	778	11,108	2123	–25	84	68
Mudanjiang	Heilongjiang	44.57 N	129.60 E	794	9464	2449	–16	85	69
Qiqihar	Heilongjiang	47.38 N	123.92 E	486	9924	2514	–18	86	69
Shangzhi	Heilongjiang	45.22 N	127.97 E	627	10,340	2189	–26	84	70
Suifenhe	Heilongjiang	44.38 N	131.15 E	1634	10,219	1714	–16	82	68
Sunwu	Heilongjiang	49.43 N	127.35 E	771	12,334	1585	–32	83	68
Tailai	Heilongjiang	46.40 N	123.42 E	492	9431	2663	–16	87	69
Tonghe	Heilongjiang	45.97 N	128.73 E	361	10,618	2210	–24	84	71
Yichun	Heilongjiang	47.72 N	128.90 E	761	11,239	1965	–28	83	68
Anyang/Zhangde	Henan	36.12 N	114.37 E	249	4318	4648	18	93	75
Boxian	Henan	33.88 N	115.77 E	138	4006	4755	20	93	77
Gushi	Henan	32.17 N	115.67 E	190	3567	4964	24	92	80
Lushi	Henan	34.05 N	111.03 E	1870	4572	3865	17	90	73
Nanyang	Henan	33.03 N	112.58 E	430	3779	4750	23	92	77
Xihua	Henan	33.78 N	114.52 E	174	4032	4623	21	93	78
Xinyang	Henan	32.13 N	114.05 E	377	3576	4922	24	92	78
Zhengzhou	Henan	34.72 N	113.65 E	364	4146	4614	19	93	75
Zhumadian	Henan	33.00 N	114.02 E	272	3885	4718	22	93	77
Fangxian	Hubei	32.03 N	110.77 E	1427	3688	4483	24	91	75
Guanghua	Hubei	32.38 N	111.67 E	299	3445	4989	26	93	79
Jiangling/Jingzhou	Hubei	30.33 N	112.18 E	108	3064	5325	29	93	81
Macheng	Hubei	31.18 N	114.97 E	194	3166	5363	27	94	80

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
(China cont.)									
Wuhan/Nanhu	Hubei	30.62 N	114.13 E	75	3140	5433	28	94	81
Yichang	Hubei	30.70 N	111.30 E	440	2812	5476	30	93	79
Zaoyang	Hubei	32.15 N	112.67 E	417	3463	5034	25	93	78
Zhongxiang	Hubei	31.17 N	112.57 E	217	3192	5240	28	92	80
Changde	Hunan	29.05 N	111.68 E	115	2896	5520	30	95	81
Chenzhou	Hunan	25.80 N	113.03 E	607	2496	6255	31	95	78
Nanyue	Hunan	27.30 N	112.70 E	4196	4866	3090	17	77	71
Sangzhi	Hunan	29.40 N	110.17 E	1056	2896	5229	30	93	77
Shaoyang	Hunan	27.23 N	111.47 E	814	2794	5651	30	93	78
Tongdao/Shuangjiang	Hunan	26.17 N	109.78 E	1302	2706	5440	30	90	76
Wugang	Hunan	26.73 N	110.63 E	1115	2854	5424	30	92	77
Yuanling	Hunan	28.47 N	110.40 E	469	2817	5442	30	93	78
Yueyang	Hunan	29.38 N	113.08 E	171	2870	5681	30	92	81
Zhijiang	Hunan	27.45 N	109.68 E	896	2857	5385	30	92	78
Abag Qi/Xin Hot	Inner Mongolia	44.02 N	114.95 E	3701	11,253	1853	–25	84	60
Arxan	Inner Mongolia	47.17 N	119.95 E	3373	13,802	964	–35	77	61
Bailing-Miao	Inner Mongolia	41.70 N	110.43 E	4518	9399	2005	–15	85	59
Bayan Mod	Inner Mongolia	40.75 N	104.50 E	4360	7762	2911	–6	89	59
Bugt	Inner Mongolia	48.77 N	121.92 E	2425	12,243	1187	–22	79	62
Bugt	Inner Mongolia	42.33 N	120.70 E	1316	7853	2855	–4	87	68
Chifeng/Ulanhad	Inner Mongolia	42.27 N	118.97 E	1877	7571	3015	–5	88	67
Dongsheng	Inner Mongolia	39.83 N	109.98 E	4787	8149	2202	–3	83	59
Duolun/Dolonnur	Inner Mongolia	42.18 N	116.47 E	4091	10,403	1547	–18	80	61
Ejin Qi	Inner Mongolia	41.95 N	101.07 E	3087	7313	3592	–5	95	62
Erenhot	Inner Mongolia	43.65 N	112.00 E	3169	9870	2442	–19	89	61
Guaizihu	Inner Mongolia	41.37 N	102.37 E	3150	7189	3769	–4	97	61
Hailar	Inner Mongolia	49.22 N	119.75 E	2005	12,730	1604	–32	82	64
Hails	Inner Mongolia	41.45 N	106.38 E	4954	8903	2317	–11	85	57
Haliut	Inner Mongolia	41.57 N	108.52 E	4232	8927	2305	–9	85	61
Hohhot	Inner Mongolia	40.82 N	111.68 E	3494	8022	2509	–4	86	63
Huade	Inner Mongolia	41.90 N	114.00 E	4869	10,129	1600	–13	80	59
Jartai	Inner Mongolia	39.78 N	105.75 E	3389	6960	3456	–3	93	62

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Wet-Bulb 1.0%
(China cont.)									
Jarud Qi/Lubei	Inner Mongolia	44.57 N	120.90 E	873	8245	2856	–7	89	68
Jining	Inner Mongolia	41.03 N	113.07 E	4646	9276	1709	–9	81	60
Jurh	Inner Mongolia	42.40 N	112.90 E	3780	9067	2401	–13	87	60
Lindong/Bairin Zuoq	Inner Mongolia	43.98 N	119.40 E	1591	8954	2352	–10	87	67
Linhe	Inner Mongolia	40.77 N	107.40 E	3415	7302	2995	–1	89	64
Linxi	Inner Mongolia	43.60 N	118.07 E	2625	9154	2171	–10	84	64
Mandal	Inner Mongolia	42.53 N	110.13 E	4012	8967	2413	–10	87	59
Naran Bulag	Inner Mongolia	44.62 N	114.15 E	3881	11,695	1655	–23	84	60
Nenjiang	Inner Mongolia	49.17 N	125.23 E	797	11,980	1880	–32	83	67
Otog Qi/Ulan	Inner Mongolia	39.10 N	107.98 E	4531	7722	2505	–5	87	60
Tongliao	Inner Mongolia	43.60 N	122.27 E	591	8319	2951	–9	88	70
Tulihe	Inner Mongolia	50.45 N	121.70 E	2405	14,791	902	–42	78	62
Uliastai	Inner Mongolia	45.52 N	116.97 E	2756	11,342	1892	–24	85	62
Xi Ujimqin Qi	Inner Mongolia	44.58 N	117.60 E	3271	11,137	1656	–21	83	62
Xilin Hot/Abagnar	Inner Mongolia	43.95 N	116.07 E	3251	10,480	2051	–20	85	62
Xin Barag Youqi	Inner Mongolia	48.67 N	116.82 E	1824	11,562	1945	–23	85	63
Dongtai	Jiangsu	32.87 N	120.32 E	16	3813	4612	24	91	81
Ganyu/Dayishan	Jiangsu	34.83 N	119.13 E	33	4412	4255	19	89	78
Liyang	Jiangsu	31.43 N	119.48 E	26	3517	4909	25	93	81
Lusi	Jiangsu	32.07 N	121.60 E	33	4613	4572	27	90	81
Qingjiang	Jiangsu	33.60 N	119.03 E	62	4018	4561	21	90	80
Shenyang/Hede	Jiangsu	33.77 N	120.25 E	23	4099	4370	22	90	80
Xuzhou	Jiangsu	34.28 N	117.15 E	138	4081	4695	20	92	77
Ganzhou	Jiangxi	25.85 N	114.95 E	410	1924	6919	34	94	78
Guangchang	Jiangxi	26.85 N	116.33 E	466	2289	6373	30	95	78
Ji'An	Jiangxi	27.12 N	114.97 E	256	2378	6378	32	95	79
Jingdezhen	Jiangxi	29.30 N	117.20 E	197	2620	5889	29	95	80
Lu Shan (Mountain)	Jiangxi	29.58 N	115.98 E	3822	4773	3240	17	80	72
Nanchang	Jiangxi	28.60 N	115.92 E	164	2685	5976	31	94	80
Nancheng	Jiangxi	27.58 N	116.65 E	269	2509	6120	31	94	79
Xiushui	Jiangxi	29.03 N	114.58 E	482	2853	5582	27	95	79
Xunwu	Jiangxi	24.95 N	115.65 E	981	1658	6685	33	92	77

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
(China cont.)									
Yichun	Jiangxi	27.80 N	114.38 E	423	2717	5726	30	94	79
Changbai	Jilin	41.35 N	128.17 E	3340	10,452	1502	–17	78	66
Changchun	Jilin	43.90 N	125.22 E	781	8844	2708	–13	85	70
Changling	Jilin	44.25 N	123.97 E	623	8939	2725	–14	86	69
Dunhua	Jilin	43.37 N	128.20 E	1726	9923	1891	–17	81	68
Huadian	Jilin	42.98 N	126.75 E	866	9326	2484	–26	84	71
Ji'An	Jilin	41.10 N	126.15 E	587	7612	2944	–9	86	72
Linjiang	Jilin	41.72 N	126.92 E	1093	8645	2573	–15	85	71
Qian Gorlos	Jilin	45.12 N	124.83 E	453	9062	2770	–16	86	71
Yanji	Jilin	42.88 N	129.47 E	584	8680	2396	–10	85	70
Chaoyang	Liaoning	41.55 N	120.45 E	577	7072	3397	–5	90	70
Dalian/Dairen/Luda	Liaoning	38.90 N	121.63 E	318	5648	3441	10	86	73
Dandong	Liaoning	40.05 N	124.33 E	46	6642	3014	2	83	74
Haiyang Island	Liaoning	39.05 N	123.22 E	33	5475	3341	13	82	77
Jinzhou	Liaoning	41.13 N	121.12 E	230	6598	3397	2	87	72
Kuandian	Liaoning	40.72 N	124.78 E	856	7744	2667	–10	84	72
Qingyuan	Liaoning	42.10 N	124.95 E	771	8373	2749	–17	87	71
Shenyang/Dongta	Liaoning	41.77 N	123.43 E	141	7218	3325	–8	87	73
Siping	Liaoning	43.18 N	124.33 E	541	8240	2898	–10	86	71
Yingkou	Liaoning	40.67 N	122.20 E	13	6765	3403	0	85	75
Zhangwu	Liaoning	42.42 N	122.53 E	276	7754	3060	–8	87	71
Yanchi	Ningxia	37.78 N	107.40 E	4426	6914	2774	–2	88	61
Yinchuan	Ningxia	38.48 N	106.22 E	3648	6617	2979	1	87	66
Zhongning	Ningxia	37.48 N	105.67 E	3888	6217	3070	3	88	66
Daqaidam	Qinghai	37.85 N	95.37 E	10,413	10,776	734	–11	74	49
Darlag	Qinghai	33.75 N	99.65 E	13,018	12,136	100	–13	62	48
Delingha	Qinghai	37.37 N	97.37 E	9783	9185	1170	–3	77	53
Dulan/Qagan Us	Qinghai	36.30 N	98.10 E	10,472	9668	770	–1	74	50
Gangca/Shaliuhe	Qinghai	37.33 N	100.13 E	10,830	11,792	174	–7	64	50
Golmud	Qinghai	36.42 N	94.90 E	9216	8414	1442	1	79	52
Henan	Qinghai	34.73 N	101.60 E	11,483	11,607	155	–17	64	50
Lenghu	Qinghai	38.83 N	93.38 E	8970	10,060	1142	–8	78	49

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)									
Madoi/Huangheyan	Qinghai	34.92 N	98.22 E	14,019	14,135	31	–18	58	43
Qumarleb	Qinghai	34.13 N	95.78 E	13,701	13,175	67	–16	62	46
Tongde	Qinghai	35.27 N	100.65 E	10,794	11,220	288	–14	68	51
Tuotuohe/Tanggulash	Qinghai	34.22 N	92.43 E	14,879	14,505	21	–21	60	42
Wudaoliang	Qinghai	35.22 N	93.08 E	15,135	15,114	8	–16	56	40
Xining	Qinghai	36.62 N	101.77 E	7421	7417	1620	3	78	57
Yushu	Qinghai	33.02 N	97.02 E	12,080	9354	550	–2	70	52
Zadoi	Qinghai	32.90 N	95.30 E	13,346	11,257	218	–9	65	48
Ankang/Xing'an	Shaanxi	32.72 N	109.03 E	955	3242	4920	28	93	76
Baoji	Shaanxi	34.35 N	107.13 E	2001	4345	3985	21	92	71
Hanzhong	Shaanxi	33.07 N	107.03 E	1670	3676	4253	27	89	75
Hua Shan (Mount)	Shaanxi	34.48 N	110.08 E	6768	7893	1516	5	72	60
Tongchuan	Shaanxi	35.17 N	109.05 E	2999	5470	3117	14	87	67
Xi'An	Shaanxi	34.30 N	108.93 E	1306	4332	4276	21	93	74
Yan An	Shaanxi	36.60 N	109.50 E	3146	5872	3132	6	89	66
Yulin	Shaanxi	38.23 N	109.70 E	3471	7039	2834	–5	88	64
Chengshantou (Cape)	Shandong	37.40 N	122.68 E	154	5125	3151	20	79	74
Dezhou	Shandong	37.43 N	116.32 E	72	4643	4591	16	91	75
Haiyang	Shandong	36.77 N	121.17 E	210	4943	3742	16	85	74
Heze/Caozhou	Shandong	35.25 N	115.43 E	167	4280	4627	18	92	77
Huimin	Shandong	37.50 N	117.53 E	39	5009	4270	12	91	75
Jinan/Sinan	Shandong	36.68 N	116.98 E	190	4161	5036	18	93	74
Linyi	Shandong	35.05 N	118.35 E	282	4388	4395	18	90	76
Longkou	Shandong	37.62 N	120.32 E	16	5167	3822	17	88	76
Quingdao/Singtao	Shandong	36.07 N	120.33 E	253	4651	3872	19	86	74
Rizhao	Shandong	35.38 N	119.53 E	49	4595	3926	19	85	78
Tai Shan (Mtns)	Shandong	36.25 N	117.10 E	5039	8288	1537	2	71	63
Weifang	Shandong	36.70 N	119.08 E	167	4816	4315	12	91	75
Xinxian	Shandong	36.03 N	115.58 E	154	4619	4426	16	92	77
Yanzhou	Shandong	35.57 N	116.85 E	174	4526	4412	15	92	76
Yiyuan/Nanma	Shandong	36.18 N	118.15 E	991	5093	3949	12	89	72
Datong	Shanxi	40.10 N	113.33 E	3507	7877	2512	–5	86	63

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)									
Hequ	Shanxi	39.38 N	111.15 E	2825	7336	2879	–7	89	66
Jiexiu	Shanxi	37.05 N	111.93 E	2461	5700	3285	8	89	68
Lishi	Shanxi	37.50 N	111.10 E	3120	6542	2959	1	88	66
Taiyuan/Wusu/Wusu	Shanxi	37.78 N	112.55 E	2556	6066	3132	5	88	69
Wutai Shan (Mtn)	Shanxi	39.03 N	113.53 E	9508	14,214	100	–19	63	53
Yangcheng	Shanxi	35.48 N	112.40 E	2162	5057	3714	14	88	69
Yuanping	Shanxi	38.75 N	112.70 E	2749	6705	2943	2	88	66
Yuncheng	Shanxi	35.03 N	111.02 E	1234	4433	4553	18	94	72
Yushe	Shanxi	37.07 N	112.98 E	3419	6482	2777	3	85	64
Barkam	Sichuan	31.90 N	102.23 E	8747	5419	1882	13	79	59
Batang	Sichuan	30.00 N	99.10 E	8494	3599	3267	22	85	59
Chengdu	Sichuan	30.67 N	104.02 E	1667	2708	4843	33	88	76
Da Xian	Sichuan	31.20 N	107.50 E	1020	2498	5455	34	94	78
Daocheng/Dabba	Sichuan	29.05 N	100.30 E	12,234	8614	624	4	68	49
Dawu	Sichuan	30.98 N	101.12 E	9708	6110	1639	11	77	57
Emei Shan	Sichuan	29.52 N	103.33 E	10,003	9458	381	8	61	54
Fengjie	Sichuan	31.05 N	109.50 E	1991	2889	5043	32	92	75
Garze	Sichuan	31.62 N	100.00 E	11,135	7656	991	5	72	53
Jiulong/Gyaisi	Sichuan	29.00 N	101.50 E	9823	5505	1568	18	75	55
Kangding/Dardo	Sichuan	30.05 N	101.97 E	8586	6870	1224	17	71	58
Langzhong	Sichuan	31.58 N	105.97 E	1263	2553	5192	34	92	77
Liangping	Sichuan	30.68 N	107.80 E	1493	2733	5111	33	92	77
Litang	Sichuan	30.00 N	100.27 E	12,959	9367	370	1	65	48
Luzhou	Sichuan	28.88 N	105.43 E	1102	2150	5690	38	93	78
Mianyang	Sichuan	31.47 N	104.68 E	1549	2771	4943	31	90	75
Nanchong	Sichuan	30.80 N	106.08 E	1017	2446	5422	35	93	78
Neijiang	Sichuan	29.58 N	105.05 E	1171	2235	5591	36	93	78
Pingwu	Sichuan	32.42 N	104.52 E	2877	3115	4327	30	88	71
Songpan/Sungqu	Sichuan	32.65 N	103.57 E	9357	7329	1094	8	74	56
Wanyuan	Sichuan	32.07 N	108.03 E	2211	3354	4305	28	90	73
Xichang	Sichuan	27.90 N	102.27 E	5246	1736	5211	35	87	65
Ya'An	Sichuan	29.98 N	103.00 E	2064	2584	4962	34	88	76

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
(China cont.)									
Yibin	Sichuan	28.80 N	104.60 E	1122	2043	5715	38	92	78
Youyang	Sichuan	28.83 N	108.77 E	2182	3311	4486	29	88	74
Baingoin	Tibet	31.37 N	90.02 E	15,423	12,487	70	–7	60	42
Dengqen	Tibet	31.42 N	95.60 E	12,710	9327	508	4	68	50
Lhasa	Tibet	29.67 N	91.13 E	11,975	6560	1433	14	75	52
Lhunze	Tibet	28.42 N	92.47 E	12,667	7949	864	8	69	49
Nagqu	Tibet	31.48 N	92.07 E	14,790	12,539	64	–11	62	44
Nyingchi	Tibet	29.57 N	94.47 E	9846	5624	1610	19	73	57
Pagri	Tibet	27.73 N	89.08 E	14,111	11,576	12	–5	55	45
Qamdo	Tibet	31.15 N	97.17 E	10,850	6550	1533	10	78	55
Shiquanhe	Tibet	32.50 N	80.08 E	14,039	12,092	517	–14	70	45
Sog Xian	Tibet	31.88 N	93.78 E	13,202	10,546	316	–6	67	49
Tingri/Xegar	Tibet	28.63 N	87.08 E	14,114	9994	456	0	67	46
Xainza	Tibet	30.95 N	88.63 E	15,325	11,849	98	–5	62	42
Xigaze	Tibet	29.25 N	88.88 E	12,589	7635	1064	6	72	51
Akqi	Xinjiang	40.93 N	78.45 E	6516	7653	2055	0	81	57
Alar	Xinjiang	40.50 N	81.05 E	3323	5921	3882	3	92	67
Altay	Xinjiang	47.73 N	88.08 E	2418	9426	2390	–21	85	63
Andir	Xinjiang	37.93 N	83.65 E	4147	6189	3804	–1	96	62
Bachu	Xinjiang	39.80 N	78.57 E	3665	5431	4284	7	94	65
Balguntay	Xinjiang	42.67 N	86.33 E	5751	7609	1963	1	81	56
Bayanbulak	Xinjiang	43.03 N	84.15 E	8068	15,010	204	–37	67	50
Baytik Shan (Mtns)	Xinjiang	45.37 N	90.53 E	5417	10,272	1357	–11	78	53
Fuyun	Xinjiang	46.98 N	89.52 E	2713	10,149	2386	–27	89	60
Hami	Xinjiang	42.82 N	93.52 E	2425	6518	3926	–1	95	66
Hoboksar	Xinjiang	46.78 N	85.72 E	4245	9445	1739	–9	81	57
Hotan	Xinjiang	37.13 N	79.93 E	4511	5069	4215	12	92	65
Jinghe	Xinjiang	44.62 N	82.90 E	1053	7844	3610	–15	94	69
Kaba He	Xinjiang	48.05 N	86.35 E	1752	9156	2491	–20	87	65
Karamay	Xinjiang	45.60 N	84.85 E	1404	7867	4225	–14	95	63
Kashi	Xinjiang	39.47 N	75.98 E	4236	5421	3784	8	90	65
Korla	Xinjiang	41.75 N	86.13 E	3061	5680	4212	7	93	66

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

Country City	Province or Region	Latitude		Longitude		Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
									99.6%	1.0%	1.0%
(China cont.)											
Kuqa	Xinjiang	41.72	N	82.95	E	3609	5703	3945	6	91	64
Mangnai	Xinjiang	38.25	N	90.85	E	9662	10,445	727	–3	76	48
Pishan	Xinjiang	37.62	N	78.28	E	4514	5337	4071	8	93	65
Qijiaojing	Xinjiang	43.48	N	91.63	E	2867	7117	3691	–2	95	60
Qitai	Xinjiang	44.02	N	89.57	E	2605	8861	2793	–20	90	63
Ruoqiang	Xinjiang	39.03	N	88.17	E	2917	5751	4280	5	98	66
Shache	Xinjiang	38.43	N	77.27	E	4042	5408	3871	9	91	66
Tacheng	Xinjiang	46.73	N	83.00	E	1755	7772	2834	–11	90	64
Tikanlik	Xinjiang	40.63	N	87.70	E	2779	6093	4132	1	96	67
Turpan	Xinjiang	42.93	N	89.20	E	121	5256	6038	7	104	70
Urumqi	Xinjiang	43.78	N	87.62	E	3015	8214	3015	–7	89	61
Yining	Xinjiang	43.95	N	81.33	E	2175	6617	3085	–8	89	66
Yiwu/Araturuk	Xinjiang	43.27	N	94.70	E	5673	9362	1538	–7	78	56
Baoshan	Yunnan	25.13	N	99.22	E	5430	2150	4324	34	81	66
Chuxiong	Yunnan	25.02	N	101.53	E	5817	2102	4413	33	82	63
Dali	Yunnan	25.70	N	100.18	E	6535	2398	3815	34	79	64
Deqen	Yunnan	28.50	N	98.90	E	11,444	7883	668	18	66	53
Guangnan	Yunnan	24.07	N	105.07	E	4104	1837	5381	33	85	67
Huili	Yunnan	26.65	N	102.25	E	5866	2471	4074	30	82	64
Huize	Yunnan	26.42	N	103.28	E	6923	3522	3015	25	78	62
Jiangcheng	Yunnan	22.62	N	101.82	E	3678	757	6438	42	85	68
Jinghong	Yunnan	22.02	N	100.80	E	1814	92	9106	49	93	72
Kunming/Wujiaba	Yunnan	25.02	N	102.68	E	6207	2461	3766	33	79	63
Lancang/Menglangba	Yunnan	22.57	N	99.93	E	3458	491	7158	41	88	66
Lijing	Yunnan	26.83	N	100.47	E	7854	3389	2818	30	76	60
Lincang	Yunnan	23.95	N	100.22	E	4931	1131	5588	39	83	64
Luxi	Yunnan	24.53	N	103.77	E	5604	2254	4341	31	81	63
Mengding	Yunnan	23.57	N	99.08	E	1680	168	8782	46	93	72
Mengla	Yunnan	21.50	N	101.58	E	2077	133	8686	47	91	72
Mengzi	Yunnan	23.38	N	103.38	E	4272	947	6397	39	86	66
Ruili	Yunnan	24.02	N	97.83	E	2546	478	7544	43	88	70
Simao	Yunnan	22.77	N	100.98	E	4275	796	6251	42	85	64

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(China cont.)									
Tengchong	Yunnan	25.12 N	98.48 E	5410	2161	4008	34	78	64
Yuanjiang	Yunnan	23.60 N	101.98 E	1306	166	9856	48	98	75
Yuanmou	Yunnan	25.73 N	101.87 E	3675	503	8165	41	93	67
Zhanyi	Yunnan	25.58 N	103.83 E	6234	2526	3855	30	80	61
Zhaotong	Yunnan	27.33 N	103.75 E	6398	4062	2977	23	80	63
Dachen Island	Zhejiang	28.45 N	121.88 E	276	2708	4966	34	84	80
Dinghai	Zhejiang	30.03 N	122.12 E	121	2799	5158	31	88	80
Hangzhou/Jianqiao	Zhejiang	30.23 N	120.17 E	141	3069	5353	28	95	81
Kuocang Shan	Zhejiang	28.82 N	120.92 E	4498	5430	2585	13	77	70
Lishui	Zhejiang	28.45 N	119.92 E	203	2311	6205	30	96	79
Qixian Shan	Zhejiang	27.95 N	117.83 E	4623	4321	3155	19	77	70
Qu Xian	Zhejiang	28.97 N	118.87 E	233	2724	5740	30	95	80
Shengsi/Caiyuanzhen	Zhejiang	30.73 N	122.45 E	266	2955	4905	31	87	79
Shengxian	Zhejiang	29.60 N	120.82 E	354	2999	5431	27	94	80
Shipu	Zhejiang	29.20 N	121.95 E	417	2785	5166	31	88	80
Taishan	Zhejiang	27.00 N	120.70 E	348	2271	5424	38	85	79
Tianmu Shan (Mtns)	Zhejiang	30.35 N	119.42 E	4902	6115	2225	11	75	69
Wenzhou	Zhejiang	28.02 N	120.67 E	23	2104	5981	34	91	81
Cuba									
Guantanamo Bay NAS	Ote.	19.90 N	75.15 W	75	0	11,719	67	93	78
Cyprus									
Akrotiri		34.58 N	32.98 E	75	1287	6147	40	89	72
Larnaca		34.88 N	33.63 E	7	1452	6028	37	91	72
Paphos		34.75 N	32.40 E	30	1279	5924	39	86	76
Czech Republic (Former Czechoslovakia)									
Prague/Libus		50.00 N	14.45 E	1001	6376	1853	3	80	64
Dominican Republic									
Santo Domingo		18.47 N	69.88 W	43	0	10,862	N.A.	N.A.	N.A.
Egypt									
Cairo		30.13 N	31.40 E	243	834	7993	45	97	69
Luxor		25.67 N	32.70 E	289	581	9849	40	108	71
Finland									
Helsinki/Seutula		60.32 N	24.97 E	167	9051	1138	–11	75	61

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
France									
Lyon/Satolas		45.73 N	5.08 E	814	4930	2609	17	86	69
Marseille		43.45 N	5.22 E	26	3194	3933	25	87	70
Nantes		47.17 N	1.60 W	89	4286	2480	23	83	68
Nice		43.65 N	7.20 E	33	2641	3983	35	83	73
Paris/Le Bourget		48.97 N	2.45 E	217	5046	2211	18	82	68
Strasbourg		48.55 N	7.63 E	502	5533	2193	12	84	68
Germany									
Berlin/Schoenfeld		52.38 N	13.52 E	154	6331	1820	11	82	65
Hamburg		53.63 N	9.98 E	52	6319	1569	11	79	64
Hannover		52.47 N	9.70 E	180	6093	1730	9	80	65
Mannheim		49.53 N	8.50 E	318	5428	2262	N.A.	N.A.	N.A.
Greece									
Souda	Crete	35.55 N	24.12 E	417	1767	5472	39	90	67
Thessalonika/Mikra		40.52 N	22.97 E	26	3389	4115	25	90	69
Greenland									
Narssarssuaq		61.18 N	45.42 W	79	11,521	292	–18	62	49
Hungary									
Budapest/Lorinc		47.43 N	19.18 E	459	5534	2647	8	86	68
Iceland									
Reykjavik		64.13 N	21.93 W	200	9286	293	14	58	52
India									
Ahmedabad		23.07 N	72.63 E	180	31	11,648	52	106	74
Bangalore		12.97 N	77.58 E	3018	2	9409	59	92	67
Bombay/Santa Cruz		19.12 N	72.85 E	26	2	11,372	62	93	74
Calcutta/Dum Dum		22.65 N	88.45 E	16	26	11,064	54	97	79
Madras		13.00 N	80.18 E	52	0	12,403	68	99	77
Nagpur Sonegaon		21.10 N	79.05 E	1014	18	11,274	53	108	71
New Delhi/Safdarjung		28.58 N	77.20 E	702	480	10,060	44	105	72
Indonesia									
Djakarta/Halimperda	Java	6.25 S	106.90 E	98	0	11,477	N.A.	N.A.	N.A.
Kupang Penfui	Sunda Island	10.17 S	123.67 E	354	2	11,686	N.A.	N.A.	N.A.
Makassar	Celebes	5.07 S	119.55 E	56	3	11,481	N.A.	N.A.	N.A.

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(Indonesia cont.)									
Medan	Sumatra	3.57 N	98.68 E	85	0	11,491	N.A.	N.A.	N.A.
Palembang	Sumatra	2.90 S	104.70 E	33	0	11,565	N.A.	N.A.	N.A.
Surabaja Perak	Java	7.22 S	112.72 E	10	0	12,088	N.A.	N.A.	N.A.
Ireland									
Dublin Airport		53.43 N	6.25 W	279	5507	1276	29	69	61
Shannon Airport		52.68 N	8.92 W	66	5106	1455	28	71	63
Israel									
Jerusalem		31.78 N	35.22 E	2654	2423	4609	33	86	64
Tel Aviv Port		32.10 N	34.78 E	33	955	6851	44	86	74
Italy									
Milano/Linate		45.43 N	9.28 E	351	4507	3335	21	87	72
Napoli/Capodichino		40.88 N	14.30 E	236	2658	4301	32	89	73
Roma/Fiumicino		41.80 N	12.23 E	7	2684	4173	30	86	74
Jamaica									
Kingston/Manley		17.93 N	76.78 W	46	0	11,860	71	98	78
Montego Bay/Sangster		18.50 N	77.92 W	3	1	10,915	70	90	79
Japan									
Fukaura		40.65 N	139.93 E	223	5522	2933	30	91	78
Sapporo		43.05 N	141.33 E	56	6753	2518	12	81	71
Tokyo		35.68 N	139.77 E	118	2986	4749	31	88	77
Jordan									
Amman		31.98 N	35.98 E	2516	2337	5427	33	92	65
Kenya									
Nairobi Airport		1.32 S	36.93 E	5328	273	6177	49	83	60
Korea									
Pyonggang		38.40 N	127.30 E	1217	6735	2840	3	85	74
Seoul		37.57 N	126.97 E	282	5007	3956	N.A.	N.A.	N.A.
Malaysia									
Kuala Lumpur		3.13 N	101.55 E	56	0	11,530	71	93	78
Penang/Bayan Lepas		5.30 N	100.27 E	10	0	11,472	N.A.	N.A.	N.A.
Mexico									
Mexico City	Distrito Federal	19.40 N	99.20 W	7572	1203	4762	39	82	57

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
(Mexico cont.)									
Guadalajara	Jalisco	20.67 N	103.38 W	5213	701	6121	N.A.	N.A.	N.A.
Monterrey	Nuevo Laredo	25.87 N	100.20 W	1476	844	8326	N.A.	N.A.	N.A.
Tampico	Tamaulipas	22.22 N	97.85 W	39	216	9870	50	90	80
Veracruz	Veracruz	19.15 N	96.12 W	52	17	10,006	57	92	80
Merida	Yucatan	20.98 N	89.65 W	30	10	11,122	57	98	76
Netherlands									
Amsterdam/Schiphol		52.30 N	4.77 E	–13	5691	1619	17	77	65
New Zealand									
Auckland Airport		37.02 S	174.80 E	23	2242	3650	35	76	66
Christchurch		43.48 S	172.55 E	118	4359	2115	28	79	61
Wellington		41.28 S	174.77 E	420	3597	2258	35	71	63
Norway									
Bergen/Florida		60.38 N	5.33 E	128	6882	1014	16	68	57
Oslo/Fornebu		59.90 N	10.62 E	52	8020	1331	0	77	62
Pakistan									
Karachi Airport		24.90 N	67.13 E	75	1155	11,049	N.A.	N.A.	N.A.
Papua New Guinea									
Port Moresby		9.43 S	147.22 E	92	2	11,272	N.A.	N.A.	N.A.
Paraguay									
Asuncion/Stroessner		25.27 S	57.63 W	331	469	9005	41	95	75
Peru									
Lima-Callao/Chavez		12.00 S	77.12 W	43	260	6745	57	84	74
San Juan de Marcona		15.35 S	75.15 W	197	306	6765	N.A.	N.A.	N.A.
Talara		4.57 S	81.25 W	282	4	8973	60	88	75
Philippines									
Manila Airport	Luzon	14.52 N	121.00 E	75	0	11,449	69	93	80
Poland									
Krakow/Balice		50.08 N	19.80 E	778	6924	2007	–1	81	67
Puerto Rico									
San Juan/Isla Verde WSFO		18.43 N	66.00 W	10	0	11,406	69	90	78
Romania									
Bucuresti/Bancasa		44.50 N	26.13 E	308	5461	2948	8	88	70

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
Russia (Former Soviet Union)									
Kaliningrad	East Prussia	54.70 N	20.62 E	89	7115	1589	–3	77	64
Krasnoiarsk		56.00 N	92.88 E	636	11,278	1351	–29	80	63
Moscow Observatory		55.75 N	37.57 E	512	8596	1708	–10	79	65
Petropavlovsk		53.02 N	158.72 E	23	10,107	530	5	66	58
Rostov-Na-Donu		47.25 N	39.82 E	259	6360	3015	2	86	68
Vladivostok		43.12 N	131.90 E	453	8915	1728	–8	75	67
Volgograd		48.68 N	44.35 E	476	7558	2840	–6	88	65
Saudi Arabia									
Dhahran		26.27 N	50.17 E	72	381	10,936	N.A.	N.A.	N.A.
Riyadh		24.70 N	46.73 E	2005	536	10,725	41	110	64
Senegal									
Dakar/Yoff		14.73 N	17.50 W	89	6	9750	61	88	77
Singapore									
Singapore/Changi		1.37 N	103.98 E	49	0	11,995	73	90	79
South Africa									
Cape Town/D F Malan		33.97 S	18.60 E	151	1685	4454	38	83	67
Johannesburg		26.13 S	28.23 E	5558	1919	4252	34	82	60
Pretoria		25.73 S	28.18 E	4364	1151	5828	39	88	63
Spain									
Barcelona		41.28 N	2.07 E	13	2638	3965	32	84	74
Madrid		40.47 N	3.57 W	1909	3669	3702	24	94	68
Valencia/Manises		39.50 N	0.47 W	203	1942	5045	34	88	72
Sweden									
Stockholm/Arlanda		59.65 N	17.95 E	200	8123	1297	–2	77	61
Switzerland									
Zurich		47.38 N	8.57 E	1867	6015	1995	13	80	65
Syria									
Damascus Airport		33.42 N	36.52 E	2001	2771	5293	25	98	64
Taiwan									
Alisan Shan		23.52 N	120.80 E	7894	4406	1958	N.A.	N.A.	N.A.
Chiayi (TW-AFB)		23.50 N	120.42 E	92	318	8926	48	91	81
Chiayyi		23.47 N	120.38 E	82	275	9288	47	92	82

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature 99.6%	Cooling Design Temperature Dry-Bulb 1.0%	Cooling Design Temperature Wet-Bulb 1.0%
(Taiwan cont.)									
Chilung		25.13 N	121.75 E	10	472	8554	50	91	79
Chinmen		24.43 N	118.43 E	39	974	7420	N.A.	N.A.	N.A.
Dawu		22.35 N	120.90 E	30	24	10,355	N.A.	N.A.	N.A.
Hengchun		22.00 N	120.75 E	79	23	10,120	60	90	80
Hengchun/Wu Lu Tien		22.03 N	120.72 E	43	21	10,407	N.A.	N.A.	N.A.
Hsinchu/Singjo		24.82 N	120.93 E	26	482	8567	48	91	82
Hua Lien		23.97 N	121.62 E	62	220	8872	N.A.	N.A.	N.A.
Hwalien		24.02 N	121.62 E	49	221	9043	N.A.	N.A.	N.A.
Joyutang		23.88 N	120.85 E	3330	583	7136	N.A.	N.A.	N.A.
Kao Hsiung Intl. Arpt.		22.57 N	120.35 E	26	111	9702	53	91	80
Kao Hsiung		22.62 N	120.27 E	95	70	9940	54	90	81
Kungkuan		24.27 N	120.62 E	666	541	8306	N.A.	N.A.	N.A.
Kungshan		22.78 N	120.25 E	33	158	9526	N.A.	N.A.	N.A.
Lan Yu		22.03 N	121.55 E	1066	95	8765	57	84	80
Makung		23.57 N	119.62 E	102	283	8957	52	89	82
Matsu Island		26.17 N	119.93 E	302	1948	5898	N.A.	N.A.	N.A.
North Pingtung		22.70 N	120.47 E	95	88	10,049	52	93	81
Peng Hu		23.52 N	119.57 E	69	287	9068	N.A.	N.A.	N.A.
Penkaiyu		25.63 N	122.07 E	335	531	8160	N.A.	N.A.	N.A.
Sing Jo		24.80 N	120.97 E	108	534	8480	N.A.	N.A.	N.A.
Sinkung		23.10 N	121.37 E	121	88	9601	N.A.	N.A.	N.A.
South Pingtung		22.67 N	120.45 E	79	71	10,228	53	93	81
Taichung		24.15 N	120.68 E	256	312	8991	49	91	79
Taichung/Shui Nan		24.18 N	120.65 E	364	381	8915	46	93	82
Tainan (TW-AFB)		22.95 N	120.20 E	52	150	9729	50	91	82
Tainan		23.00 N	120.22 E	46	178	9577	51	91	81
Taipei		25.03 N	121.52 E	26	438	8896	48	93	80
Taipei/Chiang Kai Shek		25.08 N	121.23 E	75	594	8456	48	92	80
Taipei/Sungshan		25.07 N	121.53 E	20	506	8454	48	93	81
Taitung		22.75 N	121.15 E	33	74	9754	N.A.	N.A.	N.A.
Taitung/Fongyentsun		22.80 N	121.18 E	121	72	9767	N.A.	N.A.	N.A.
Taoyuan (AB)		25.07 N	121.23 E	164	626	8315	47	92	82

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

Country City	Province or Region	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature Dry-Bulb	Cooling Design Temperature Wet-Bulb
							99.6%	1.0%	1.0%
(Taiwan cont.)									
Tung Shih		23.27 N	119.67 E	148	191	9217	N.A.	N.A.	N.A.
Wu-Chi		24.25 N	120.52 E	16	405	8691	50	90	81
Yilan		24.77 N	121.75 E	23	411	8416	N.A.	N.A.	N.A.
Tanzania									
Dar es Salaam		6.88 S	39.20 E	180	4	10,755	N.A.	N.A.	N.A.
Thailand									
Bangkok		13.73 N	100.57 E	52	0	12,430	65	97	79
Tunisia									
Tunis/El Aouina		36.83 N	10.23 E	16	1657	5769	41		73
Turkey									
Adana		37.00 N	35.42 E	217	1847	6098	32	94	71
Ankara/Etimesgut		39.95 N	32.68 E	2644	5162	3077	2	86	63
Istanbul/Yesilkoy		40.97 N	28.82 E	121	3534	3777	26	84	69
United Kingdom									
Birmingham	England	52.45 N	1.73 W	325	5866	1355	21	75	62
Edinburgh	Scotland	55.95 N	3.35 W	135	6347	1001	21	69	60
Glasgow Apt	Scotland	55.87 N	4.43 W	23	6287	1041	21	71	61
London/Heathrow	England	51.48 N	0.45 W	79	5015	1894	25	78	64
Uruguay									
Montevideo/Carrasco		34.83 S	56.03 W	108	2124	4602	35	86	71
Venezuela									
Caracas/Maiquetia		10.60 N	66.98 W	236	9	11,501	70	91	83
Vietnam									
Hanoi/Gialam		21.02 N	105.80 E	26	330	9868	N.A.	N.A.	N.A.
Saigon (Ho Chi Minh)		10.82 N	106.67 E	62	0	12,057	68	94	77

(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 90.1-2010 and to acknowledge source documents when appropriate. Some documents are also included in Section 12, "Normative References," because there are other citations of those documents within the standard that are normative.

Address/Contact Information

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

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

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

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

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

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

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

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

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

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

Subsection No.	Reference	Title/Source
Exception to 5.5.3.1	CRRC-1-2006	Cool Roof Rating Council Product Rating Program
6.4.2	*2005 ASHRAE Handbook—Fundamentals*	ASHRAE
6.4.4.1.1	MICA Insulation Standards—6th Edition	National Commercial and Industrial Insulation Standards
6.4.4.2.1	SMACNA Duct Construction Standards—2005	HVAC Duct Construction Standards, Metal and Flexible
6.4.4.2.2	SMACNA Duct Leakage Test Procedures—1985	*HVAC Air Duct Leakage Test Manual* Sections 3,5, and 6
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, National Standards for Total System Balance
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	*2007 ASHRAE Handbook—HVAC Applications*	Chapter 49, Service Water Heating/ASHRAE
11.2.1	DOE-2	Support provided by Lawrence Berkeley National Laboratory at the referenced Web site
11.2.1	BLAST	University of Illinois
11.2.2	IWEC	International Weather for Energy Calculations
11.2.2	TMY 2 Data	Typical Meteorological Year

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INFORMATIVE APPENDIX F
ADDENDA DESCRIPTION INFORMATION

ASHRAE/IES Standard 90.1-2010 incorporates ANSI/ASHRAE/IESNA Standard 90.1-2007 all addenda to ANSI/ASHRAE/IESNA Standard 90.1-2007. The following table lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE, IES, and ANSI approval dates for each addendum.

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

Addendum	Section(s) Affected	Description of Changes*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES BOD Approval	ANSI Approval
a	6.8.1G	This addendum seeks to clarify that the current cooling tower requirements in the Standard apply to open-circuit cooling towers only.	6/23/2007	6/27/2007	6/12/2007	7/25/2007
b	6.5.2.3	This addendum updates the references for outdoor *ventilation* rates.	6/23/2007	6/27/2007	6/12/2007	7/25/2007
c	6.5.2.3	This addendum adds vivariums to the list of *spaces* that require specific humidity levels to satisfy process needs.	6/23/2007	6/27/2007	6/12/2007	7/25/2007
d	5.5.4.4, 9.7	This addendum modifies the daylighting requirements to allow the use of photocontrols combined with skylighting to reduce the electricity used for lighting.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
e	6.5.6	This addendum modifies the requirements for Energy Recovery by expanding them to cover the use of energy recovery by weather zone	1/23/2010	1/27/2010	1/20/2010	1/28/2010
f	5.5.3.1	This addendum sets requirements for high-albedo *roofs*	6/26/2010	6/30/2010	6/23/2010	7/1/2010
g	Section 5, Normative Appendix A2.3	This addendum updates the building envelope criteria for *metal buildings*.	6/21/2008	6/25/2008	6/30/2008	7/26/2008
h	6.5.2.1	This addendum adds a new exception that is geared toward zones with *direct digital controls* (DDC).	6/21/2008	6/25/2008	6/30/2008	7/26/2008
i	9.4.5	This addendum applies a four-zone *lighting power density* approach to exterior lighting requirements.	6/21/2008	6/25/2008	6/30/2008	7/26/2008
j	Section 12, Informative Appendix E	This addendum updates references in the Standard.	1/19/2008	1/23/2008	1/28/2008	1/26/2008
k	Table 6.8.1E, Table 7.8	This addendum specifies specific sections of reference standards in Tables 6.8.1E and 7.8.	1/19/2008	1/23/2008	1/28/2008	7/24/2008
l	Table 6.8.1G, Section 12	This Addendum adds minimum *efficiency* and certification requirements for both axial and centrifugal fan closed-circuit cooling towers (also known as *fluid coolers*) to Table 6.8.1G. In addition, a reference to ATC-105S, the Cooling Technology Institute test standard for closed-circuit cooling towers, has been added to Section 12, Normative References.	1/19/2008	1/23/2008	1/28/2008	7/24/2008

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

m	Section 6.4.1.2, Table 6.8.1C	This addendum establishes effective January 1, 2010, an additional path of compliance for water-cooled chillers and also combines all water-cooled positive displacement chillers into one category and adds a new size category for centrifugal chillers at or above 2110 kW.	10/12/2008	10/24/2008	10/10/2008	10/27/2008
n	6.4.3.10	This addendum extends variable air volume fan *control* requirements to large single-zone units.	6/21/2008	6/25/2008	6/30/2008	7/26/2008
o	8.1	This provides the necessary pressure credits for laboratory exhaust *systems* that allow prescriptive compliance of *systems* serving fume hoods.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
p	6.5.3.1.1	This addendum addresses fan power limitations to all fan *systems* with exception to those serving fume hoods.	6/21/2008	6/25/2008	6/30/2008	7/26/2008
q	5.4.3.4	This addendum modifies the vestibule requirements for climate zone 4.	1/19/2008	1/23/2008	1/28/2008	7/24/2008
r	Appendix G	This changes Appendix G from an informative appendix to a normative appendix.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
s	Table 6.8.1A, Table 6.8.1B	This addendum updates the COP at –8.3°C *efficiency* levels for commercial heat pumps and introduces a new part load energy *efficiency* descriptor for all commercial unitary products above 19 kW of cooling capacity.	10/12/2008	10/24/2008	10/10/2008	10/27/2008
t	6.4.1.5.2, Table 6.8.1D	This addendum removes the terms "replacement" and "new *construction*" from the product classes listed in Table 6.8.1D and replaces them with the terms "non-standard size" and "standard size," respectively, to clarify that one product class is intended for applications with non-standard size exterior *wall* openings while the other is intended for applications with standard size exterior *wall* openings. The addendum also amends Section 6.4.1.5.2 and footnote b to Table 6.8.1D to clarify that non-standard size packaged *terminal equipment* have sleeves with an external *wall* opening less than 46 cm high or less than 107 cm wide to reflect existing applications where the *wall* opening is not necessarily less than 46 cm high and less than 107 cm wide.	10/12/2008	10/24/2008	10/10/2008	10/27/2008
u	6.5.5.3	This addendum adds requirements for axial fan open-circuit cooling towers.	10/12/2008	10/24/2008	10/10/2008	10/27/2008
v	6.4.2	This modifies the requirements for axial fan open circuit cooling towers	1/24/2009	1/28/2009	1/26/2009	1/29/2009
w	Table G3.1.1A, Section G3.1.2.10	This addendum modifies requirements on exhaust air energy recovery for multifamily buildings in Appendix G.	10/12/2008	10/24/2008	10/10/2008	10/27/2008
x	9.4.1.1	This revision updates the requirements for *automatic* lighting shutoffs, adds specific occupancysensor applications, and provides additional clarification.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
y	Table 7.8, Section 12	This addendum establishes AHRI 1160 as the test procedure for heat pump *pool* heaters and that the minimum COP be met at the low outdoor temperature of 10°C.	6/21/2008	6/25/2008	6/30/2008	7/26/2008
aa	9.4.1	This change mandates that lighting *controls* have a "*manual* on" capability	6/20/2009	6/24/2009	6/15/2009	7/22/2009
ab	9.4.1	This change modifies skylighting and daylighting requirements from addendum "d" to 90.1-2007.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
ac	9.1.4, 9.6.2	This addendum modifies requirements for controls in the following applications: personal and manual dimming, multi-scene, manual and automatic bi-level switching, daylighting.	6/21/2008	6/25/2008	6/30/2008	7/24/2008

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

ad	Table 6.8.1K, Section 6.4.1.4, Section 12	This addendum adds requirements for liquid to liquid heat exchangers and adds a reference to AARI 400-2008.	6/21/2008	6/25/2008	6/30/2008	7/24/2008
ae	6.4.4.1.4	This change adds requirements for radiant heating panels.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
af	6.5.4.5	This change modifies the pipe sizing requirements.	1/24/2009	1/28/2009	1/26/2009	1/29/2009
ag	5.8.1.10	This adds a requirement for joint insulation overlap.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
ai	G3.1.1.3	This clarifies how distribution pump *energy* is to be addressed when using purchased heat or purchased chilled water.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
aj	10.4.1	This update the test and table of Chapter 10 to comply with the new federal law. Since the new law and the new version of ASHRAE 90.1 will both occur in 2010, this change will ensure that there is no confusion about the new *energy efficiency* standards for motors that are manufactured in 2010 and beyond.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
ak	6.5.4	This modifies requirements for Heat Pump and Water-Cooled Unitary Air-Conditioners, Differential Pressure Reset, fan power limitations, chilled water cooling, and deletion of 10 HP from Section 6.5.4	6/6/2009	6/24/2009	6/15/2009	6/25/2009
al	5.5.4.2.3,	This adds *skylight* requirements in certain *space* types to promote daylighting *energy* savings.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
am	5.4.3.2	The intent of this addendum is to revise air leakage criteria so they more closely reflect current practice.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
an	Appendix A2.4	This expand the table of default *U-Factors* for single digit rafter *roofs*.	1/24/2009	1/28/2009	1/26/2009	1/29/2009
ao	Table 6.8.1E	This corrects errors in Table 6.8.1E, re-orders footnotes, and changes one *efficiency*.	1/24/2009	1/28/2009	1/26/2009	1/29/2009
ap	6.3.2	This modifies the requirements for *Demand Control Ventilation* (DCV).	1/24/2009	1/28/2009	1/26/2009	1/29/2009
aq	1. Purpose, 2. Scope	This addendum modifies the Purpose and expands the scope so the standard may regulate *process loads*	6/26/2010	6/30/2010	6/23/2010	7/1/2010
ar	9.1.3, 9.4.5	This addendum adds exterior lighting power requirements.	1/23/2010	1/27/2010	1/20/2010	1/24/2010
as	6.5.2.1	This addendum adds lab exhaust requirements.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
at	6.4.3.4	This change modifies the exhaust air damper requirements in 90.1	6/20/2009	6/24/2009	6/15/2009	7/22/2009
au	6.3.2	This change modifies the economizer requirements in Standard 90.1.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
av	9.1.2.1	This modifies the requirements of section 9.1.2 Lighting Alterations and replaces the previous public review draft of addendum "av" in its entirety.	1/23/2010	1/27/2010	1/20/2010	1/24/2010
aw	9.4.1.4	This change recognizes the practical design application of excluding bathroom lighting from "master" switch *control* in hotel/motel guest rooms and adds a requirement to eliminate wasted light in guest room bathrooms.	1/19/2008	1/23/2008	1/28/2008	7/26/2008
ax	6.5.7.1	This modifies requirements for kitchen exhaust.	6/26/2010	6/30/2010	6/23/2010	7/1/2010

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

ay	9.6.1	This change more correctly requires users to identify *spaces* by function and is consistent with a previous interpretation. It is expected that the net *energy* result will be positive.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
az	9.4.6	Lighting *controls* must be functionally tested to ensure their proper use and appropriate *energy* savings. This addendum provides requirements for those tests.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
ba	6.8.3	This a *system* performance option that allows compensating for the insulating value of the piping while maintaining the same net thermal requirements.	6/20/2009	6/24/2009	6/15/2009	7/22/2009
bc	5.1.2.2	This clarifies that the requirements in Section 5.5.4.2.3 are also specified for *unconditioned spaces*.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
bd	8.4.1	This addendum removes emergency circuits not used for normal building operation from the requirements which will lead to increased compliance.	6/6/2009	6/24/2009	6/15/2009	6/25/2009
bf	5.4.3.1	This provides performance requirements for air leakage of the *opaque* envelope.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
bg	Table 6.8.1B	This provides requirements for water-to-water heat pumps	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bh	6.5.3.3	This provides requirements for multiple zone *HVAC systems* (that include simultaneous heating and cooling) to include *controls* that automatically raise the supply-air temperature when the *spaces* served are not at peak load conditions.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bi	6.4.4.1.3	This provides updated requirements for pipe insulation.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
bj	G3.1.2.5	This adds an exception within Appendix G that allows users to claim *energy* cost savings credit for the increased *ventilation* effectiveness of certain *HVAC system* designs.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bk	10.4.1	This language distinguishes Subtype I and Subtype II motors. Addendum "aj" to ASHRAE Standard 90.1-2007 first incorporated these changes into Standard 90.1. This proposed language has different minimum *efficiency* requirements as called out in EISA 2007, Section 313 and clarified in the Federal Register.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bl	6.4.1.2.1	This adds requirements for chillers with secondary coolants (glycol or brine). In additions, there are changes to footnote a to Table 6.8.1C in recognition of lower practical scope limits for positive displacement (both air- and water-cooled) and corrects for the lower limit introduced in Addendum M for centrifugal chillers.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bm	3.3	The intent of this addendum is to coordinate terminology for *visible transmittance* with NFRC 200	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bn	5.5.4.5	This limits poorly oriented *fenestration*. Compliance can be shown by having more south facing *fenestration* than west facing *fenestration*. For those buildings affected by this requirement, this reduces envelope loads, *energy* usage and thereby costs	6/26/2010	6/30/2010	6/23/2010	7/1/2010
bo	11.3.2, G3.1.2.1	This is part of an ongoing effort to keep the requirements of Section 11 and Appendix G consistent with other addenda to the Standard. This addendum makes changes to Section 11 and G related to Addenda e, s, and u.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bp	9.4.1	This allows the use of *control* that provides *automatic* 50% auto on with the capability to manually activate the remaining 50% and has full auto-off.	1/23/2010	1/27/2010	1/20/2010	1/24/2010

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

bq	9.6.2	This changes the requirements for retail *space* lighting which will make use of more recent *lamp* technology that is readily available.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
br	9.4.5	This adds an exterior zone 0 to cover very low light requirement areas	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bs	8.4.2	This new requirement will provide the means for non-critical receptacle loads to be automatically controlled (turned off) based on occupancy or scheduling without additional individual desk top or similar controllers.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
bt	6.4.1.2	This addendum modifies centrifugal chiller adjustment factor for nonstandard conditions.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
bu	6.4.1.1, 6.5.1, Table 6.8.1H	This addendum adds *efficiency* requirements to *HVAC systems* dedicated to computer rooms and data centers.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
bv	G3.1.2.9	The addendum makes Appendix G of Standard 90.1 consistent with addenda aj, bk, and ax.	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bw	Table 6.8.1D	The addendum modifies *efficiency* requirements for *packaged terminal air conditioner*(PTAC).	1/23/2010	1/27/2010	1/20/2010	1/28/2010
bx	6.5.2.1	This addendum modifies VAV reheat requirements.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
by	9.6.2, Table 9.5.1	This proposes new Lighting Power Densities for both the whole building and space-by-*space* compliance methods. In addition, the *Lighting Power Density* may be re-calculated based on room geometry.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
ca	6.5.3.1.1	This change closes a loophole in the fan power allowances for *Variable Air Volume* (VAV) *systems*. Standard VAV *systems* are multi-zone *systems* with *terminal* units containing *control* dampers to vary airflow to individual zone	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cb	6.3.2, 6.4.3.4.2	This addendum includes a number of changes to require simple *systems* to meet prescriptive *outdoor air* damper requirements, allow backdraft dampers only for exhaust and relief dampers in buildings less than three stories in height, require backdraft dampers on *outdoor air* intakes to be protected from wind limiting wind blown infiltration through the damper.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cc	Table 6.5.4.5	This addendum fixes a mistake in the way 200 mm pipe was analyzed. RS Means data for threaded pipe was used for 8" when welded pipe data should have been used. It also includes a minor editorial change since it is not possible to operate more than 8760 hrs/yr	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cd	9.4	These additions 1) strengthen the language to actually require exterior *control* rather than just require the *control* capability; 2) add bi-level *control* for general all-night applications such as parking lots to reduce lighting when not needed; 3) add *control* for façade and landscaping lighting not needed after midnight	7/20/2010	7/23/2010	7/24/2010	7/26/2010
ce	9.4.1.2	This additional *control* requires that all *spaces* (unless exempted) have multilevel *control* capability (also commonly known as bi-level switching).	6/26/2010	6/30/2010	6/23/2010	7/1/2010

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

cf	9.4.1.4	Stairwell lighting represents the "Emergence Egress Light Level" with stairwell occupancy. However the occupancy percentage of a stairwell is only 10%, thus offering savings. Various case studies and demonstrations have shown significant *energy* savings for this strategy.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
ch	11.3.2, G3.1.1	This addendum makes Appendix G and Section 11 consistent with requirements approved in Addenda h (dual minimum *controls*) and as (lab exhaust)	6/26/2010	6/30/2010	6/23/2010	7/1/2010
ck	6.5.3	This addendum expands zone level demand controlled *ventilation* to include various forms of *system* level strategies.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
cl	5.5.4.4.2, Appendix C	The proposed text would clarify how to interpret the use of *dynamic glazing* products that are designed to be able to vary a performance property such as SHGC, rather than having just a single value.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cn	Table 9.6.2	This change adds two versions of a combined advanced *control* to the control incentives table. These *control system*combinations involve personal workstation *control* and workstation-specific occupancy sensors for open office applications. The *control* incentive will apply only to the particular *controls* when they are applied in open office areas.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
co	Table 6.8.1A	This proposal makes three major amendments to Table 6.8.1A. First, it updates EER and IEER values for all condensing units and water and evaporatively cooled air conditioners with cooling capacities greater than 19 kW. Second, the proposal establishes a separate product class for evaporatively cooled air conditioners with different *energy efficiency* standards. Third, the proposal replaces the IPLV descriptor for condensing units with the new IEER metric and amends the EERs with more stringent values.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
cp	6.4.1.1, Table 6.8.1I	This proposal establishes, for the first time in ASHRAE 90.1, *efficiency* requirements for VRF air conditioners and heat pumps, including heat pumps that use a water source for heat rejection.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cq	6.4.4.2	This addendum modifies the duct sealing requirements in ANSI/ASHRAE/IESNA Standard 90.1-2007.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
cr	Table 11.3.1, Appendix G	The definition for an *unmet load hour* is currently lacking a throttling range or limit to the *setpoint*. It was decided that the baseline and proposed shall have the same *thermostat* throttling range. This required additional language in the *unmet load hour* definition as to how throttling range effects determination of an unmet hour along with additional language in Table 11.3.1 and Table G3.1, Design Model sections.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cs	8.4.2	This change originated with a continuous maintenance proposal to address information received on addendum bs on receptacles after the public review period closed and which the committee found to have merit.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
ct	9.4.1.3	This addendum sets *controls* for the the "night lights" that are part of the emergency *system* when there are no occupants in the *space*. This has definite *energy* savings and is not prohibited by the electrical codes.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
cv	10.4.2	This addendum adds *energy efficiency* requirements for *service* water pressure booster *systems*.	7/20/2010	7/23/2010	7/24/2010	7/26/2010

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

cw	11.3.1	These changes address corrections and clarifications necessary to Section 11, Table 11.3.1 and Section 11 *Service* Hot Water *Systems*.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
cy	6.5.1	This addendum makes several revisions to the economizer requirements in Section 6.5.1 and in Section 6.3.2. With increased envelope insulation levels and higher internal plug loads we are seeing commercial buildings operating in cooling at lower ambient temperatures. This allows for greater air and *water economizers* to be used instead of *mechanical cooling*.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
cz	9.4.1.3	This change incorporates bi-level *control* for parking garages to reduce the wasted *energy* associated with unoccupied periods for many garages AND allows an exception for lighting in the transition (entrance/exit) areas to accommodate IES recommendations.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
da	G3.1.2.5	The intent of this addendum is to establish that an Appendix G baseline shall be based on the minimum *ventilation* requirements required by local codes or a rating authority and not the *proposed design ventilation* rates.	6/26/2010	6/30/2010	6/23/2010	7/1/2010
db	G3.1.2	This addendum modifies the fan power requirements in the *energy cost budget* section.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dc	9.4.2	The conditions and common practice that existed to create the need for this requirement on tandem wiring are no longer practiced primarily with the new Federal *efficacy* requirements and products available on the market	6/26/2010	6/30/2010	6/23/2010	7/1/2010
dd	5.5.4.2.3	This addendum modifies the VAV fan power limitation requirements.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
de	Table 9.6.1	This addendum lowers the Lighting Power Densities in 90.1 to reflect advances in lighting technology.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
df	10.4.3	This addendum sets requirements elevator *ventilation* and lighting, which have been unregulated, regardless of occupancy.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dg	Table G3.1	This addendum adds a definition for the term field fabricated used in Section 5.4.3.2, which is similar to the definition in CA Title 24	7/20/2010	7/23/2010	7/24/2010	7/26/2010
di	6.4.3.4.6	This addendum allows for a reduction in *ventilation* in uncontaminated garages	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dj	Table 6.5.3.1.1B	This addendum provides limits on the pressure drop of *energy* recovery devices.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dk	Appendix C	This addendum makes 90.1-2010 consistent with changes made in addenda al, bc, and bn.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dl	Appendix C	This addendum gives instruction to the users of Appendix C on how to model the base envelope design and the proposed envelope design in complying with the cool roof provisions in Section 5.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dn	G3.1.1	This addendum modifies the efficiencies for *variable refrigerant flow equipment*	7/20/2010	7/23/2010	7/24/2010	7/26/2010
do	9.7	This addendum attempts to clearly establish the goals and requirements of the *lighting system* including *controls* and to ensure that the owner is provided all information necessary to best use and maintain the *lighting systems*	7/20/2010	7/23/2010	7/24/2010	7/26/2010

TABLE F-1 Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Changes Identified

dp	Section 12	This addendum updates the references in Standard 90.1. While these changes reflect the current edition of the cited standard it should be noted that substantive changes in the referenced documents did not affect the requirements in 90.1 or change the stringency of the requirements of 90.1.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dq	Appendix C	This addendum modifies the calculations found in Appendix C in order to reflect modifications to the modeling assumptions in the equations.	7/20/2010	7/23/2010	7/24/2010	7/26/2010
dr	9.4.4	The original purpose for this provision was to limit the use of inefficient lighting sources for high wattage applications when there was not a comprehensive table of exterior LPD limits. With the table of requirements now in the 2007 and beyond versions of the standard, the need for this limit is superseded.	7/20/2010	7/23/2010	7/24/2010	7/26/2010

(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.)

NORMATIVE APPENDIX G PERFORMANCE RATING METHOD

G1. GENERAL

G1.1 Performance Rating Method Scope. This building *performance rating method* is a modification of the Energy Cost Budget (ECB) Method in Section 11 and is intended for use in rating the *energy efficiency* of building designs that exceed the requirements of this standard. This appendix does NOT offer an alternative compliance path for minimum standard compliance; that is the intent of Section 11, Energy Cost Budget Method. Rather, this appendix is provided for those wishing to use the methodology developed for this standard to quantify performance that substantially exceeds the requirements of Standard 90.1. It shall be used for evaluating the performance of all such *proposed designs*, including *alterations* and *additions* to *existing buildings*, except designs with no mechanical *systems*.

G1.2 Performance Rating. This *performance rating method* requires conformance with the following provisions:

All requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met. These sections contain the mandatory provisions of the standard and are prerequisites for this rating method. The improved performance of the proposed building design is calculated in accordance with provisions of this appendix using the following formula:

Percentage improvement
= 100 × (*Baseline building performance*
– *Proposed building performance*) / *Baseline building performance*

Notes:

1. Both the *proposed building performance* and the *baseline building performance* shall include all end-use load components, such as receptacle and *process loads*.
2. Neither the *proposed building performance* nor the *baseline building performance* are predictions of actual *energy* consumption or costs for the *proposed design* after *construction*. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, *energy* use not covered by this procedure, changes in *energy* rates between design of the building and occupancy, and the precision of the calculation tool.

G1.3 Trade-Off Limits. When the proposed modifications apply to less than the whole building, only parameters related to the *systems* to be modified shall be allowed to vary. Parameters relating to unmodified existing conditions or to future building components shall be identical for determining both the *baseline building performance* and the *proposed building performance*. Future building components shall meet the prescriptive requirements of Sections 5.5, 6.5, 7.5, 9.5, and 9.6.

G1.4 Documentation Requirements. Simulated performance shall be documented, and documentation shall be submitted to the *rating authority*. The information shall be submitted in a report and shall include the following:

a. A brief description of the project, the key *energy efficiency* improvements, the *simulation program* used, the version of the *simulation program*, and the results of the *energy* analysis. This summary shall contain the calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.
b. An overview of the project that includes: the number of stories (above and below *grade*), the typical floor size, the uses in the building (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is *conditioned space*.
c. A list of the energy-related features that are included in the design and on which the performance rating is based. This list shall document all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.
d. A list showing compliance for the *proposed design* with all the requirements of 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).
e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of 5.5, 6.5, 7.5, 9.5, and 9.6 (prescriptive provisions).
f. A table with a summary by end use of the *energy* cost savings in the *proposed building performance*.
g. A site plan showing all adjacent buildings and topography which may shade the proposed building (with estimated height or number of stories).
h. Building elevations and floor plans (schematic is acceptable).
i. A diagram showing the *thermal blocks* used in the computer simulation.
j. An explanation of any significant modeling assumptions.
k. Back-up calculations and material to support data inputs (e.g., *U-factors* for envelope assemblies, NFRC ratings for *fenestration*, end-uses identified in 1. Design Model, paragraph (a), in Table G3.1.
l. Input and output report(s) from the *simulation program* or compliance software including a breakdown of *energy* usage by at least the following components: lights, internal *equipment* loads, *service water heating equipment*, *space* heating *equipment*, *space* cooling and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of *unmet load hours* for both the *proposed design* and *baseline building design*.
m. *Purchased energy rates* used in the simulations.
n. An explanation of any error messages noted in the *simulation program* output.

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

G2. SIMULATION GENERAL REQUIREMENTS

G2.1 Performance Calculations. The *proposed building performance* and *baseline building performance* shall be calculated using the following:

a. the same *simulation program*
b. the same weather data
c. the same *energy* rates

G2.2 Simulation Program. The *simulation program* shall be a computer-based program for the analysis of *energy* consumption in buildings (a program such as, but not limited to, DOE-2, BLAST, or EnergyPlus). The *simulation program* shall include calculation methodologies for the building components being modeled. For components that cannot be modeled by the *simulation program*, the exceptional calculation methods requirements in Section G2.5 shall be used.

G2.2.1 The *simulation program* shall be approved by the *rating authority* and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year
b. hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat setpoints*, and *HVAC system* operation, defined separately for each day of the week and holidays
c. thermal mass effects
d. ten or more thermal zones
e. part-load performance curves for mechanical *equipment*
f. capacity and *efficiency* correction curves for *mechanical heating* and cooling *equipment*
g. air-side economizers with integrated *control*
h. *baseline building design* characteristics specified in Section G3

G2.2.2 The *simulation program* shall have the ability to either (1) directly determine the *proposed building performance* and *baseline building performance* or (2) produce hourly reports of *energy* use by an *energy* source suitable for determining the *proposed building performance* and *baseline building performance* using a separate calculation engine.

G2.2.3 The *simulation program* shall be capable of performing design load calculations to determine required HVAC *equipment* capacities and air and water flow rates in accordance with *generally accepted engineering standards* and handbooks (for example, *ASHRAE Handbook—Fundamentals*) for both the *proposed design* and *baseline building design*.

G2.2.4 The *simulation program* shall be tested according to ASHRAE Standard 140, and the results shall be furnished by the software provider.

G2.3 Climatic Data. The *simulation program* shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the *proposed design* is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the *construction* site. The selected weather data shall be approved by the *rating authority*.

G2.4 Energy Rates. Annual *energy* costs shall be determined using either actual rates for *purchased energy* or state average *energy* prices published by DOE's Energy Information Administration (EIA) for commercial building customers, but rates from different sources may not be mixed in the same project.

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

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

G2.5 Exceptional Calculation Methods. When the *simulation program* does not model a design, material, or device of the *proposed design*, an Exceptional Calculation Method shall be used if approved by the *Rating Authority*. If there are multiple designs, materials, or devices that the *simulation program* does not model, each shall be calculated separately and Exceptional Savings determined for each. At no time shall the total Exceptional Savings constitute more than half of the difference between the *baseline building performance* and the *proposed building performance*. All applications for approval of an exceptional method shall include:

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

G3. CALCULATION OF THE PROPOSED AND BASELINE BUILDING PERFORMANCE

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

G3.1.1 Baseline HVAC System Type and Description. *HVAC systems* in the *baseline building design* shall be based on usage, number of floors, *conditioned floor area*, and heating source as specified in Table G3.1.1A and shall conform with the *system* descriptions in Table G3.1.1B. For *systems* 1, 2, 3, and 4, each *thermal block* shall be modeled with its own *HVAC system*. For *systems* 5, 6, 7, 8, 9, and 10 each floor shall be modeled with a separate *HVAC system*. Floors with identical *thermal blocks* can be grouped for modeling purposes.

Exceptions:

a. Use additional *system* type(s) for nonpredominant conditions (i.e., *residential/nonresidential* or heating source) if those conditions apply to more than 20,000 ft^2 of *conditioned floor area*.

b. If the baseline *HVAC system* type is 5, 6, 7, 8, 9, or 10 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 10 Btu/h·ft^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. For laboratory *spaces* in a building having a total laboratory exhaust rate greater than 5000 cfm, use a single *system* of type 5 or 7 serving only those *spaces*. For all-electric buildings, the heating shall be *electric resistance*

d. For kitchens with a total exhaust hood airflow rate greater than 5,000 cfm, use *system* type 5 or 7 with a demand *ventilation system* on 75% of the exhaust air. The *system* shall reduce exhaust and *replacement air system* airflow rates by 50% for one half of the kitchen occupied hours in the baseline design. If the *proposed design* uses demand *ventilation* the same air flow rate schedule shall be used. The maximum exhaust flow rate allowed for the hood or hood section shall meet the requirements of Section 6.5.7.1.3 for the numbers and types of hoods and appliances provided for the in the *proposed design*. For all-electric buildings, the heating shall be *electric resistance*.

e. Thermal zones designed with heating only *systems* in the *proposed design*, serving storage rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the *proposed design* shall use System type 9 or 10 in the *baseline building design*.

f. If the baseline *HVAC system* type is 9 or 10, all *spaces* that are mechanically cooled in the *proposed building design* shall be assigned to a separate baseline *system* determined by using the area and heating source of the mechanically *cooled spaces*.

G3.1.1.1 Purchased Heat. For *systems* using purchased hot water or steam, the heating source shall be modeled as purchased hot water or steam in both the *proposed* and *baseline building designs*. Hot water or steam costs shall be based on actual utility rates, and on-site *boilers*, electric heat, and furnaces shall not be modeled in the *baseline building design*.

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

No.	Proposed Building Performance	Baseline Building Performance
1. Design Model		
a.	The simulation model of the *proposed design* shall be consistent with the design documents, including proper accounting of *fenestration* and *opaque* envelope types and areas; interior lighting power and *controls*; *HVAC system* types, sizes, and *controls*; and *service water heating systems* and *controls*. All end-use load components within and associated with the building shall be modeled, including, but not limited to, exhaust fans, parking garage *ventilation* fans, snow-melt and freeze-protection *equipment*, facade lighting, swimming *pool* heaters and pumps, elevators and escalators, refrigeration, and cooking. Where the *simulation program* does not specifically model the functionality of the installed *system*, spreadsheets or other documentation of the assumptions shall be used to generate the power *demand* and operating schedule of the *systems*.	The *baseline building design* shall be modeled with the same number of floors and identical *conditioned floor area* as the *proposed design*.
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. Temperature and humidity *control setpoints* and schedules as well as *temperature control throttling range* shall be the same for *proposed* and *baseline building designs*. **Exception:** *Spaces* using Baseline System types 9 and 10 shall not be simulated with *mechanical cooling*.	
c.	When the *performance rating method* is applied to buildings in which energy-related features have not yet been designed (e.g., a *lighting system*), those yet-to-be-designed features shall be described in the *proposed design* exactly as they are defined in the *baseline building design*. Where the *space* classification for a *space* is not known, the *space* shall be categorized as an office *space*.	

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

2. Additions and Alterations	
It is acceptable to predict performance using building models that exclude parts of the *existing building* provided that all of the following conditions are met: a. Work to be performed in excluded parts of the building shall meet the requirements of Sections 5 through 10. b. Excluded parts of the building are served by *HVAC systems* that are entirely separate from those serving parts of the building that are included in the building model. c. Design *space* temperature and *HVAC system* operating *setpoints* and schedules on either side of the boundary between included and excluded parts of the building are essentially the same. d. If a declining block or similar utility rate is being used in the analysis and the excluded and included parts of the building are on the same utility meter, the rate shall reflect the utility block or rate for the building plus the *addition*.	Same as Proposed Design
3. Space Use Classification	
Usage shall be specified using the building type or *space* type lighting classifications in accordance with Section 9.5.1 or 9.6.1. The user shall specify the *space* use classifications using either the building type or *space* type categories but shall not combine the two types of categories. More than one building type category may be used in a building if it is a mixed-use facility. If *space* type categories are used, the user may simplify the placement of the various *space* types within the building model, provided that building-total areas for each *space* type are accurate.	Same as Proposed Design
4. Schedules	
Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat setpoints*, and *HVAC system* operation shall be used. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *rating authority*. **HVAC Fan Schedules**. Schedules for HVAC fans that provide *outdoor air* for *ventilation* shall run continuously whenever *spaces* are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours. **Exceptions:** a. Where no heating and/or cooling *system* is to be installed and a heating or cooling *system* is being simulated only to meet the requirements described in this table, heating and/or cooling *system* fans shall not be simulated as running continuously during occupied hours but shall be cycled on and off to meet heating and cooling loads during all hours. b. HVAC fans shall remain on during occupied and unoccupied hours in *spaces* that have health and safety mandated minimum *ventilation* requirements during unoccupied hours.	Same as Proposed Design **Exception:** Schedules may be allowed to differ between *proposed design* and *baseline building design* when necessary to model nonstandard *efficiency* measures, provided that the revised schedules have the approval of the *rating authority*. Measures that may warrant use of different schedules include, but are not limited to, *automatic* lighting *controls*, *automatic* natural *ventilation controls*, *automatic demand control ventilation controls*, and *automatic controls* that reduce *service water heating* loads. In no case shall schedules differ where the *controls* are *manual* (e.g., *manual* operation of light switches or *manual* operation of windows).

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

No. Proposed Building Performance	Baseline Building Performance
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, *roof* parapet) shall be separately modeled using either of the following techniques: 1. Separate model of each of these assemblies within the *energy* simulation model. 2. Separate calculation of the *U-factor* for each of these assemblies. The *U-factors* of these assemblies are then averaged with larger adjacent surfaces using an area-weighted average method. This average *U-factor* is modeled within the *energy* simulation model. Any other envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior *walls*) need not be separately described provided that it is similar to an assembly being modeled. If not separately described, the area of an envelope assembly shall be added to the area of an assembly of that same type with the same *orientation* and thermal properties. b. Exterior surfaces whose azimuth *orientation* and tilt differ by less than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers. c. The exterior *roof* surface shall be modeled using the aged solar *reflectance* and thermal *emittance* determined in accordance with Section 5.5.3.1.1(a). Where aged test data is unavailable, the *roof* surface may be modeled with a *reflectance* of 0.30 and a thermal *emittance* of 0.90. d. *Manual fenestration* shading devices such as blinds or shades shall be modeled or not modeled, the same as in the baseline. Automatically controlled *fenestration* shades or blinds shall be modeled. Permanent shading devices such as fins, overhangs, and light shelves shall be modeled. e. Automatically controlled *dynamic glazing* may be modeled. Manually controlled *dynamic glazing* shall use the average of the minimum and maximum *SHGC* and *VT*.	Equivalent dimensions shall be assumed for each exterior envelope component type as in the *proposed design*; i.e., the total gross area of exterior *walls* shall be the same in the *proposed* and *baseline building designs*. The same shall be true for the areas of *roofs*, floors, and *doors*, and the exposed perimeters of concrete slabs on *grade* shall also be the same in the *proposed* and *baseline building designs*. The following additional requirements shall apply to the modeling of the *baseline building design*: a. **Orientation.** The *baseline building performance* shall be generated by simulating the building with its actual *orientation* and again after rotating the entire building 90, 180, and 270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself. **Exceptions:** 1. If it can be demonstrated to the satisfaction of the *Program Evaluator* that the building *orientation* is dictated by site considerations. 2. Buildings where the *vertical fenestration area* on each *orientation* varies by less than 5%. b. **Opaque Assemblies.** *Opaque* assemblies used for new buildings or *additions* shall conform with the following common, lightweight assembly types and shall match the appropriate assembly maximum *U-factors* in Tables 5.5-1 through 5.5-8: • *Roofs*—Insulation entirely above deck • *Above-grade walls*—Steel-framed • Floors—Steel-joist • *Opaque door* types shall match the *proposed design* and conform to the *U-factor* requirements from the same tables. • *Slab-on-grade floors* shall match the *F-factor* for unheated slabs from the same tables. *Opaque* assemblies used for *alterations* shall conform with Section 5.1.3. c. **Vertical Fenestration.** *Vertical fenestration areas* for new buildings and *additions* shall equal that in the *proposed design* or 40% of gross *above-grade wall* area, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the *proposed design*. *Fenestration U-factors* shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. *Fenestration* SHGC shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. All vertical glazing shall be assumed to be flush with the exterior *wall*, and no shading projections shall be modeled. *Manual* window shading devices such as blinds or shades are not required to be modeled. The *fenestration areas* for envelope *alterations* shall reflect the limitations on area, *U-factor*, and SHGC as described in Section 5.1.3. d. **Skylights and Glazed Smoke Vents.** Skylight area shall be equal to that in the proposed building design or 5% of the gross roof area that is part of the *building envelope*, whichever is smaller. If the skylight area of the proposed building design is greater than 5% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 5% skylight-to-roof ratio. Skylight orientation and tilt shall be the same as in the proposed building design. Skylight U-factor and SHGC properties shall match the appropriate requirements in Tables 5.5-1 through 5.5-8. e. **Roof Solar *Reflectance* and Thermal *Emittance*.** The exterior *roof* surfaces shall be modeled with a solar *reflectance* and thermal *emittance* as required in Section 5.5.3.1.1(a). All other *roofs*, including *roofs* exempted from the requirements in Section 5.5.3.1.1, shall be modeled using a solar *reflectance* of 0.30 and a thermal *emittance* of 0.90. 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 Modeling Requirements for Calculating Proposed and Baseline Building Performance *(continued)*

No. Proposed Building Performance	Baseline Building Performance
6. Lighting	
Lighting power in the *proposed design* shall be determined as follows: a. Where a complete *lighting system* exists, the actual lighting power for each *thermal block* shall be used in the model. b. Where a *lighting system* has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where lighting neither exists nor is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type. d. *Lighting system* power shall include all *lighting system* components shown or provided for on the plans (including *lamps* and *ballasts* and task and furniture-mounted *fixtures*). **Exception:** For multifamily *dwelling units*, hotel/motel guest rooms, and other *spaces* in which *lighting systems* are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for the *proposed* and *baseline building designs* in the simulations. e. Lighting power for parking garages and building facades shall be modeled. f. Credit may be taken for the use of *automatic controls* for daylight utilization but only if their operation is either modeled directly in the building simulation or modeled in the building simulation through schedule adjustments determined by a separate daylighting analysis approved by the *rating authority*. g. For *automatic* lighting *controls* in addition to those required for minimum code compliance under Section 9.4.1, credit may be taken for automatically controlled *systems* by reducing the connected lighting power by the applicable percentages listed in Table G3.2. Alternatively, credit may be taken for these devices by modifying the lighting schedules used for the *proposed design*, provided that credible technical documentation for the modifications are provided to the *rating authority*.	Lighting power in the *baseline building design* shall be determined using the same categorization procedure (building area or space-by-space method) and categories as the *proposed design* with lighting power set equal to the maximum allowed for the corresponding method and category in Section 9.2. Lighting shall be modeled having the *automatic* and *manual controls* in Section 9.4. No additional *automatic* lighting *controls* (e.g., *automatic controls* for daylight utilization) shall be modeled in the *baseline building design*, as the lighting schedules used are understood to reflect the mandatory *control* requirements in this standard.
7. Thermal Blocks—HVAC Zones Designed	
Where *HVAC zones* are defined on HVAC design drawings, each *HVAC zone* shall be modeled as a separate *thermal block*. **Exception:** Different *HVAC zones* may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied, provided that all of the following conditions are met: a. The *space* use classification is the same throughout the *thermal block*. b. All *HVAC zones* in the *thermal block* that are adjacent to glazed exterior *walls* face the same *orientation* or their *orientations* vary by less than 45 degrees. c. All of the zones are served by the same *HVAC system* or by the same kind of *HVAC system*.	Same as Proposed Design.
8. Thermal Blocks—HVAC Zones Not Designed	
Where the *HVAC zones* and *systems* have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and *space* temperature schedules, and in combination with the following guidelines: a. Separate *thermal blocks* shall be assumed for interior and perimeter *spaces*. Interior *spaces* shall be those located greater than 15 ft from an exterior *wall*. Perimeter *spaces* shall be those located within 15 ft 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 15 ft or less from a glazed perimeter *wall*, except that floor area within 15 ft of glazed perimeter *walls* having more than one *orientation* shall be divided proportionately between zones. c. Separate *thermal blocks* shall be assumed for *spaces* having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. d. Separate *thermal blocks* shall be assumed for *spaces* having exterior ceiling or *roof* assemblies from zones that do not share these features.	Same as Proposed Design.
9. Thermal Blocks—Multifamily Residential Buildings	
Residential spaces shall be modeled using at least one *thermal block* per *dwelling unit*, except that those units facing the same *orientations* may be combined into one *thermal block*. Corner units and units with *roof* or floor loads shall only be combined with units sharing these features.	Same as Proposed Design.

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

No. Proposed Building Performance	Baseline Building Performance
10. HVAC Systems	
The *HVAC system* type and all related performance parameters in the *proposed design*, such as *equipment* capacities and efficiencies, shall be determined as follows: a. Where a complete *HVAC system* exists, the model shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where an *HVAC system* has been designed, the HVAC model shall be consistent with design documents. Mechanical *equipment* efficiencies shall be adjusted from actual *design conditions* to the standard rating conditions specified in Section 6.4.1 if required by the simulation model. c. Where no heating *system* exists or no heating *system* has been specified, the heating *system* classification shall be assumed to be electric, and the *system* characteristics shall be identical to the *system* modeled in the *baseline building design*. d. Where no cooling *system* exists or no cooling *system* has been specified, the cooling *system* shall be identical to the *system* modeled in the *baseline building design*. **Exception to d:** *Spaces* using baseline *HVAC system* types 9 and 10.	The *HVAC system(s)* in the *baseline building design* shall be of the type and description specified in Section G3.1.1, shall meet the general *HVAC system* requirements specified in Section G3.1.2, and shall meet any system-specific requirements in Section G3.1.3 that are applicable to the baseline *HVAC system* type(s).

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

No. Proposed Building Performance	Baseline Building Performance
11. Service Hot-Water Systems	
The *service* hot-water *system* type and all related performance parameters, such as *equipment* capacities and efficiencies, in the *proposed design* shall be determined as follows: a. Where a complete *service* hot-water *system* exists, the *proposed design* shall reflect the actual *system* type using actual component capacities and efficiencies. b. Where a *service* hot-water *system* has been specified, the *service* hot-water model shall be consistent with design documents. c. Where no *service* hot-water *system* exists or has been specified but the building will have *service* hot-water loads, a *service* hot-water *system* shall be modeled that matches the *system* in the *baseline building design* and serves the same hot-water loads. d. For buildings that will have no *service* hot-water loads, no *service* hot-water *system* shall be modeled.	The *service* hot-water *system* in the *baseline building design* shall use the same *energy* source as the corresponding *system* in the *proposed design* and shall conform with the following conditions: a. Where the complete *service* hot-water *system* exists, the *baseline building design* shall reflect the actual *system* type using the actual component capacities and efficiencies. b. Where a new *service* hot-water *system* has been specified, the *system* shall be sized according to the provisions of Section 7.4.1 and the *equipment* shall match the minimum *efficiency* requirements in Section 7.4.2. Where the *energy* source is electricity, the heating method shall be electrical resistance. c. Where no *service* hot-water *system* exists or has been specified but the building will have *service* hot-water loads, a *service* water *system(s)* using electrical-resistance heat and matching minimum *efficiency* requirements of Section 7.4.2 shall be assumed and modeled identically in the *proposed* and *baseline building designs*. d. For buildings that will have no *service* hot-water loads, no *service* hot-water heating shall be modeled. e. Where a combined *system* has been specified to meet both *space* heating and *service water heating* loads, the baseline building *system* shall use separate *systems* meeting the minimum *efficiency* requirements applicable to each *system* individually. f. For large, 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery *systems* described in Section 6.5.6.2, a *system* meeting the requirements of that section shall be included in the *baseline building design* regardless of the exceptions to Section 6.5.6.2. **Exception:** If a condenser heat recovery *system* meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a *system* in the actual building shall be met as a prescriptive requirement in accordance with Section 6.5.6.2, and no heat-recovery *system* shall be included in the *proposed* or *baseline building designs*. g. *Service* hot-water *energy* consumption shall be calculated explicitly based upon the volume of *service* hot water required and the entering makeup water and the leaving *service* hot-water temperatures. Entering water temperatures shall be estimated based upon the location. Leaving temperatures shall be based upon the end-use requirements. h. Where recirculation pumps are used to ensure prompt availability of *service* hot water at the end use, the *energy* consumption of such pumps shall be calculated explicitly. i. *Service* water loads and usage shall be the same for both the *baseline building design* and the *proposed design* and shall be documented by the calculation procedures described in Section 7.2.1. **Exceptions:** 1. *Service* hot-water usage can be demonstrated to be reduced by documented water conservation measures that reduce the physical volume of *service* water required. Examples include low-flow shower heads. Such reduction shall be demonstrated by calculations. 2. *Service* hot-water *energy* consumption can be demonstrated to be reduced by reducing the required temperature of *service* mixed water, by increasing the temperature, or by increasing the temperature of the entering makeup water. Examples include alternative sanitizing technologies for dishwashing and heat recovery to entering makeup water. Such reduction shall be demonstrated by calculations. 3. *Service* hot-water usage can be demonstrated to be reduced by reducing the hot fraction of mixed water to achieve required operational temperature. Examples include shower or laundry heat recovery to incoming cold-water supply, reducing the hot-water fraction required to meet required mixed-water temperature. Such reduction shall be demonstrated by calculations.

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

No. Proposed Building Performance	Baseline Building Performance
12. Receptacle and Other Loads	
Receptacle and *process loads*, such as those for office and other *equipment*, shall be estimated based on the building type or *space* type category and shall be assumed to be identical in the *proposed* and *baseline building designs*, except as specifically authorized by the *rating authority*. These loads shall be included in simulations of the building and shall be included when calculating the *baseline building performance* and *proposed building performance*.	Other *systems*, such as motors covered by Section 10, and miscellaneous loads shall be modeled as identical to those in the *proposed design* including schedules of operation and *control* of the *equipment*. Where there are specific *efficiency* requirements listed in Sections 5 through 10, these *systems* or components shall be modeled as having the lowest *efficiency* allowed by those requirements.Where no efficiency requirements exist, power and *energy* rating or capacity of the *equipment* shall be identical between the *baseline building* and the *proposed design* with the following exception: variations of the power requirements, schedules, or *control* sequences of the *equipment* modeled in the *baseline building* from those in the *proposed design* shall be allowed by the *rating authority* based upon documentation that the *equipment* installed in the *proposed design* represents a significant verifiable departure from documented conventional practice. The burden of this documentation is to demonstrate that accepted conventional practice would result in *baseline building equipment* different from that installed in the *proposed design*. Occupancy and occupancy schedules shall not be changed.
13. Modeling Limitations to the Simulation Program	
If the *simulation program* cannot model a component or *system* included in the *proposed design* explicitly, substitute a thermodynamically similar component model that can approximate the expected performance of the component that cannot be modeled explicitly.	Same as Proposed Design.
14. Exterior Conditions	
a. **Shading by adjacent structures and terrain:** The effect that structures and significant vegetation or topographical features have on the amount of solar radiation being received by a structure shall be adequately reflected in the computer analysis. All elements whose effective height is greater than their distance from a proposed building and whose width facing the proposed building is greater than one-third that of the proposed building shall be accounted for in the analysis. If the computer program has a subroutine to simulate shading by adjacent structures, then this option shall be used. If the computer program does not have a subroutine to simulate shading by adjacent structures, then any portion of a structure that is shaded most of the time is allowed to be modeled as having a north-facing *orientation*. b. **Ground temperatures for below-grade wall and basement floor heat loss calculations:** It is acceptable to use either an annual average ground temperature or monthly average ground temperatures for calculation of heat loss through *below-grade walls* and basement floors. c. **Water main temperatures for service water heating calculations:** It is acceptable to use either an annual water main supply temperature or monthly average water main supply temperatures for calculating *service water heating*. If annual or monthly water main supply temperatures are not available from the local water utility, annual average ground temperatures may be used.	Same as Proposed Design.

G3.1.1.2 Purchased Chilled Water. For *systems* using purchased chilled water, the cooling source shall be modeled as purchased chilled water in both the proposed and *baseline building designs*. Purchased chilled water costs shall be based on actual utility rates, and on-site chillers and direct expansion *equipment* shall not be modeled in the *baseline building design*.

G3.1.1.3 *Baseline* HVAC System Requirements for Systems Utilizing Purchased Chilled Water and/or Purchased Heat. If the *proposed building design* uses purchased chilled water and/or purchased heat, the following modifications to the Baseline *HVAC System* Types in Table G3.1.1B shall be used:

G3.1.1.3.1 Purchased Heat Only. If the *proposed building design* uses purchased heat, but does not use purchased chilled water, then Table G3.1.1A and Table G3.1.1B shall be used to select the Baseline *HVAC System* Type and purchased heat shall be substituted for the Heating Type in Table G3.1.1B. The same heating source shall be used in the *proposed* and *baseline building design*.

G3.1.1.3.2 Purchased Chilled Water Only. If the *proposed building design* uses purchased chilled water, but does not use purchased heat, then Table G3.1.1A and Table G3.1.1B shall be used to select the Baseline *HVAC System* Type, with the modifications listed below:

a. Purchased chilled water shall be substituted for the Cooling Types in Table G3.1.1B.
b. System 1 and 2 shall be constant volume fan coil units with *fossil fuel boiler*(s).
c. System 3 and 4 shall be constant volume single zone air handlers with *fossil fuel* furnace(s).
d. System 7 shall be used in place of System 5.
e. System 8 shall be used in place of System 6.

G3.1.1.3.3 Purchased Chilled Water and Purchased Heat. If the *proposed building design* uses purchased chilled water and purchased heat, then Table G3.1.1A and Table G3.1.1B shall be used to select the Baseline *HVAC System* Type, with the following modifications:

a. Purchased heat and purchased chilled water shall be substituted for the Heating Types and Cooling Types in Table G3.1.1B.
b. System 1 shall be constant volume fan coil units.
c. System 3 shall be constant volume single zone air handlers.
d. System 7 shall be used in place of System 5.

G3.1.1.3.4 On-Site Distribution Pumps. All on-site distribution pumps shall be modeled in both the baseline and *proposed designs*.

G3.1.2 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 IEER and ICOP, include fan *energy*, the descriptor shall be broken down into its components so that supply fan *energy* can be modeled separately.

G3.1.2.2 Equipment Capacities. The *equipment* capacities (i.e. *system* coil capacities) for the *baseline building design* shall be based on sizing runs for each *orientation* (per Table G3.1, No. 5a) and shall be oversized by 15% for cooling and 25% for heating, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating.

TABLE G3.1.1A Baseline HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less and <25,000 ft^2	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <25,000 ft^2 or 5 Floors or Less and 25,000 ft^2 to 150,000 ft^2	System 5—Packaged VAV with Reheat	System 6—Packaged VAV with PFP Boxes
Nonresidential and More than 5 Floors or >150,000 ft^2	System 7—VAV with Reheat	System 8—VAV with PFP Boxes
Heated Only Storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

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 except as noted in Exception a to Section G3.1.1.
For laboratory *spaces* in a building having a total laboratory exhaust rate greater than 5000 cfm, use a single *system* of type 5 or 7 serving only those *spaces*. For all-electric buildings, the heating shall be *electric resistance*

TABLE G3.1.1B Baseline System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1. PTAC	Packaged terminal air conditioner	Constant volume	Direct expansion	Hot-water fossil fuel boiler
2. PTHP	Packaged terminal heat pump	Constant volume	Direct expansion	Electric heat pump
3. PSZ-AC	Packaged rooftop air conditioner	Constant volume	Direct expansion	Fossil fuel furnace
4. PSZ-HP	Packaged rooftop heat pump	Constant volume	Direct expansion	Electric heat pump
5. Packaged VAV with Reheat	Packaged rooftop VAV with reheat	VAV	Direct expansion	Hot-water fossil fuel boiler
6. Packaged VAV with PFP Boxes	Packaged rooftop VAV with parallel fan power boxes and reheat	VAV	Direct expansion	Electric resistance
7. VAV with Reheat	VAV with reheat	VAV	Chilled water	Hot-water fossil fuel boiler
8. VAV with PFP Boxes	VAV with parallel fan-powered boxes and reheat	VAV	Chilled water	Electric resistance
9. Heating and Ventilation	Warm air furnace, gas fired	Constant volume	None	Fossil fuel furnace
10. Heating and Ventilation	Warm air furnace, electric	Constant volume	None	Electric resistance

Note:
For purchased chilled water and purchased heat, see G3.1.1.3.

G3.1.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine *baseline equipment* capacities shall be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% *heating design temperatures* and 1% dry-bulb and 1% wet-bulb *cooling design temperatures*.

G3.1.2.3 Unmet Loads. *Unmet load hours* for the *proposed design* or *baseline building designs* shall not exceed 300 (of the 8760 hours simulated). Alternatively, *unmet load hours* exceeding these limits may be accepted at the discretion of the *rating authority* provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

G3.1.2.4 Preheat Coils. If the *HVAC system* in the *proposed design* has a preheat coil and a preheat coil can be modeled in the *baseline system*, the *baseline system* shall be modeled with a preheat coil controlled in the same manner as the *proposed design*.

G3.1.2.5 Fan System Operation. Supply and return fans shall operate continuously whenever *spaces* are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. If the supply fan is modeled as cycling and fan *energy* is included in the energy-efficiency rating of the *equipment*, fan *energy* shall not be modeled explicitly. Supply, return, and/or exhaust fans will remain on during occupied and unoccupied hours in *spaces* that have health and safety mandated minimum *ventilation* requirements during unoccupied hours.

G3.1.2.6 Ventilation. Minimum *ventilation system outdoor air* intake flow shall be the same for the *proposed* and *baseline building designs*.

Exceptions:

a. When modeling demand-control *ventilation* in the *proposed design* when its use is not required by Section 6.3.2(p) or Section 6.4.3.9.

b. When designing *systems* in accordance with Standard 62.1 Section 6.2 Ventilation Rate Procedure, reduced *ventilation* airflow rates may be calculated for each *HVAC zone* in the *proposed design* with a zone air distribution effectiveness (Ez) > 1.0 as defined by Table 6-2 in Standard 62.1. Baseline *ventilation* airflow rates in those zones shall be calculated using the *proposed design* Ventilation Rate Procedure calculation with the following change only. Zone air distribution effectiveness shall be changed to (Ez)=1.0 in each zone having a zone air distribution effectiveness (Ez)>1.0. *Proposed design* and *baseline design* Ventilation Rate Procedure calculations, as described in Standard 62.1, shall be submitted to the *rating authority* to claim credit for this exception.

c. If the minimum *outdoor air* intake flow in the *proposed design* is provided in excess of the amount required by the *rating authority* or *building official* then the *baseline building design* shall be modeled to reflect the greater of that required by the *rating authority* or *building official* and will be less than the *proposed design*.

G3.1.2.7 Economizers. *Outdoor air economizers* shall not be included in *baseline HVAC Systems* 1, 2, 9, and 10. *Outdoor air economizers* shall be included in *baseline HVAC Systems* 3 through 8 based on climate as specified in Table G3.1.2.6A.

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

a. *Systems* that include gas-phase air cleaning to meet the requirements of Section 6.1.2 in Standard 62.1. This exception shall be used only if the *system* in the *proposed design* does not match the *building design*.

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

G3.1.2.8 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb switch with *setpoint* temperatures in accordance with the values in Table G3.1.2.6B.

G3.1.2.9 Design Air Flow Rates.

G3.1.2.9.1 Baseline System Types 1 through 8. *System* design supply air flow rates for the *baseline building design* shall be based on a supply-air-to-room-air temperature difference of 20°F or the minimum *outdoor air* flow rate, or the air flow rate required to comply with applicable codes or accreditation standards, whichever is greater. If return or relief fans are specified in the *proposed design*, the *baseline building design* shall also be modeled with fans serving the same functions and sized for the *baseline system* supply fan air quantity less the minimum *outdoor air*, or 90% of the supply fan air quantity, whichever is larger.

Exception: For *systems* serving laboratory *spaces*, use a supply-air-to-room-air temperature difference of 17°F or the required *ventilation* air or *makeup air*, whichever is greater.

G3.1.2.9.2 Baseline System Types 9 and 10. *System* design supply airflow rates for the *baseline building design* shall be based on the temperature difference between a supply air temperature *setpoint* of 105° F and the design *space* heating temperature *setpoint*, the minimum *outdoor air* flow rate, or the air flow rate required to comply with applicable codes or accreditation standards, whichever is greater. If the *Proposed Building Design* includes a fan(s) sized and controlled to provide non-*mechanical cooling*, the baseline building design shall include a separate fan to provide non-*mechanical cooling*, sized and controlled the same as the *proposed building design*.

G3.1.2.10 System Fan Power. *System* fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:

For Systems 1 and 2,

$$P_{fan} = CFMs \times 0.3$$

For Systems 3 through 8,

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

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

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

TABLE G3.1.2.6B Economizer High-Limit Shutoff

Climate Zone	High-Limit Shutoff
1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	75°F
5a, 6a, 7a	70°F
Others	65°F

TABLE G3.1.2.9 Baseline Fan Brake Horsepower

Baseline Fan Motor Brake Horsepower	
Constant Volume Systems 3–4	Variable Volume Systems 5–8
$CFM_s \cdot 0.00094 + A$	$CFM_s \cdot 0.0013 + A$

Where *A* is calculated according to Section 6.5.3.1.1 using the pressure drop adjustment from the proposed building design and the design flow rate of the baseline building *system*.
Do not include pressure drop adjustments for evaporative coolers or heat recovery devices that are not required in the baseline building *system* by Section G3.1.2.10.

TABLE G3.1.3.7 Type and Number of Chillers

Building Peak Cooling Load	Number and Type of Chiller(s)
≤300 tons	1 water-cooled screw chiller
>300 tons, <600 tons	2 water-cooled screw chillers sized equally
≥600 tons	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

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

For Systems 9 and 10 (supply fan),

$$P_{fan} = CFMs \times 0.3$$

For Systems 9 and 10 (non-*mechanical cooling* fan if required by Section G3.1.2.8.2)

$$P_{fan} = CFM_{nmc} \times 0.054$$

where

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

and

bhp = brake horsepower of baseline fan motor from Table G3.1.2.9

Fan Motor Efficiency = the efficiency from Table 10.8B for the next motor size greater than the bhp using a totally enclosed fan cooled motor at 1800 rpm.

CFMs = the baseline *system* maximum design supply fan airflow rate in cfm

CFM_{nmc} = the baseline non-*mechanical cooling* fan airflow in cfm

G3.1.2.10.1 The calculated *system* fan power shall be distributed to supply, return, exhaust, and relief fans in the same proportion as the proposed design.

G3.1.2.11 Exhaust Air Energy Recovery. Exhaust air energy recovery shall be modeled for the *budget building design* in accordance with Section 6.5.6.1.

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

G3.1.3.1 Heat Pumps (Systems 2 and 4). Electric air-source heat pumps shall be modeled with electric auxiliary heat. The *systems* shall be controlled with multistage *space thermostats* and an *outdoor air thermostat* wired to energize auxiliary heat only on the last *thermostat* stage and when outdoor air temperature is less than 40°F.

G3.1.3.2 Type and Number of Boilers (Systems 1, 5, and 7). The *boiler* plant shall use the same *fuel* as the *proposed design* and shall be natural draft, except as noted in Section G3.1.1.1. The *baseline building design boiler* plant shall be modeled as having a single *boiler* if the *baseline building design* plant serves a *conditioned floor area* of 15,000 ft^2 or less and as having two equally sized *boilers* for plants serving more than 15,000 ft^2. *Boilers* shall be staged as required by the load.

G3.1.3.3 Hot-Water Supply Temperature (Systems 1, 5, and 7). Hot-water design supply temperature shall be modeled as 180°F and design return temperature as 130°F.

G3.1.3.4 Hot-Water Supply Temperature Reset (Systems 1, 5, and 7). Hot-water supply temperature shall be *reset* based on outdoor dry-bulb temperature using the following schedule: 180°F at 20°F and below, 150°F at 50°F and above, and ramped linearly between 180°F and 150°F at temperatures between 20°F and 50°F.

G3.1.3.5 Hot Water Pumps. The *baseline building design* hot-water pump power shall be 19 W/gpm. The pumping *system* shall be modeled as primary-only with continuous variable flow. Hot-water *systems* serving120,000 ft^2or more shall be modeled with variable-speed drives, and *systems* serving less than 120,000 ft^2shall be modeled as riding the pump curve.

Exception to G3.1.3.5: The pump power for *systems* using purchased heat shall be 14 W/gpm.

G3.1.3.6 Piping Losses. 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 or absorption from purchased steam. The *baseline building design's* chiller plant shall be modeled with chillers having the number and type as indicated in Table G3.1.3.7 as a function of building peak cooling load.

Exception: *Systems* using purchased chilled water shall be modeled in accordance with Section G3.1.1.3.

G3.1.3.8 Chilled-Water Design Supply Temperature (Systems 7 and 8). Chilled-water design supply temperature shall be modeled at 44°F and return water temperature at 56°F.

G3.1.3.9 Chilled-Water Supply Temperature Reset (Systems 7 and 8). Chilled-water supply temperature shall be *reset* based on outdoor dry-bulb temperature using the following schedule: 44°F at 80°F and above, 54°F at 60°F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F.

G3.1.3.10 Chilled-Water Pumps. The *baseline building design* pump power shall be 22 W/gpm. Chilled-water *systems* with a cooling capacity of 300 tons 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 300 tons cooling capacity shall be modeled as a primary/secondary *systems* with secondary pump riding the pump curve.

Exception: The pump power for *systems* using purchased chilled water shall be 16 W/gpm.

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, and shall meet the performance requirements of Table 6.8.1G. Condenser water design supply temperature shall be 85°F or 10°F approaching design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F 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 19 W/gpm. Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller.

G3.1.3.12 Supply Air Temperature Reset (Systems 5 through 8). The air temperature for cooling shall be *reset* higher by 5°F under the minimum cooling load conditions.

G3.1.3.13 VAV Minimum Flow Setpoints (Systems 5 and 7). Minimum volume *setpoints* for VAV reheat boxes shall be 30%of zone peak air flow, the minimum *outdoor air* flow rate or the air flow rate required to comply with applicable codes or accreditation standards, whichever is larger.

Exception: *Systems* serving laboratory *spaces* shall reduce the exhaust and *makeup air* volume during unoccupied periods to the largest of 50% of zone peak air flow, the minimum *outdoor air* flow rate, or the air flow rate required to comply with applicable codes or accreditation standards.

G3.1.3.14 Fan Power (Systems 6 and 8). Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design primary air (from the VAV air-handling unit) flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume *setpoints* for fan-powered boxes shall be equal to 30% of peak design primary airflow rate or the rate required to meet the minimum *outdoor air ventilation* requirement, whichever is larger. The supply air temperature *setpoint* shall be constant at the design condition.

G3.1.3.15 VAV Fan Part-Load Performance (Systems 5 through 8). 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 L/s/design L/s).

TABLE G3.2 Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Device(s)	Non-24-h and ≤ 5000 ft²	All Other
1. Programmable timing control	10%	0%
2. Occupancy sensor	15%	10%
3. Occupancy sensor and programmable timing control	15%	10%

Note: These credits are only allowed where the control is not required by Section 9.4. The 5000 ft² condition pertains to the total *conditioned floor area* of the building.

NOTICE

INSTRUCTIONS FOR SUBMITTING A PROPOSED CHANGE TO THIS STANDARD UNDER CONTINUOUS MAINTENANCE

This standard is maintained under continuous maintenance procedures by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. SSPC consideration will be given to proposed changes within 13 months of receipt by the manager of standards (MOS).

Proposed changes must be submitted to the MOS in the latest published format available from the MOS. However, the MOS may accept proposed changes in an earlier published format if the MOS concludes that the differences are immaterial to the proposed change submittal. If the MOS concludes that a current form must be utilized, the proposer may be given up to 20 additional days to resubmit the proposed changes in the current format.

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Use the appropriate file format for your word processor and save the file in either a recent version of Microsoft Word (preferred) or another commonly used word-processing program. Please save each change proposal file with a different name (for example, "prop01.doc," "prop02.doc," etc.). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as word-processed or scanned documents.

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Manager of Standards
ASHRAE
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
E-mail: change.proposal@ashrae.org
(Alternatively, mail paper versions to ASHRAE address or fax to 404-321-5478.)

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

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Product code: 86267 7/12

Errata noted in the list dated 4/2/12 have been corrected.

ADDENDA

2012 Supplement

ANSI/ASHRAE/IES Addenda a, b, c, g, h, j, k, o, p, s, y, z, bz, cg, ci, and ds to ANSI/ASHRAE/IES Standard 90.1-2010

Energy Standard for Buildings Except Low-Rise Residential Buildings

See Appendix for approval dates.

These addenda were approved 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 (www.ashrae.org) or in paper form from the Manager of Standards.

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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.

CONTENTS

ANSI/ASHRAE Addenda to ANSI/ASHRAE/IES Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings

NOTE

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

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FOREWORD

This addendum updates the test procedure references in the tables in Section 10.8 and adds a normative reference in Chapter 12. This makes the table references more consistent with other equipment tables (and other test procedure references) in the standard.

Note: *In this addendum, changes to the current standard are indicated in the text by* underlining *(for additions) and* ~~strikethrough~~ *(for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum a to Standard 90.1-2010

Modify the footnotes to Tables 10.8A, 10.8B, and 10.8C as follows (I-P and SI units):

TABLE 10.8A Minimum Nominal Efficiency for General Purpose Design A and Design B Motors Rated 600 Volts or Less[a]

Minimum Nominal Full-Load Motor Efficiency (%) prior to December 19, 2010

	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles =>	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Horsepower						
1	NR	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

a Nominal efficiencies shall be established in accordance with ~~NEMA Standard MG1~~ DOE 10 CFR 431. ~~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.~~
NR—No requirement

TABLE 10.8B Minimum Nominal Full-Load Efficiency for 60 HZ NEMA General Purpose Electric Motors (Subtype I) Rated 600 Volts or Less (Random Wound)[a]

Minimum Nominal Full Load Efficiency (%) for Motors Manufactured on or after December 19, 2010

	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles =>	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Horsepower						
1	77.0	85.5	82.5	77.0	85.5	82.5
1.5	84.0	86.5	86.5	84.0	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	89.5	88.5	89.5	89.5
7.5	88.5	91.0	90.2	89.5	91.7	91.0
10	89.5	91.7	91.7	90.2	91.7	91.0
15	90.2	93.0	91.7	91.0	92.4	91.7
20	91.0	93.0	92.4	91.0	93.0	91.7
25	91.7	93.6	93.0	91.7	93.6	93.0
30	91.7	94.1	93.6	91.7	93.6	93.0
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93.0	94.5	94.1	93.0	94.5	94.1
60	93.6	95.0	94.5	93.6	95.0	94.5
75	93.6	95.0	94.5	93.6	95.4	94.5
100	93.6	95.4	95.0	94.1	95.4	95.0
125	94.1	95.4	95.0	95.0	95.4	95.0
150	94.1	95.8	95.4	95.0	95.8	95.8
200	95.0	95.8	95.4	95.4	96.2	95.8
250	95.0	95.8	95.4	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	95.8	96.2	96.2	95.8	96.2	95.8
500	95.8	96.2	96.2	95.8	96.2	95.8

a Nominal efficiencies shall be established in accordance with ~~NEMA Standard MG1~~ DOE 10 CFR 431.

TABLE 10.8C Minimum Nominal Full-Load Efficiency of General Purpose Electric Motors (Subtype II and Design B)[a]

Minimum Nominal Full Load Efficiency (%) for Motors Manufactured on or after December 19, 2010

	Open Drip-Proof Motors				Totally Enclosed Fan Cooled Motors			
Number of Poles =>	**2**	**4**	**6**	**8**	**2**	**4**	**6**	**8**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**	**900**	**3600**	**1800**	**1200**	**900**
Motor Horsepower								
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
350	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
400	95.4	95.4	NR	NR	95.4	95.4	NR	NR
450	95.8	95.8	NR	NR	95.4	95.4	NR	NR
500	95.8	95.8	NR	NR	95.4	95.8	NR	NR

a Nominal efficiencies shall be established in accordance with ~~NEMA Standard MG1~~ DOE 10 CFR 431.

NR—No requirement

In Section 12, Normative References, add the following under U.S. Department of Energy:

10 CFR 431 Subpart B, App B, Uniform Test Method for Measuring Nominal Full Load Efficiency of Electric Motors.

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FOREWORD

The 2010 edition of the ASME Safety Code for Elevators and Escalators *added allowances to permit varying the speed of escalators and moving walks to conserve energy. It does not yet permit automatically stopping and starting of escalators or moving walks. Variable-speed technology is common for this application in other countries.*

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum b to Standard 90.1-2010

Revise the standard as follows (I-P and SI units):

10.4.4 Escalators and Moving Walks. Escalators and moving walks shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 or applicable local code, when not conveying passengers.

12. NORMATIVE REFERENCES

American Society of Mechanical Engineers, ASME, Three Park Avenue, New York, NY 10016-5990	
ASME A17.1-2010/CSA B44-10	Safety Code for Elevators and Escalators

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FOREWORD

The treatment of laboratory exhaust fans is currently not specified. Laboratory exhaust design requires sufficient momentum of exhaust volume to exit the building wake in order to prevent re-entrainment of exhaust air. The standard design approach to accomplish this for VAV supply systems utilizes an outdoor air bypass damper that ensures a constant volume stack discharge (brings in outdoor air to supplement any decrease in exhaust volume from the building). Clarifying this as the baseline approach will make it clear to design teams that other approaches considered to be energy reduction strategies will be acknowledged as such and appropriately credited.

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum c to Standard 90.1-2010

Revise the standard as follows (I-P and SI units):

G3.1.1 Baseline HVAC System Type and Description. *HVAC systems* in the *baseline building design* shall be based on usage, number of floors, *conditioned floor area*, and heating source as specified in Table G3.1.1A and shall conform with the *system* descriptions in Table G3.1.1B. For *systems* 1, 2, 3, and 4, each *thermal block* shall be modeled with its own *HVAC system*. For *systems* 5, 6, 7, 8, 9, and 10 each floor shall be modeled with a separate *HVAC system*. Floors with identical *thermal blocks* can be grouped for modeling purposes.

Exceptions:

a. Use additional *system* type(s) for nonpredominant conditions (i.e., *residential/nonresidential* or heating source) if those conditions apply to more than 20,000 ft^2 (1900 m^2) of *conditioned floor area*.

b. If the baseline *HVAC system* type is 5, 6, 7, 8, 9, or 10 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 10 Btu/h·ft^2 (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. For laboratory *spaces* in a building having a total laboratory exhaust rate greater than 5000 cfm (2400 L/s), use a single *system* of type 5 or 7 serving only those *spaces*. For all-electric buildings, the heating shall be *electric resistance*. The lab exhaust fan shall be modeled as constant horsepower reflecting constant volume stack discharge with outdoor air bypass.

(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

With the approval of Addendum aq to Standard 90.1-2010, this standard can now add requirements for some of the process and plug loads within a building. The Department of Energy has defined minimum efficiency requirements for some Commercial Refrigerator and Freezers that went into effect as of 1/1/2010. Additional requirements for commercial refrigeration equipment have also been defined and approved per 10CFR Part 431 and will go into effect on 1/1/2012. This addendum adds these requirements to Standard 90.1-2010.

As part of the DOE evaluation, they have calculated that the standard changes will result in 1.035 quads of energy savings over a 30 year period from 2012-2042. The economic analysis shows a scalar (payback) of 1.3 to 3.9.

This addendum adds two additional tables, Table 6.8.1L and 6.8.1M, which define the minimum efficiency requirements for commercial refrigerators and freezers. Also a reference to AHRI Standard 1200 and AHAM Standard HRF-1 is added in Section 12.

***Note:** In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum g to Standard 90.1-2010

Add new Tables 6.8.1L and 6.8.1M.

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

Tables are as follows:

a. Table 6.8.1A—Air Conditioners and Condensing Units
b. Table 6.8.1B—Heat Pumps
c. Table 6.8.1C—Water-Chilling Packages (see Section 6.4.1.2 for water-cooled centrifugal water-chilling packages that are designed to operate at nonstandard conditions)
d. Table 6.8.1D—Packaged Terminal and Room Air Conditioners and Heat Pumps
e. Table 6.8.1E—Furnaces, Duct Furnaces, and Unit Heaters
f. Table 6.8.1F—Boilers
g. Table 6.8.1G—Heat Rejection Equipment
h. Table 6.8.1H—Heat Transfer Equipment
i. Table 6.8.1 I—Variable Refrigerant Flow Air Conditioners
j. Table 6.8.1 J—Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps
k. Table 6.8.1K—Air Conditioners Serving Computer Rooms
l. Table 6.8.1L—Commercial Refrigerator and Freezers
m. Table 6.8.1M—Commercial Refrigeration Equipment

All furnaces with input ratings of ≥225,000 Btu/h (65 kW), including electric furnaces, that are not located within the conditioned space shall have jacket losses not exceeding 0.75% of the input rating. Air conditioners primarily serving computer rooms and covered by ASHRAE Standard 127 shall meet the requirements in Table 6.8.1K. All other air conditioners shall meet the requirements in Table 6.8.1A.

Add the following tables in I-P units:

TABLE 6.8.1L Commercial Refrigerator and Freezers (I-P Units)

Equipment Type	Application	Energy Use Limits (kWh per day)	Test Procedure
Refrigerator with solid doors		$0.10 \times V + 2.04$	
Refrigerator with transparent doors		$0.12 \times V + 3.34$	
Freezers with solid doors	Holding Temperature	$0.40 \times V + 1.38$	AHRI 1200
Freezers with transparent doors		$0.75 \times V + 4.10$	
Refrigerators/freezers with solid doors		the greater of $0.12 \times V + 3.34$ or 0.70	
Commercial refrigerators	Pulldown	$0.126 \times V + 3.51$	

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

TABLE 6.8.1M Commercial Refrigeration Minimum Efficiency Requirements (I-P Units)

Equipment Type				Energy Use Limits (kWh/day) as of 1/1/2012[b,c]	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical Open	Remote Condensing	Medium Temperature	0.82 × TDA + 4.07	AHRI 1200
SVO.RC.M	Semivertical Open	Remote Condensing	Medium Temperature	0.83 × TDA + 3.18	
HZO.RC.M	Horizontal Open	Remote Condensing	Medium Temperature	0.35 × TDA + 2.88	
VOP.RC.L	Vertical Open	Remote Condensing	Low Temperature	2.27 × TDA + 6.85	
HZO.RC.L	Horizontal Open	Remote Condensing	Low Temperature	0.57 × TDA + 6.88	
VCT.RC.M	Vertical Transparent Door	Remote Condensing	Medium Temperature	0.22 TDA + 1.95	
VCT.RC.L	Vertical Transparent Door	Remote Condensing	Low Temperature	0.56 × TDA + 2.61	
SOC.RC.M	Service Over Counter	Remote Condensing	Medium Temperature	0.51 × TDA + 0.11	
VOP.SC.M	Vertical Open	Self Contained	Medium Temperature	1.74 × TDA + 4.71	
SVO.SC.M	Semivertical Open	Self Contained	Medium Temperature	1.73 × TDA + 4.59	
HZO.SC.M	Horizontal Open	Self Contained	Medium Temperature	0.77 × TDA + 5.55	
HZO.SC.L	Horizontal Open	Self Contained	Low Temperature	1.92 × TDA + 7.08	
VCT.SC.I	Vertical Transparent Door	Self Contained	Ice Cream	0.67 × TDA + 3.29	
VCS.SC.I	Vertical Solid Door	Self Contained	Ice Cream	0.38 × V + 0.88	
HCT.SC.I	Horizontal Transparent Door	Self Contained	Ice Cream	0.56 × TDA + 0.43	
SVO.RC.L	Semivertical Open	Remote Condensing	Low Temperature	2.27 × TDA + 6.85	
VOP.RC.I	Vertical Open	Remote Condensing	Ice Cream	2.89 × TDA + 8.7	
SVO.RC.I	Semivertical Open	Remote Condensing	Ice Cream	2.89 × TDA + 8.7	
HZO.RC.I	Horizontal Open	Remote Condensing	Ice Cream	0.72 × TDA + 8.74	
VCT.RC.I	Vertical Transparent Door	Remote Condensing	Ice Cream	0.66 × TDA + 3.05	
HCT.RC.M	Horizontal Transparent Door	Remote Condensing	Medium Temperature	0.16 × TDA + 0.13	
HCT.RC.L	Horizontal Transparent Door	Remote Condensing	Low Temperature	0.34 × TDA + 0.26	
HCT.RC.I	Horizontal Transparent Door	Remote Condensing	Ice Cream	0.4 × TDA + 0.31	
VCS.RC.M	Vertical Solid Door	Remote Condensing	Medium Temperature	0.11 × V + 0.26	
VCS.RC.L	Vertical Solid Door	Remote Condensing	Low Temperature	0.23 × V + 0.54	
VCS.RC.I	Vertical Solid Door	Remote Condensing	Ice Cream	0.27 × V + 0.63	
HCS.RC.M	Horizontal Solid Door	Remote Condensing	Medium Temperature	0.11 × V + 0.26	
HCS.RC.L	Horizontal Solid Door	Remote Condensing	Low Temperature	0.23 × V + 0.54	
HCS.RC.I	Horizontal Solid Door	Remote Condensing	Ice Cream	0.27 × V + 0.63	

TABLE 6.8.1M Commercial Refrigeration Minimum Efficiency Requirements (I-P Units)

Equipment Type				Energy Use Limits (kWh/day) as of 1/1/2012[b,c]	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
HCS.RC.I	Horizontal Solid Door	Remote Condensing	Ice Cream	0.27 × V + 0.63	AHRI 1200
SOC.RC.L	Service Over Counter	Remote Condensing	Low Temperature	1.08 × TDA + 0.22	
SOC.RC.I	Service Over Counter	Remote Condensing	Ice Cream	1.26 × TDA + 0.26	
VOP.SC.L	Vertical Open	Self Contained	Low Temperature	4.37 × TDA + 11.82	
VOP.SC.I	Vertical Open	Self Contained	Ice Cream	5.55 × TDA + 15.02	
SVO.SC.L	Semivertical Open	Self Contained	Low Temperature	4.34 × TDA + 11.51	
SVO.SC.I	Semivertical Open	Self Contained	Ice Cream	5.52 × TDA + 14.63	
HZO.SC.I	Horizontal Open	Self Contained	Ice Cream	2.44 × TDA + 9.0	
SOC.SC.I	Service Over Counter	Self Contained	Ice Cream	1.76 × TDA + 0.36	
HCS.SC.I	Horizontal Solid Door	Self Contained	Ice Cream	0.38 × V + 0.88	

[a] Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of:
(AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical transparent doors, VCS = vertical solid doors, HCT = horizontal transparent doors, HCS = horizontal solid doors, or SOC = service over counter);
(BB)—An operating mode code (RC = remote condensing or SC = self contained); and
(C)—A rating temperature code (M = medium temperature (38°F), L = low temperature (0°F), or I = ice cream temperature (15°F)). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.
[b] V is the volume of the case, as measured in AHRI Standard 1200, Appendix C.
[c] TDA is the total display area of the case, as measured in the AHRI Standard 1200, Appendix D.

Add the following tables in SI Units:

Table 6.8.1L Commercial Refrigerator and Freezers (SI)

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

V means the chiller or frozen compartment volume (m^3) as defined in the Association of Home Appliance Manufacturers Standard HRF-1-2008

Table 6.8.1M Commercial Refrigeration Minimum Efficiency Requirements (SI)

Equipment Type				Energy Use Limits (kWh/day) as of 1/1/2012[b,c]	Test Procedure
Equipment Class[a]	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical Open	Remote Condensing	Medium Temperature	8.83 × TDA + 4.07	AHRI 1200
SVO.RC.M	Semivertical Open	Remote Condensing	Medium Temperature	8.93 × TDA + 3.18	
HZO.RC.M	Horizontal Open	Remote Condensing	Medium Temperature	3.77 × TDA + 2.88	
VOP.RC.L	Vertical Open	Remote Condensing	Low Temperature	24.43 × TDA + 6.85	
HZO.RC.L	Horizontal Open	Remote Condensing	Low Temperature	6.14 × TDA + 6.88	
VCT.RC.M	Vertical Transparent Door	Remote Condensing	Medium Temperature	2.37 × TDA + 1.95	
VCT.RC.L	Vertical Transparent Door	Remote Condensing	Low Temperature	6.03 × TDA + 2.61	
SOC.RC.M	Service Over Counter	Remote Condensing	Medium Temperature	5.49 × TDA + 0.11	
VOP.SC.M	Vertical Open	Self Contained	Medium Temperature	18.73 × TDA + 4.71	
SVO.SC.M	Semivertical Open	Self Contained	Medium Temperature	18.62 × TDA + 4.59	
HZO.SC.M	Horizontal Open	Self Contained	Medium Temperature	8.29 × TDA + 5.55	
HZO.SC.L	Horizontal Open	Self Contained	Low Temperature	20.67 × TDA + 7.08	
VCT.SC.I	Vertical Transparent Door	Self Contained	Ice Cream	7.21 × TDA + 3.29	
VCS.SC.I	Vertical Solid Door	Self Contained	Ice Cream	13.42 × V + 0.88	
HCT.SC.I	Horizontal Transparent Door	Self Contained	Ice Cream	6.03 × TDA + 0.43	
SVO.RC.L	Semivertical Open	Remote Condensing	Low Temperature	24.43 × TDA + 6.85	
VOP.RC.I	Vertical Open	Remote Condensing	Ice Cream	31.11 × TDA + 8.7	
SVO.RC.I	Semivertical Open	Remote Condensing	Ice Cream	31.11 × TDA + 8.7	
HZO.RC.I	Horizontal Open	Remote Condensing	Ice Cream	7.75 × TDA + 8.74	
VCT.RC.I	Vertical Transparent Door	Remote Condensing	Ice Cream	7.10 × TDA + 3.05	
HCT.RC.M	Horizontal Transparent Door	Remote Condensing	Medium Temperature	1.72 × TDA + 0.13	
HCT.RC.L	Horizontal Transparent Door	Remote Condensing	Low Temperature	3.66 × TDA + 0.26	
HCT.RC.I	Horizontal Transparent Door	Remote Condensing	Ice Cream	4.31 × TDA + 0.31	
VCS.RC.M	Vertical Solid Door	Remote Condensing	Medium Temperature	3.88 × V + 0.26	
VCS.RC.L	Vertical Solid Door	Remote Condensing	Low Temperature	8.12 × V + 0.54	
VCS.RC.I	Vertical Solid Door	Remote Condensing	Ice Cream	9.53 × V + 0.63	
HCS.RC.M	Horizontal Solid Door	Remote Condensing	Medium Temperature	3.88 × V + 0.26	
HCS.RC.L	Horizontal Solid Door	Remote Condensing	Low Temperature	8.12 × V + 0.54	
HCS.RC.I	Horizontal Solid Door	Remote Condensing	Ice Cream	9.53 × V + 0.63	
HCS.RC.I	Horizontal Solid Door	Remote Condensing	Ice Cream	9.53 × V + 0.63	AHRI 1200
SOC.RC.L	Service Over Counter	Remote Condensing	Low Temperature	11.63 × TDA + 0.22	
SOC.RC.I	Service Over Counter	Remote Condensing	Ice Cream	13.56 × TDA + 0.26	
VOP.SC.L	Vertical Open	Self Contained	Low Temperature	47.04 × TDA + 11.82	
VOP.SC.I	Vertical Open	Self Contained	Ice Cream	59.74 × TDA + 15.02	
SVO.SC.L	Semivertical Open	Self Contained	Low Temperature	46.72 × TDA + 11.51	
SVO.SC.I	Semivertical Open	Self Contained	Ice Cream	5.52 × TDA + 14.63	
HZO.SC.I	Horizontal Open	Self Contained	Ice Cream	59.42 × TDA + 9.0	
SOC.SC.I	Service Over Counter	Self Contained	Ice Cream	18.94 × TDA + 0.36	
HCS.SC.I	Horizontal Solid Door	Self Contained	Ice Cream	13.42 × V + 0.88	

[a,c] Equipment class designations consist of a combination (in sequential order separated by periods(AAA).(BB).(C)) of:

(AAA)—An equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter);

(BB)—An operating mode code (RC=remote condensing or SC=self contained); and

(C)—A rating temperature code (M=medium temperature (3.3 °C), L=low temperature (-17.8 °C), or I=ice-cream temperature (-9.4 °C)). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.

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

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

Add a reference in Section 12 under Air-Conditioning, Heating, and Refrigeration Institute:

Air Conditioning, Heating and Refrigeration Institute, 2111 Wilson Blvd., Suite 500, Arlington, VA 22201	
AHRI 1200-2010	Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets

Add a reference in Section 12 under Association of Home Appliance Manufacturers

Association of Home Appliance Manufacturers, 1111 19th Street NW, Suite 402, Washington, DC 20036	
ANSI/AHAM HRF-1-2008	Energy and Internal Volume of Refrigerating Appliances (including errata issued November 17, 2009)

(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

This addendum amends the minimum energy efficiency standards for water-to-air heat pumps (water loop, ground water, and ground loop) listed in Table 6.8.1B of Standard 90.1-2010. These new minimum efficiencies meet or exceed the Energy Star Tier 1 levels for Ground Water and Ground Source heat pumps that were in effect until January 1, 2011. Proposed cooling EERs and heating COPs are on average 3% to 11% more stringent than values currently listed in the standard. These new minimums are proposed to become effective immediately upon publication of the addendum. Finally, the proposal corrects the minimum efficiencies for through-the-wall products and removes the small-duct, high-velocity product class from Table 6.8.1B.

***Note:** In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum h to Standard 90.1-2010

Amend Table 6.8.1B to modify minimum energy efficiency requirements for water to air heat pumps as follows (I-P units):

TABLE 6.8.1 B Electrically Operated Unitary and Applied Heat Pumps— Minimum Efficiency Requirements (I-P Units)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[~~b~~a]
Air cooled (cooling mode)	<65,000 Btu/h[~~c~~b]	All	Split system	13.0 SEER	AHRI 210/240
			Single packaged	13.0 SEER	
Through-the-wall, air cooled	≤30,000 Btu/h[~~c~~b]	All	Split system	12.0 SEER	
			Single packaged	12.0 SEER	
~~Single-duct high-velocity air cooled~~	~~<65,000 Btu/h[c]~~[b]	~~All~~	~~Split system~~	~~10.0 SEER~~	
Air cooled (cooling mode)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split system and single package	11.0 EER 11.2 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split system and single package	10.6 EER 10.7 IEER	
		All other	Split system and single package	10.4 EER 10.5 IEER	
	≥240,000 Btu/h	Electric Resistance (or None)	Split system and single package	9.5 EER 9.6 IEER	
		All other	Split system and single package	9.3 EER 9.4 IEER	
Water to air: water loop ~~source~~ (cooling mode)	<17,000 Btu/h	All	86°F entering water	~~11.2 EER~~ 12.2 EER	ISO 13256-1
	≥17,000 Btu/h and <65,000 Btu/h	All	86°F entering water	~~12.0 EER~~ 13 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	86°F entering water	~~12.0 EER~~ 13 EER	
Water to air: ground water ~~water source~~ (cooling mode)	<135,000 Btu/h	All	59°F entering water	~~16.2 EER~~ 18.0 EER	
Brine to air: ground loop ~~source~~ (cooling mode)	<135,000 Btu/h	All	77°F entering water	~~13.4 EER~~ 14.1 EER	

TABLE 6.8.1 B Electrically Operated Unitary and Applied Heat Pumps— Minimum Efficiency Requirements (I-P Units) (Continued)

Water to water: water loop ~~source~~ ~~water to water~~ (cooling mode)	<135,000 Btu/h	All	86°F entering water	10.6 EER	ISO-13256-2
Water to water: ground~~water~~ water ~~source~~ ~~water to water~~ (cooling mode)	<135,000 Btu/h	All	59°F entering water	16.3 EER	
Brine to water: ground loop ~~source~~ ~~brine to water~~ (cooling mode)	<135,000 Btu/h	All	77°F entering water	12.1 EER	
Air cooled (heating mode)	<65,000 Btu/h~~c~~b	—	Split system	7.7 HSPF	AHRI 210/240
		—	Single package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤30,000 Btu/h~~c~~b (cooling capacity)	—	Split system	7.4 HSPF	
		—	Single package	7.4 HSPF	
~~Small-duct high velocity (air cooled, heating mode)~~	~~<65,000 Btu/h~~~~c~~b	—	~~Split system~~	~~6.8 HSPF~~	
Air cooled (heating mode)	≥65,000 Btu/h and <135,000 Btu/h (Cooling Capacity)	—	47°F db/43°F wb outdoor air	3.3 COP	AHRI 340/360
			17°F db/15°F wb outdoor air	2.25 COP	
	≥135,000 Btu/h (Cooling Capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb outdoor air	2.05 COP	
Water to air: water loop ~~source~~ (heating mode)	<135,000 Btu/h (cooling capacity)	—	68°F entering water	~~4.2 COP~~ 4.3 COP	ISO 13256-1
Water to air: ground water ~~water source~~ (heating mode)	<135,000 Btu/h (cooling capacity)	—	50°F entering water	~~3.6 COP~~ 3.7 COP	
Brine to air: ground loop ~~source~~ (heating mode)	<135,000 Btu/h (cooling capacity)	—	32°F entering fluid	~~3.1 COP~~ 3.2 COP	
Water to water: water loop ~~source~~ ~~water to water~~ (heating mode)	<135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
Water to water: ground~~water~~ water ~~source water to water~~ (heating mode)	<135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	
Brine to water: ground loop ~~source~~ ~~brine to water~~ (heating mode)	<135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

~~[a] IPLV and part load rating conditions are only applicable to equipment with capacity modulation.~~

[~~a~~b] Section 12 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure

[~~c~~b] Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA, SEER values are those set by NAECA

Amend Table 6.8.1B to modify minimum energy efficiency requirements for water to air heat pumps as follows (SI units):

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

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure[~~b~~a]
Air cooled (cooling mode)	<19 kW[~~c~~b]	All	Split system	3.81 $SCOP_C$	AHRI 210/240
			Single packaged	3.81 $SCOP_C$	
Through-the-wall, air cooled	≥9 kW[~~c~~b]	All	Split system	3.51 $SCOP_C$	
			Single packaged	3.51 $SCOP_C$	
~~Single-duct high-velocity air cooled~~	~~<19 kW~~[~~c~~b]	~~All~~	~~Split system~~	~~2.93 $SCOP_C$~~	
Air cooled (cooling mode)	≥19 kW and <40 kW	Electric Resistance (or None)	Split system and single package	3.22 COP_C 3.28 $ICOP_C$	AHRI 340/360
		All other	Split system and single package	3.16 COP_C 3.22 $ICOP_C$	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split system and single package	3.13 $ICOP_C$	
		All other	Split system and single package	3.05 COP_C 3.07 $ICOP_C$	
	≥70 kW	Electric Resistance (or None)	Split system and single package	2.78 COP_C 2.81 $ICOP_C$	
		All other	Split system and single package	2.72 COP_C 2.75 $ICOP_C$	
Water to air: water loop ~~source~~ (cooling mode)	<5 kW	All	30°C entering water	~~3.28 COP_C~~ 3.57 COP_C	ISO 13256-1
	≥5 kW and <19 kW	All	30°C entering water	~~3.51 COP_C~~ 3.81 COP_C	
	≥19 kW and <40 kW	All	30°C entering water	~~3.51 COP_C~~ 3.81 COP_C	
Water to air: ground water ~~water source~~ (cooling mode)	<40 kW	All	15°C entering water	~~4.74 COP_C~~ 5.27 COP_C	
Brine to air: ground loop ~~source~~ (cooling mode)	<40 kW	All	25°C entering water	~~3.92 COP_C~~ 4.13 COP_C	
Water to water: water loop ~~source~~ ~~water to water~~ (cooling mode)	<40 kW	All	30°C entering water	3.10 COP_C	ISO-13256-2
Water to water: Ground~~water~~ water ~~source~~ ~~water to water~~ (cooling mode)	<40 kW	All	15°C entering water	4.77 COP_C	
Brine to water: ground loop ~~source~~ ~~Brine to water~~ (cooling mode)	<40 kW	All	25°C entering water	3.55 COP_C	

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

Air cooled (heating mode)	<19 kW[~~c~~b]	—	Split system	2.26 $SCOP_H$	AHRI 210/240
		—	Single package	2.26 $SCOP_H$	
Through-the-wall, (air cooled, heating mode)	≤9 kW[~~c~~b] (cooling capacity)	—	Split system	2.17 $SCOP_H$	
		—	Single package	2.17 $SCOP_H$	
~~Small-duct high velocity (air cooled, heating mode)~~	~~<19 kW~~[~~c~~b]	—	~~Split system~~	~~2.0 HSPF~~	
Air cooled (heating mode)	≥19 kW and <40 kW (Cooling Capacity)	—	8.3°C db/6.1°C wb outdoor air	3.3 COP_H	AHRI 340/360
			–8.3°C db/–9.4°C wb outdoor air	2.25 COP_H	
	≥40 kW (Cooling Capacity)	—	8.3°C db/6.1°C wb outdoor air	3.2 COP_H	
			–8.3°C db/–9.4°C wb outdoor air	2.05 COP_H	
Water to air: water loop ~~source~~ (heating mode)	<40 kW (cooling capacity)	—	20°C entering water	~~4.2 COP~~ 4.3 COP_H	ISO 13256-1
Water to air: ground water ~~water source~~ (heating mode)	<40 kW (cooling capacity)	—	10°C entering water	~~3.6 COP~~ 3.7 COP_H	
Brine to air: ground loop ~~source~~ (heating mode)	<40 kW (cooling capacity)	—	0°C entering fluid	~~3.1 COP~~ 3.2 COP_H	
Water to water: water loop ~~source water to water~~ (heating mode)	<40 kW (cooling capacity)	—	20°C entering water	3.7 COP_H	ISO 13256-2
Water to water: ground~~water~~ water ~~source water to water~~ (heating mode)	<40 kW (cooling capacity)	—	10°C entering water	3.1 COP_H	
Brine to water: ground loop ~~source brine to water~~ (heating mode)	<40 kW (cooling capacity)	—	0°C entering fluid	2.5 COP_H	

[a] ~~IPLV and part-load rating conditions are only applicable to equipment with capacity modulation.~~
[~~b~~a] Section 12 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure
[~~c~~b] Single-phase, air-cooled air conditioners <19 kW are regulated by NAECA. SEER values are those set by NAECA

(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

In Table 6.8.1A, three issues need to be corrected.

1. *In the preparation of Table 6.8.1, as a result of addendum CO, a mistake was found for the efficiency requirements for the new category of evaporatively cooled units with a capacity from 240,000 Btu/h to 760,000 Btu/h in the category of other heat. The EER as of 6/1/2011 is shown as 12.2 EER, whereas the EER for the same unit with electric heat is 11.9 EER. The EER for other size units is 0.2 EER lower for other heat to account for the increased pressure drop. The current value for this product results in a 0.3 increase, which is an error. The values of 12.2 EER should be 11.7 EER, which is 0.2 below the 11.9 listed for the electric heat unit.*
2. *In addition, the small duct high velocity requirements have been dropped by DOE and they are only allowing such systems under a waiver clause so the addendum has also made a change to remove the small duct high velocity systems from Tables 6.8.1A and 6.8.1B.*
3. *Note a states that the "IPLV and part load rating conditions are only applicable to equipment with capacity modulation". The IPLV term is no longer used and has been replaced by the IEER which applies to all units including those that do not have capacity modulation.*

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum j to Standard 90.1-2010

Modify the standard as follows (I-P and SI units):

TABLE 6.8.1A Electrically Operated Unitary Air Conditioners and Condensing Units— Minimum Efficiency Requirements (I-P Units)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, air cooled	<65,000 Btu/h[~~c~~b]	All	Split system	13.0 SEER	AHRI 210/240
			Single package	13.0 SEER	
Through-the-wall (air cooled)	≤30,000 Btu/h[~~c~~b]	All	Split system	12.0 SEER	
			Single package	12.0 SEER	
~~Small-duct high-velocity (air cooled)~~	~~<65,000 Btu/h~~[~~c~~b]	~~All~~	~~Split system~~	~~10.0 SEER~~	
Air conditioners, air cooled	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.2 EER 11.4 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER 11.2 IEER	
		All other	Split system and single package	10.8 EER 11.0 IEER	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	10.0 EER 10.1 IEER	
		All other	Split system and single package	9.8 EER 9.9 IEER	
	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	9.7 EER 9.8 IEER	
		All other	Split system and single package	9.5 EER 9.6 IEER	

TABLE 6.8.1A Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements (I-P Units)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, water cooled	<65,000 Btu/h	All	Split system and single package	12.1 EER 12.3 IEER	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.5 EER (before 6/1/2011) 12.1 EER (as of 6/1/2011) 11.7 IEER (before 6/1/2011) 12.3 IEER (as of 6/1/2011)	AHRI 340/360
		All other	Split system and single package	11.3 EER (before 6/1/2011) 11.9 EER (as of 6/1/2011) 11.5 IEER (before 6/1/2011) 12.1 IEER (as of 6/1/2011)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 12.5 EER (as of 6/1/2011) 11.2 IEER (before 6/1/2011) 12.5 IEER (as of 6/1/2011)	
		All other	Split system and single package	10.8 EER (before 6/1/2011) 12.3 EER (as of 6/1/2011) 11.0 IEER (before 6/1/2011) 12.5 IEER (as of 6/1/2011)	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 12.4 EER (as of 6/1/2011)11.1 EER (before 6/1/2011) 12.6 EER (as of 6/1/2011)	
		All other	Split system and single package	10.8 EER (before 6/1/2011) 12.2 EER (as of 6/1/2011) 10.9 EER (before 6/1/2011) 12.4 EER (as of 6/1/2011)	
Air conditioners, water cooled	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 12.2 EER (as of 6/1/2011) 11.1 EER (before 6/1/2011) 12.4 EER (as of 6/1/2011	AHRI 340/360
		All other	Split system and single package	10.8 EER (before 6/1/2011) 12.0 EER (as of 6/1/2011) 10.9 EER (before 6/1/2011) 12.2 EER (as of 6/1/2011)	

TABLE 6.8.1A Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements (I-P Units)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, evaporatively cooled	<65,000 Btu/h[~~c~~b]	All	Split system and single package	12.1 EER 12.3 IEER	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.5 EER (before 6/1/2011) 12.1 EER (as of 6/1/2011) 11.7 IEER (before 6/1/2011) 12.3 IEER (as of 6/1/2011)	AHRI 340/360
		All other	Split system and single package	11.3 EER (before 6/1/2011) 11.9 EER (as of 6/1/2011) 11.5 IEER (before 6/1/2011) 12.1 IEER (as of 6/1/2011)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 12.0 EER (as of 6/1/2011) 11.2 IEER (before 6/1/2011) 12.2 IEER (as of 6/1/2011)	
		All other	Split system and single package	10.8 EER (before 6/1/2011) 11.8 EER (as of 6/1/2011) 11.0 IEER (before 6/1/2011) 12.0 IEER (as of 6/1/2011)	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 11.9 EER (as of 6/1/2011) 11.1 IEER (before 6/1/2011) 12.1 IEER (as of 6/1/2011)	
		All other	Split system and single package	10.8 EER (before 6/1/2011) ~~12.2~~ 11.7 EER (as of 6/1/2011) 10.9 IEER (before 6/1/2011) 11.9 IEER (as of 6/1/2011)	
	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER (before 6/1/2011) 11.7 EER (as of 6/1/2011) 11.1 IEER (before 6/1/2011) 11.9 IEER (as of 6/1/2011)	
		All other	Split system and single package	10.8 EER (before 6/1/2011) 11.5 EER (as of 6/1/2011) 10.9 IEER (before 6/1/2011) 11.7 IEER (as of 6/1/2011)	
Condensing units air cooled	≥135,000Btu/h	—	—	10.1 EER (before 6/1/2011) 10.5 EER (as of 6/1/2011) 11.4 IEER (before 6/1/2011) 11.8 IEER (as of 6/1/2011)	AHRI 365
Condensing units water cooled	≥135,000Btu/h	—	—	13.1 EER (before 6/1/2011) 13.5 EER (as of 6/1/2011) 13.6 IEER (before 6/1/2011) 14.0 IEER (as of 6/1/2011)	
Condensing units evaporatively cooled	≥135,000Btu/h	—	—	13.1 EER (before 6/1/2011) 13.5 EER (as of 6/1/2011) 13.6 IEER (before 6/1/2011) 14.0 IEER (as of 6/1/2011)	

~~a IPLV and part load rating conditions are only applicable to equipment with capacity modulation~~

~~b~~a Section 12 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure

~~c~~b Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA, SEER valu~~v~~es are those set by NAECA

TABLE 6.8.1A Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements (SI)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air Conditioners, Air Cooled	<19 kW[cb]	All	Split System	3.81 $SCOP_C$	AHRI 210/240
			Single Package	3.81 $SCOP_C$	
Through-the-Wall (air cooled)	≤9 kW[cb]	All	Split system	3.52 $SCOP_C$	
			Single Package	3.52 $SCOP_C$	
Small-Duct High-Velocity (Air Cooled)	<19 kW[cb]	All	Split System	2.93 SCOP	
Air Conditioners, Air Cooled	≥19 kW and <40 kW	Electric Resistance (or None)	Split System and Single Package	3.28 COP_C 3.34 ICOP	AHRI 340/360
		All other	Split System and Single Package	3.22 COP_C 3.28 ICOP	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C 3.28 ICOP	
		All other	Split System and Single Package	3.17 COP_C 3.22 ICOP	
	≥70 kW and <223 kW	Electric Resistance (or None)	Split System and Single Package	2.93 COP_C 2.96 ICOP	
		All other	Split System and Single Package	2.87 COP_C 2.90 ICOP	
	≥223 kW	Electric Resistance (or None)	Split System and Single Package	2.84 COP_C 2.87 ICOP	
		All other	Split System and Single Package	2.78 COP_C 2.81 ICOP	
Air Conditioners, Water Cooled	< 19 kW	All	Split System and Single Package	3.55 COP_C 3.6 ICOP	AHRI 210/240
	≥19 kW and <40 kW	Electric Resistance (or None)	Split System and Single Package	3.37 COP_C (before 6/1/2011) 3.55 COP_C (as of 6/1/2011) 3.43 ICOP (before 6/1/2011) 3.60 ICOP (as of 6/1/2011)	AHRI 340/360
		All other	Split System and Single Package	3.31 COP_C (before 6/1/2011) 3.49 COP_C (as of 6/1/2011) 3.37 ICOP (before 6/1/2011) 3.55 ICOP (as of 6/1/2011)	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C (before 6/1/2011) 3.66 COP_C (as of 6/1/2011) 3.28 ICOP (before 6/1/2011) 3.66 ICOP (as of 6/1/2011)	
		All other	Split System and Single Package	3.17 COP_C (before 6/1/2011) 3.58 COP_C (as of 6/1/2011) 3.19 ICOP (before 6/1/2011) 3.63 ICOP (as of 6/1/2011)	
	≥70 kW and <223 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C (before 6/1/2011) 3.63 COP_C (as of 6/1/2011) 3.25 ICOP (before 6/1/2011) 3.69 ICOP (as of 6/1/2011)	
		All other	Split System and Single Package	3.17 COP_C (before 6/1/2011) 3.58 COP_C (as of 6/1/2011) 3.19 ICOP (before 6/1/2011) 3.63 ICOP (as of 6/1/2011)	

TABLE 6.8.1A Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements (SI)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air Conditioners, Water Cooled	≥223 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C (before 6/1/2011) 3.58 COP_C (as of 6/1/2011) 3.25 ICOP (before 6/1/2011) 3.63 ICOP (as of 6/1/2011	AHRI 340/360
		All other	Split System and Single Package	3.17 COP_C (before 6/1/2011) 3.52 COP_C (as of 6/1/2011) 3.19 ICOP (before 6/1/2011) 3.58 ICOP (as of 6/1/2011)	
Air Conditioners, Evaporatively Cooled	<19 kW[~~e~~b]	All	Split System and Single Package	3.55 COP_C 3.60 ICOP	AHRI 210/240
	≥19 kW and <40 kW	Electric Resistance (or None)	Split System and Single Package	3.37 COP_C (before 6/1/2011) 3.55 COP_C (as of 6/1/2011) 3.43 ICOP (before 6/1/2011) 3.60 ICOP (as of 6/1/2011)	AHRI 340/360
		All other	Split System and Single Package	3.31 COP_C (before 6/1/2011) 3.49 COP_C (as of 6/1/2011) 3.37 ICOP (before 6/1/2011) 3.55 ICOP (as of 6/1/2011)	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C (before 6/1/2011) 3.52 COP_C (as of 6/1/2011) 3.28 ICOP (before 6/1/2011) 3.58 ICOP (as of 6/1/2011)	
		All other	Split System and Single Package	3.17 COP_C (before 6/1/2011) 3.46 COP_C (as of 6/1/2011) 3.22 ICOP (before 6/1/2011) 3.52 ICOP (as of 6/1/2011)	
	≥70 kW and <223 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C (before 6/1/2011) 3.49 COP_C (as of 6/1/2011) 3.25 ICOP (before 6/1/2011) 3.55 ICOP (as of 6/1/2011)	
		All other	Split System and Single Package	3.17 COP_C (before 6/1/2011) ~~3.58~~3.43 COP_C (as of 6/1/2011) 3.19 ICOP (before 6/1/2011) 3.49 ICOP (as of 6/1/2011)	
	≥223 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_C (before 6/1/2011) 3.43 COP_C (as of 6/1/2011) 3.25 ICOP (before 6/1/2011) 3.49 ICOP (as of 6/1/2011)	
		All other	Split System and Single Package	3.17 COP_C (before 6/1/2011) 3.37 COP_C (as of 6/1/2011) 3.19 ICOP (before 6/1/2011) 3.43 ICOP (as of 6/1/2011)	

TABLE 6.8.1A Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements (SI)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Condensing Units Air Cooled	≥40 kW			2.96 COP_C (before 6/1/2011) 3.08 COP_C (as of 6/1/2011) 3.34 ICOP (before 6/1/2011) 3.46 ICOP (as of 6/1/2011)	AHRI 365
Condensing Units Water Cooled	≥40 kW			3.84 COP_C (before 6/1/2011) 3.96 COP_C (as of 6/1/2011) 3.99 ICOP (before 6/1/2011) 4.10 ICOP (as of 6/1/2011)	
Condensing Units Evaporatively Cooled	≥40 kW			3.84 COP_C (before 6/1/2011) 3.96 COP_C (as of 6/1/2011) 3.99 ICOP (before 6/1/2011) 4.10 ICOP (as of 6/1/2011)	

[a] ~~IPLV and part load rating conditions are only applicable to equipment with capacity modulation~~
[ba] Section 12 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure
[cb] Single phase, air cooled air conditioners <19 kW are regulated by NAECA, SEER valuves are those set by NAECA

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FOREWORD

This will make the transformer test procedure references consistent with other references in Chapter 6.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum k to Standard 90.1-2010

Modify the standard as follows (I-P and SI units):

8.1 General.

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

8.1.1.1 New Buildings. Equipment installed in new buildings shall comply with the requirements of this section.

8.1.1.2 Addition to Existing Buildings. Equipment installed in *additions* to *existing buildings* shall comply with the requirements of this section.

8.1.1.3 Alterations to Existing Buildings.

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

8.1.1.3.2 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 shall comply with the specific requirements applicable to that equipment.

Exception to 8.1.1.3: Compliance shall not be required for the relocation or reuse of existing equipment at the same site.

8.1.2 Low Voltage Dry-Type Distribution *Transformers.* Low voltage *dry-type transformers* shall comply with the provisions of the Energy Policy Act of 2005 where applicable, as shown in Table 8.1. *Transformers* that are not included in the scope of the Energy Policy Act of 2005 have no performance requirements in this section, and are listed for ease of reference below as exceptions.

TABLE 8.1 Minimum Nominal Efficiency Levels for ~~NEMA Class I~~ 10 CFR 431 Low Voltage Dry-Type Distribution Transformers[a]

Single Phase Transformers		Three Phase Transformers	
kVA[a,b]	Efficiency (%)[b,c]	kVA[a,b]	Efficiency (%)[b,c]
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

a. A low voltage distribution transformer is a transformer that is aircooled, does not use oil as a coolant, has an input voltage ≤600 Volts, and is rated for operation at a frequency of 60 Hz.
b. Kilovolt-ampere rating.
c. Nominal efficiencies shall be established in accordance with the ~~NEMA TP-1 2002~~ 10 CFR 431 test procedure for low-voltage, dry-type transformers. ~~Class I Low Voltage Dry-Type is a National Electrical Manufacturers Association (NEMA) design class designation.~~

Exceptions: *Transformers* that meet the Energy Policy Act of 2005 exclusions based on ~~NEMA TP-1~~ 10 CFR 431 definition:

a. special purpose applications

b. not likely to be used in general purpose applications

c. *transformers* with multiple voltage taps where the highest tap is at least 20% more than the lowest tap.

Products meeting these criteria and exempted from 8.1.2 include the following: drive transformer, rectifier transformer, auto-transformer, uninterruptible power system transformer, impedance transformer, regulating transformer, sealed and nonventilating transformer, machine tool transformer, welding transformer, grounding transformer, or testing transformer.

Add to Normative References:

U.S. Department of Energy **1000 Independence Avenue, SW, Washington, DC 20585**	
10 CFR 431 Subpart K, App A	Uniform Test Method for Measuring the Energy Consumption of Distribution Transformers

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FOREWORD

This addendum updates the fenestration air leakage provisions of Standard 90.1-2010 to clarify the requirements for glazed sectional garage doors. A definition for sectional garage doors is also added.

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum o to Standard 90.1-2010

Revise the standard as follows (I-P and SI units).

Add the following definition:

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

Modify Section 5.4.3.2, Fenestration and Doors, as follows (sections not shown remain unchanged):

d. 0.4 cfm/ft^2 for *nonswinging opaque doors* and glazed *sectional garage doors*, tested at a pressure of at least 1.57 pounds per square foot (psf) or higher in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.

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FOREWORD

This addendum adds a reference to CRRC-1 for cool roof testing requirements.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum p to Standard 90.1-2010

Modify Section 5.5.3.1 as follows (I-P and SI units):

5.5.3.1.1 Roof Solar Reflectance and Thermal Emittance. *Roofs*, in climate zones 1 through 3 shall have one of the following:

a. a minimum three-year-aged solar reflectance of 0.55 ~~when tested in accordance with ASTM C1549 or ASTM E1918,~~ and ~~in addition,~~ a minimum three-year-aged thermal emittance of 0.75, when tested in accordance with ~~ASTM C1371 or ASTM E408~~ CRRC-1 Standard.

b. a minimum ~~three-year-aged~~ Solar Reflectance Index of 64 when determined in accordance with the Solar Reflectance Index method in ASTM E1980 using a convection coefficient of 2.1 Btu/h·ft^2·°F, based on three-year-aged solar reflectance and three-year-aged thermal emittance tested in accordance with CRRC-1 Standard.

c. increased roof insulation levels found in Table 5.5.3.1.2.

Exceptions:

a. Ballasted *roofs* with a minimum stone ballast of 17 lb/ft^2 or 23 lb/ft^2 pavers.

b. *Vegetated Roof Systems* that contain a minimum thickness of 2.5 in. of growing medium and covering a minimum of 75% of the roof area with durable plantings.

c. *Roofs*, where a minimum of 75% of the roof area:

  i. Is shaded during the peak sun angle on June 21st by permanent components or features of the building, or

  ii. Is covered by offset photovoltaic arrays, building integrated photovoltaic arrays, or solar air or water collectors, or

  iii. Is permitted to be interpolated using a combination of parts i and ii above.

d. Steep sloped *roofs*

e. Low sloped metal building roofs in climate zones 2 and 3.

f. *Roofs* over ventilated attics or *roofs* over *semi-heated spaces* or *roofs* over *conditioned spaces* that are not *cooled spaces*.

g. Asphaltic membranes in climate zones 2 and 3.

The values for three-year-aged solar reflectance and three-year-aged thermal emittance shall be determined by a laboratory accredited by a nationally recognized accreditation organization~~, such as the Cool Roof Rating Council CRRC-1 Product Rating Program,~~ and shall be labeled and certified by the manufacturer.

Modify Section 12 as follows:

12. NORMATIVE REFERENCES

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

~~ASTM C1371-04~~	~~Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers~~
~~ASTM C1549-04~~	~~Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer~~
~~ASTM E408-71 (2002)~~	~~Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques~~
~~ASTM E903-96~~	~~Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres~~

Cool Roof Rating Council
1610 Harrison Street, Oakland, CA 94612

ANSI/CRRC-1 Standard-2010	Cool Roof Rating Council—ANSI/CRRC-1 Standard

Modify Informative Appendix E as follows:

INFORMATIVE APPENDIX E— INFORMATIVE REFERENCES

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

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FOREWORD

Large amounts of fan energy can be wasted when zones report incorrect information to the control system, which causes the supply fan speed to increase, often to maximum speed. This addendum requires additional safeguards to prevent this, and for non-DDC systems requires location of sensors in locations that do not require high setpoints.

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum s to Standard 90.1-2010

Revise the standard as follows (I-P and SI units):

6.5.3.2.2 Static Pressure Sensor Location. Static pressure sensors used to control VAV fans shall be ~~placed in a position~~ located such that the controller setpoint is no greater than ~~one third the total design fan static pressure~~ 1.2" w.c. (300 Pa)~~, except for systems with zone reset control complying with Section 6.5.3.2.3~~. If this results in the sensor being located downstream of major duct splits, ~~multiple~~ sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.

Exception: Systems complying with Section 6.5.3.2.3.

6.5.3.2.3 Setpoint Reset. For systems with DDC of individual zones ~~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. Controls shall provide the following:

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

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FOREWORD

These tables update the standard to include the new federal energy efficiency standards for motors used in HVAC equipment that will be in effect starting in 2015. It is consistent with how Standard 90.1 has provided motor efficiency to the users of this standard.

The edits also clarify the minimum efficiency values for Design B motors, which can be subtype I or subtype II design (based on information from NEMA).

Definitions are added to help end users with different motors that have different efficiency standards but the same horsepower ratings.

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum y to Standard 90.1-2010

Add the following to Section 3 of Standard 90.1-2010 as follows (I-P and SI Units):

0.1 Abbreviations and Acronyms

IEC International Electrotechnical Commission

Modify Section 3 and Section 10 of Standard 90.1-2010 as follows (I-P Units):

3.2 Definitions

~~***General Purpose Electric Motor (subtype I)***: any electric motor that meets the definition of "general purpose" motor as codified by the Department of Energy rule in 10 CFR 431 in effect on December 19, 2007.~~

general purpose electric motor (subtype I): a motor that is designed in standard ratings with either

1. standard operating characteristics and standard mechanical construction for use under usual service conditions, such as those specified in NEMA Standards Publication MG1–1993, paragraph 14.02, "Usual Service Conditions," and without restriction to a particular application or type of application; or

2. standard operating characteristics or standard mechanical construction for use under unusual service conditions, such as those specified in NEMA Standards Publication MG1–1993, paragraph 14.03, "Unusual Service Conditions," or for a particular type of application, and which can be used in most general-purpose applications.

General purpose electric motors (subtype I) are constructed in NEMA T-frame sizes, or IEC metric equivalent, starting at 143T.

~~***General Purpose Electric Motor (subtype II)***: any electric motor incorporating the design elements of a general purpose electric motor (subtype I) that are configured as a U-frame motor, design C motor, close-coupled pump motor, footless motor, vertical solid shaft, normal thrust motor (tested in a horizontal configuration), 8-pole motor (900 rpm), or polyphase motor with voltage no more than 600 volts (other than 230 or 460 volts).~~

general purpose electric motor (subtype II): a motor incorporating the design elements of a general purpose electric motor (subtype I) that is configured as one of the following:

(i) A U-frame motor

(ii) A Design C motor

(iii) A close-coupled pump motor

(iv) A footless motor

(v) A vertical, solid-shaft, normal-thrust motor (as tested in a horizontal configuration)

(vi) An 8-pole motor (900 rpm)

(vii) A polyphase motor with voltage of not more than 600 volts (other than 230 or 460 volts)

Except for U-frame sizes, general purpose electric motor (subtype II) refers to motors constructed in NEMA T-frame sizes, or IEC metric equivalent, starting at 143T.

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

10. OTHER EQUIPMENT

10.8 Product Information:

10.8B Minimum Nominal Full-Load Efficiency for 60 HZ NEMA ~~General Purpose Electric Motors (Subtype I)~~ *general purpose electric motors (subtype I)* Rated 600 Volts or Less (Random Wound)[a]

10.8C Minimum Nominal Full-Load Efficiency of ~~General Purpose Electric Motors (Subtype II and Design B)~~ *general purpose electric motors (subtype II* and all Design B motors greater than 200 horsepower)[a]

Table 10.8D Minimum Average Full-Load Efficiency for Polyphase *Small Electric Motors*[a]

Minimum Average Full-Load Efficiency (%) for Motors Manufactured on or after March 9, 2015			
Open Motors			
Number of Poles =>	**2**	**4**	**6**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**
Motor Horsepower			
0.25	65.6	69.5	67.5
0.33	69.5	73.4	71.4
0.50	73.4	78.2	75.3
0.75	76.8	81.1	81.7
1	77.0	83.5	82.5
1.5	84.0	86.5	83.8
2	85.5	86.5	N/A
3	85.5	86.9	N/A

[a] Average full-load efficiencies shall be established in accordance with 10 CFR 431.

Table 10.8E Minimum Average Full-Load Efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run *Small Electric Motors*[a]

Minimum Average Full-Load Efficiency (%) for Motors Manufactured on or after March 9, 2015			
Open Motors			
Number of Poles =>	**2**	**4**	**6**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**
Motor Horsepower			
0.25	66.6	68.5	62.2
0.33	70.5	72.4	66.6
0.50	72.4	76.2	76.2
0.75	76.2	81.8	80.2
1	80.4	82.6	81.1
1.5	81.5	83.8	N/A
2	82.9	84.5	N/A
3	84.1	N/A	N/A

[a] Average full-load efficiencies shall be established in accordance with 10 CFR 431.

Add Tables 10.8D and 10.8E as follows (SI units):

Table 10.8D Minimum Average Full-Load Efficiency for Polyphase *Small Electric Motors*[a]

Minimum Average Full-Load Efficiency (%) for Motors Manufactured on or after March 9, 2015			
	Open Motors		
Number of Poles =>	**2**	**4**	**6**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**
Motor Size (kW)			
0.19	65.6	69.5	67.5
0.25	69.5	73.4	71.4
0.37	73.4	78.2	75.3
0.56	76.8	81.1	81.7
0.75	77.0	83.5	82.5
1.1	84.0	86.5	83.8
1.5	85.5	86.5	N/A
2.2	85.5	86.9	N/A

[a] Average full-load efficiencies shall be established in accordance with 10 CFR 431.

Table 10.8E Minimum Average Full-Load Efficiency for Capacitor-Start Capacitor-Run and Capacitor-Start Induction-Run *Small Electric Motors*[a]

Minimum Average Full-Load Efficiency (%) for Motors Manufactured on or after March 9, 2015			
	Open Motors		
Number of Poles =>	**2**	**4**	**6**
Synchronous Speed (RPM) =>	**3600**	**1800**	**1200**
Motor Size (kW)			
0.19	66.6	68.5	62.2
0.25	70.5	72.4	66.6
0.37	72.4	76.2	76.2
0.56	76.2	81.8	80.2
0.75	80.4	82.6	81.1
1.1	81.5	83.8	N/A
1.5	82.9	84.5	N/A
2.2	84.1	N/A	N/A

[a] Average full-load efficiencies shall be established in accordance with 10 CFR 431.

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FOREWORD

The existing wording regarding water economizers is often overlooked by designers. This addendum relocates it to the economizer requirements.

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Addendum z to Standard 90.1-2010

Revise the standard as follows (I-P and SI units):

6.5.~~2.4~~1.5 Economizer Humidification System Impact. Systems with hydronic cooling and humidification systems designed to maintain inside humidity at a dew-point temperature greater than 35°F shall use a water economizer if an economizer is required by Section 6.5.1.

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FOREWORD

This electrical monitoring addendum provides the requirement to install basic electrical metering of important major end uses and to provide appropriate basic reporting of the resulting consumption data. The resulting information will be available to the occupant and operator to support decisions on efficient energy use and reduction through operational change, maintenance, control adjustment, and facility upgrade.

Monitoring of energy use can be accomplished from very simple to complicated arrangements.

Actual energy savings from monitoring feedback availability can be difficult to measure. General assessments by case study and review of applications indicates typical conservative savings from 5% to 10% of whole-building energy. The paper "The Effectiveness of Feedback on Energy Consumption" (by Sarah Darby, April 2006, Environmental Change Institute, University of Oxford) is one collective study on energy monitoring feedback that provides references to many of the available case studies and other research on the subject, most of which are based on U.S. data.

***Note:** In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum bz to Standard 90.1-2010

Modify the standard as follows (I-P and SI units):

8.4.2 Electrical Energy Monitoring

8.4.2.1 Monitoring. Measurement devices shall be installed to monitor the electrical energy use for each of the following separately:

a. Total electrical energy
b. HVAC Systems
c. Interior lighting
d. Exterior lighting
e. Receptacle circuits

For buildings with tenants, these systems shall be separately monitored for the total building and (excluding shared systems) for each individual tenant.

8.4.2.2 Recording and Reporting. The electrical energy usage for all loads specified in Section 8.4.2.1 shall be recorded a minimum of every 15 minutes and reported at least hourly, daily, monthly, and annually. The data for each tenant space shall be made available to that tenant. The system shall be capable of maintaining all data collected for a minimum of 36 months.

Exceptions to 8.4.2.1 and 8.4.2.2:

a. Building or additions less than 10,000 ft^2 (929 m^2)
b. Individual tenant spaces less than 5,000 ft^2 (929 m^2)
c. *Dwelling units*
d. Residential buildings with less than 10,000 ft^2 (929 m^2) of common area
e. Critical and Equipment branches of NEC Article 517

Add the following reference to Section 12 (I-P and SI units):

12. NORMATIVE REFERENCES

Reference	Title
National Fire Protection Association 1 Battery March Park, P.O Box 9101, Quincy, MA 02269-9101	
ANSI/NFPA 70-2008	National Electric Code

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FOREWORD

Changes were made in Addenda d, x, ab, and ac that affected Section 11 and Appendix G of Standard 90.1. This addendum makes Section 11 and Appendix G consistent with those changes.

Note: *In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum cg to Standard 90.1-2010

Modify Table 11.3.1 as follows (I-P and SI units):

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
6. Lighting		
	Lighting power in the *proposed building design* shall be determined as follows: a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model. b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type. d. Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures). e. The lighting schedules in the *proposed building design* shall reflect the mandatory automatic lighting control requirements in Section 9.4.1 (e.g., programmable controls or occupancy sensors). **Exception**: Automatic daylighting controls required by Section 9.4.1 shall be modeled directly in the *proposed building design* or through schedule adjustments determined by a separate daylighting analysis approved by the rating authority. f. Automatic lighting controls included in the *proposed building design* but not required by Section 9.4.1 may be modeled directly in the building simulation or be modeled in the building simulation through schedule adjustments determined by a separate analysis approved by the *authority having jurisdiction*. As an alternative to modeling such lighting controls, the *proposed building design* lighting power density may be reduced by the sum of all additional allowances per Section 9.6.2c and Table 9.6.2, which are calculated individually as the lighting power under control multiplied by *cf*, where *cf* is the appropriate control factor given in Table 9.6.2 corresponding to the space type and the lighting controls designed to be used.	a. Lighting power in the *budget building design* shall be determined using the same categorization procedure (building area method or space-by-space method ~~function~~) and categories as the *proposed design* with lighting power set equal to the maximum allowed for the corresponding method and category in ~~either~~ Section 9.2 ~~5 or 9.6~~. Additional *interior lighting power* for nonmandatory controls allowed under Section 9.6.2.c shall not be included in the *budget building design*. b. Power for fixtures not included in the *LPD* calculation shall be modeled identically in the *proposed building design* and *budget building design*. ~~Lighting controls shall be the minimum required.~~ c. Mandatory automatic lighting controls required by Section 9.4.1 shall be modeled the same as the *proposed building design*.

Modify Table G3.1 as follows (I-P and SI units):

No.	Proposed Building Performance	Baseline Building Performance
6. Lighting		
	Lighting power in the *proposed design* shall be determined as follows: a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model. b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where lighting neither exists nor is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type. d. Lighting system power shall include all lighting system components shown or provided for on the plans (including lamps and ballasts and task and furniture-mounted fixtures). **Exception:** For multifamily *dwelling units*, hotel/motel guest rooms, and other spaces in which lighting systems are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for the *proposed* and *baseline building designs* in the simulations. e. Lighting power for parking garages and building facades shall be modeled. ~~f. Credit may be taken for the use of automatic controls for daylight utilization but only if their operation is either modeled directly in the building simulation or modeled in the building simulation through schedule adjustments determined by a separate daylighting analysis approved by the *rating authority*.~~ ~~g. For automatic lighting controls in addition to those required for minimum code compliance under Section 9.4.1, credit may be taken for automatically controlled systems by reducing the connected lighting power by the applicable percentages listed in Table G3.2. Alternatively, credit may be taken for these devices by modifying the lighting schedules used for the *proposed design*, provided that credible technical documentation for the modifications are provided to the *rating authority*.~~ f. The lighting schedules in the *proposed building design* shall reflect the mandatory automatic lighting control requirements in Section 9.4.1 (e.g., programmable controls or occupancy sensors). **Exception**: Automatic daylighting controls required by Section 9.4.1 shall be modeled directly in the *proposed building design* or through schedule adjustments determined by a separate daylighting analysis approved by the rating authority. g. Automatic lighting controls included in the *proposed building design* but not required by Section 9.4.1 may be modeled directly in the building simulation or be modeled in the building simulation through schedule adjustments determined by a separate analysis approved by the *authority having jurisdiction.* As an alternative to modeling such lighting controls, the *proposed building design* lighting power may be reduced by the sum of all additional allowances per Section 9.6.2c and Table 9.6.2, which are calculated individually as the lighting power under control multiplied by *cf*, where *cf* is the appropriate control factor given in Table 9.6.2 corresponding to the space type and the lighting controls designed to be used.	a. Lighting power in the baseline building design shall be determined using the same categorization procedure (building area method or space-by-space method ~~function~~) and categories as the *proposed design* with lighting power set equal to the maximum allowed for the corresponding method and category in Section 9.2. Additional *interior lighting power* for nonmandatory controls allowed under Section 9.6.2.c shall not be included in the *baseline building design.* ~~No automatic lighting controls (e.g., programmable controls or occupancy sensors) shall be modeled in the baseline building design, as the lighting schedules used are understood to reflect the mandatory control requirements in this standard.~~ b. Mandatory automatic lighting controls required by Section 9.4.1 shall be modeled the same as the *proposed building design.*

Delete Table G3.2 as follows (I-P and SI units):

TABLE G3.2 Power Adjustment Percentages for Automatic Lighting Controls

~~Automatic Control Device(s)~~	~~Non-24-h and ≤5000 ft²~~	~~All Other Spaces not required to have automatic lighting control~~
~~1. Programmable timing control~~	~~10%~~	~~0%~~
~~2. Occupancy sensor~~	~~15%~~	~~10%~~
~~3. Occupancy sensor and programmable timing control~~	~~15%~~	~~10%~~

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FOREWORD

Since the ECB method and Addendum G were initially adopted into Standard 90.1, the cooling tower market has moved to variable-speed fan controls rather than two-speed fan motors on cooling towers. The change to variable-speed drives on the cooling tower fan(s) reflects current practice and will serve as a truer baseline for comparisons between the baseline system (Systems 7 and 8) and the proposed building system by users of Appendix G as well as the Energy Cost Budget Method.

In addition, an exception has been added for climates with extremely high design wet-bulb temperatures such that the baseline system will not require an unreasonably large cooling tower. In such climate zones, the current requirement is not a realistic baseline and unfairly penalizes the proposed design. The changes in this Addendum correct this condition by providing a more realistic baseline.

Finally, the use of "open circuit" as opposed to "closed circuit" cooling towers has been clarified in the text (reference Addendum ad to Standard 90.1-2007).

***Note:** In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum ci to Standard 90.1-2010

Modify Section 3.2—Definitions as follows (I-P and SI units):

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

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

Modify footnote e to Table 11.3.2A as follows (I-P and SI units):

e. **Chilled water:** For *systems* using purchased chilled water, the chillers are not explicitly modeled and chilled-water costs shall be based as determined in Section 11.2.3. Otherwise, the *budget building design's* chiller plant shall be modeled with chillers having the number as indicated in Table 11.3.2B as a function of *budget building design* chiller plant load and type as indicated in Table 11.3.2C as a function of individual chiller load. Where chiller fuel source is mixed, the system in the *budget building design* shall have chillers with the same fuel types and with capacities having the same proportional capacity as the *proposed building design's* chillers for each fuel type. Chilled-water supply temperature shall be modeled at 44°F (6.7°C) design supply temperature and 56°F (13°C) return temperature. Piping losses shall not be modeled in either building model. Chilled-water supply water temperature shall be reset in accordance with Section 6.5.4.3. Pump system power for each pumping system shall be the same as the *proposed building design*; if the *proposed building design* has no chilled-water pumps, the *budget building design* pump power shall be 22 W/gpm (349 kW/1000 L/s) (equal to a pump operating against a 75 ft (23 m) head, 65% combined impeller and motor *efficiency*). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled-water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in Section 6.5.4.1. The heat rejection device shall be an axial fan open circuit cooling tower with ~~two-speed~~ variable-speed fan~~s~~ control if required in Section 6.5.5. Condenser water design supply temperature shall ~~be 85°F or 10° F (29°C or 5.6°C)~~ be calculated using the cooling tower approach to ~~1%~~ the 0.4% *evaporation design wet-bulb temperature* ~~design wet-bulb temperature~~ as generated by the formula below, ~~whichever is lower,~~ with a design temperature rise of 10°F (5.6°C).

$$\text{Approach}_{10°\text{F Range}} = 25.72 - (0.24 \times \text{WB})$$

where WB is the *0.4% evaporation design wet-bulb temperature* in °F; valid for wet bulbs from 55°F to 90°F.

$$\text{Approach}_{5.6°\text{C Range}} = 10.02 - (0.24 \times \text{WB})$$

where WB is the *0.4% evaporation design wet-bulb temperature* in °C; valid for wet bulbs from 12.8°C to 32.2°C.

The tower shall be controlled to maintain a 70°F (21°C) leaving-water temperature where weather permits, floating up to leaving-water temperature at design conditions. Pump system power for each pumping system shall be the same as the *proposed building design*; if the *proposed building design* has no condenser water pumps, the *budget building design* pump power shall be 19 W/gpm (310 kW/1000 L/s) (equal to a pump operating against a 60 ft head (18 m), 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.

Modify G3.1.3.11 as follows (I-P and SI units):

G3.1.3.11 Heat Rejection (Systems 7 and 8). The heat rejection device shall be an axial fan open circuit cooling tower with ~~two-speed~~ variable-speed fan~~s~~ control. Condenser water design supply temperature shall ~~be 85°F or 10°F (29°C or 5.6°C)~~ be calculated using the cooling tower approach to ~~1%~~ the 0.4% *evaporation design wet-bulb temperature* as generated by the formula below ~~design wet-bulb temperature, whichever is lower,~~ with a design temperature rise of 10°F (5.6°C).

$$\text{Approach}_{10°\text{F Range}} = 25.72 - (0.24 \times \text{WB})$$

where WB is the *0.4% evaporation design wet-bulb temperature* in °F; valid for wet bulbs from 55°F to 90°F.

$$\text{Approach}_{5.6°\text{C Range}} = 10.02 - (0.24 \times \text{WB})$$

where WB is the *0.4% evaporation design wet-bulb temperature* in °C; valid for wet bulbs from 12.8°C to 32.2°C.

The tower shall be controlled to maintain a 70°F (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 19 W/gpm (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.

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FOREWORD

This addendum corrects the definitions of primary sidelighted area, secondary sidelighted area, and sidelighting effective area to use the term "vertical fenestration" instead of "window" to clarify that glazed doors and other fenestration products are included as well as windows.

Additionally, the definition of daylight area under rooftop monitors is corrected to include the spread of light beyond the width of the rooftop monitor glazing.

***Note:** In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.*

Addendum ds to Standard 90.1-2010

Revise the Standard as follows (I-P and SI units).

Modify definitions in Section 3.2 as follows:

daylight area:

b. ***under ~~rooftop monitors~~ clerestories:*** the *daylight area under ~~rooftop monitors~~ clerestories* is the combined *daylight area* under each *clerestory* or *rooftop monitor* without double counting overlapping areas. The *daylight area* under each *clerestory* or *rooftop monitor* is ~~the product of~~ the width of the *vertical ~~glazing~~ fenestration* above the ceiling level plus 2 ft (0.6 m) on each side, multiplied by ~~and~~ the smallest of the following horizontal distances inward from the bottom edge of the glazing, (See Figure 3.2):

1. the monitor sill height, MSH, (the vertical distance from the floor to the bottom edge of the monitor glazing), or
2. the distance to the edge of any *primary sidelighted area,* or
3. the distance to the front face of any vertical obstruction where any part of the obstruction is farther away than the difference between the height of the obstruction and the monitor sill height (MSH-OH).

primary sidelighted area: the total *primary sidelighted area* is the combined *primary sidelighted area* without double counting overlapping areas. The floor area for each *primary sidelighted area* is directly adjacent to *vertical ~~glazing~~ fenestration* below the ceiling with an area equal to the product of the *primary sidelighted area* width and the *primary sidelighted area* depth. See Figure 3.3.

The *primary sidelighted area* width is the width of the ~~window~~ *vertical fenestration* plus, on each side, the smallest of:

1. 2 ft (0.6 m), or
2. the distance to any 5 ft (1.5 m) or higher vertical obstruction.

The *primary sidelighted area* depth is the horizontal distance perpendicular to the ~~glazing~~ *vertical fenestration* which is the smaller of:

1. one ~~window~~ *vertical fenestration* head height (head height is the distance from the floor to the top of the glazing), or
2. the distance to any 5 ft (1.5 m) or higher vertical obstruction.

secondary sidelighted area: the total *secondary sidelighted area* is the combined *secondary sidelighted area* without double counting overlapping areas. The floor area for each *secondary sidelighted area* is directly adjacent to a *primary sidelighted area* with an area equal to the product of the *secondary sidelighted area* width and the *secondary sidelighted area* depth. See Figure 3.4.

The *secondary sidelighted area* width is the width of the ~~window~~ *vertical fenestration* plus, on each side, the smallest of:

1. 2 ft (0.6 m), or
2. the distance to any 5 ft (1.5 m) or higher vertical obstruction.

The *secondary sidelighted area* depth is the horizontal distance perpendicular to the *vertical fenestration* ~~glazing~~ which begins at the edge of the *primary sidelighted area* depth and ends at the smaller of:

1. one *vertical fenestration* ~~window~~ head height (head height is the distance from the floor to the top of the glazing), or
2. the distance to any 5 ft (1.5 m) or higher vertical obstruction.

If the adjacent *primary sidelighted area* ends at a 5 ft (1.5 m) or higher vertical obstruction or beyond the nearest edge of a neighboring *daylight area under skylight* or *primary sidelighted area,* there is no *secondary sidelighted area* beyond such obstruction or the edge of such areas.

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

Sidelighting Effective Aperture =

$$\frac{\sum \text{~~window~~ } \textit{vertical fenestration area} \times \text{~~window~~ } \textit{vertical fenestration VT}}{\text{~~Area of~~ primary sidelighted area}}$$

where ~~window~~ *vertical fenestration VT* is the *visible transmittance* of ~~windows~~ *vertical fenestration* as determined in accordance with Section 5.8.2.6.

9.4.1.4 Automatic Daylighting Controls for *Toplighting.* When the total *daylight area under skylights* plus the total *daylight area under ~~roof top monitors~~ clerestories* in an *enclosed space* exceeds 4,000 ft^2, the lamps for *general lighting* in the daylight area shall be separately controlled by at least one multilevel photocontrol (including continuous dimming devices) having the following characteristics:

(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— 18-MONTH SUPPLEMENT: ADDENDA TO ANSI/ASHRAE/IES STANDARD 90.1-2010

This supplement includes Addenda a, b, c, g, h, j, k, o, p, s, y, z, bz, cg, ci, and ds to ANSI/ASHRAE/IES Standard 90.1-2010. The following table lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE, IES, and ANSI approval dates for each addendum.

Addendum	Section(s) Affected	Description of Change(s)*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES Approval	ANSI Approval
90.1a	6. Heating, Ventilating, and Air Conditioning	This addendum updates the test procedure references for Design A and Design B motors in the tables in Section 10.8 and adds a normative reference in Section 12. This makes the table references more consistent with other equipment tables (and other test procedure references) in the standard.	1/21/12	1/26/12	1/18/12	1/26/12
90.1b	10. Other Equipment, 12. Normative References	This addendum requires escalators and moving walks to slow to the minimum permitted speed found in ASME A17.1/CSA B44.	6/25/11	6/29/11	6/30/11	6/30/11
90.1c	Informative Appendix G	This addendum clarifies the lab exhaust requirements for modeling in Appendix G.	6/25/11	6/29/11	6/30/11	6/30/11
90.1g	6. Heating, Ventilating, and Air Conditioning	This addendum adds two tables, Tables 6.8.1L and 6.8.1M, which define the minimum efficiency requirements for commercial refrigerators and freezers. Also references to AHRI Standard 1200 and AHAM Standard HRF-1 are added in Section 12.	6/25/11	6/29/11	6/30/11	6/30/11
90.1h	6. Heating, Ventilating, and Air Conditioning	This addendum amends the minimum energy efficiency standards for water-to-air heat pumps (water loop, ground water, and ground loop) listed in Table 6.8.1B ("Electrically Operated Unitary and Applied Heat Pumps").	6/25/11	6/29/11	6/30/11	6/30/11
90.1j	6. Heating, Ventilating, and Air Conditioning	This addendum corrects three issues in Table 6.8.1A ("Electrically Operated Unitary Air Conditioners and Condensing Units").	6/25/11	6/29/11	6/30/11	6/30/11
90.1k	8. Power	This addendum makes the transformer test procedure references consistent with other references in Section 6.	6/25/11	6/29/11	6/30/11	6/30/11
90.1o	5. Building Envelope	This addendum updates the fenestration air leakage provisions of Standard 90.1-2010 to clarify the requirements for glazed sectional garage doors. A definition for sectional garage doors is also added.	1/21/12	1/26/12	1/18/12	1/26/12
90.1p	5. Building Envelope	This addendum adds a reference to CRRC-1 for cool roof testing requirements.	1/21/12	1/26/12	1/18/12	1/26/12
90.1s	6. Heating, Ventilating, and Air Conditioning	This addendum requires additional safeguards to prevent incorrect information from being sent to the fan control system, and for non-DDC systems requires location of sensors in locations that do not require high setpoints.	1/21/12	1/26/12	1/18/12	1/26/12

Addendum	Section(s) Affected	Description of Change(s)*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	IES Approval	ANSI Approval
90.1y	10. Other Equipment	This addendum updates the standard to include the new federal energy efficiency standards for motors used in HVAC equipment that will be in effect starting in 2015. It is consistent with how Standard 90.1 has provided motor efficiency to the users of this standard.	1/21/12	1/26/12	1/18/12	1/26/12
90.1z	6. Heating, Ventilating, and Air Conditioning	This addendum relocates the water economizer requirements to the economizer section of the standard.	1/21/12	1/26/12	1/18/12	1/26/12
90.1bz	8. Power	This addendum provides electrical monitoring requirement to install basic electrical metering of important major end uses and to provide appropriate basic reporting of the resulting consumption data. The resulting information will be available to the occupant and operator to support decisions on efficient energy use and reduction through operational change, maintenance, control adjustment, and facility upgrade.	1/21/12	1/26/12	1/18/12	2/24/12
90.1cg	11. Energy Cost Budget Method, Informative Appendix G	This addendum makes Section 11 and Appendix G of Standard 90.1 consistent with Addenda d, x, ab, and ac to Standard 90.1-2007 (see Appendix F to Standard 90.1-2007 for more information on these addenda)	1/21/12	1/26/12	1/18/12	1/26/12
90.1ci	11. Energy Cost Budget Method, Informative Appendix G	This addendum makes requirements in Section 11 and Appendix G related to cooling towers consistent with current industry practice, which will serve as a truer baseline for comparisons between Systems 7 and 8.	1/21/12	1/26/12	1/18/12	2/24/12
90.1ds	5. Building Envelope	This addendum corrects the definitions of primary sidelighted area, secondary sidelighted area, and sidelighting effective area to use the term "vertical fenestration" instead of "window" to clarify that glazed doors and other fenestration products are included as well as windows.	1/21/12	1/26/12	1/18/12	2/24/12

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

NOTE

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

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

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

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

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

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

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

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

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