ANSI/ASHRAE Addendum *i* to
ANSI/ASHRAE Standard 90.2-2001

ASHRAE® STANDARD

Energy-Efficient Design of Low-Rise Residential Buildings

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FOREWORD

The purpose of this addendum is to recognize and respond to the individuals, groups, and entities that use energy codes that govern one- and two-family dwellings and low-rise multi-family structures. Many of the comments received by SSPC 90.2 from users of the former CABO Model Energy Code and present International Energy Conservation Code (IECC) and persons involved in standards activities with the National Fire Protection Association are that the contents of the current standard are too design intensive and complex for simple structures, that the standard is not written in mandatory language, and that the standard is not maintained. The intent of this addendum is to overcome these perceptions and observations by developing a standard that contains only the essential information necessary to design and enforce energy conservation requirements for single-family houses and multi-family structures. This addendum, for example, replaces over 45 figures and tables regarding thermal envelope provisions with two tables. It eliminates commentary style and permissive language by substituting mandatory language. It removes outdated information and HVAC tables that are already covered by federal regulations.

Note: All of the 90.2-2001 addenda ("a" through "g") were incorporated with appropriate changes in order to coordinate these changes with the changes in Addendum i. Addendum g removed manufactured housing from the scope of the standard. This addendum (Addendum i) deletes Addendum a completely, so in effect this addendum incorporates Addenda b through g. A detailed description of the changes made in Addendum i follows.

Sections 1 and 2. *This addendum does not involve any changes to Section 1, "Purpose," and Section 2, "Scope", except for an editorial change to remove redundant language unrelated to title, purpose, and scope: Section 2.3, which specifies the technical compliance paths for the standard and is already covered in Section 4, is deleted to remove redundancy from the standard.*

Section 3. *The definitions, abbreviations, acronyms, and symbols have been modified to reflect the changes in Sections 5, 6, 7, 8, and 9.*

Section 4. *This section has been modified to remove text representative of commentary language and/or text written in nonmandatory language. As a result, the language has been reduced to the basic requirements needed to specify the compliance methods available to the user of the standard in mandatory language.*

Section 5. *Much of the content in this section has been deleted and replaced with only essential mandatory language for a user to construct single-family and low-rise multifamily structures. All of the tables and figures associated with single-family houses and multi-family structures (over fifty in all) have been deleted and replaced with eight tables to show compliance of the envelope requirements using a prescriptive or performance method path.*

Section 5 – Steel Provisions. *An additional enhancement of the standard is in Section 5. The present Standard 90.2-2001 does not contain provisions for floor or roof/ceiling envelope assemblies containing truss type or C-shaped cold-formed steel framing. This addendum adds those requirements to the standard to allow a user to analyze floor and roof/ceiling envelope assemblies containing truss type or C-shaped cold-formed steel framing. This permits Standard 90.2 to be used instead of the IECC-2003, which contains these same provisions.*

The values in the equations and table were derived from steady-state hot box apparatus tests that were conduced by Owens Corning–Science and Technology Center (tests conducted 1995-1999) and by Oak Ridge National Laboratory–Building Technology Center (tests conducted 2000-2001). The hot box apparatus tests consisted of (a) full-scale cold-formed steel truss framed assemblies that were tested with various levels of insulation located in the cavity portion and above the framing members and that were tested with various numbers of intermediate framing members penetrating the insulation and (b) full-scale C-shape cold-formed steel framing roof/ceiling assemblies that were tested with various levels of insulation located in the cavity portion and above the framing members. In assessing the results of the tests, it was found that the calculations for roof/ceilings containing wood truss framing would not be appropriate for determining the overall performance of roof/ceiling envelopes containing cold-formed steel framing. Thus, requirements for buildings using steel frame construction were needed.

Section 5– Steel Bibliography.

Desjarlais, A.O., Kosny, J., Petrie, T.W., Effect of Steel Framing in Attic/Ceiling Assemblies on the Overall Thermal Resistance Away from the Edge of Ceiling, Oak Ridge National Laboratory, Building Technology Center, Oak Ridge, TN, May 2001.

McBride, M., Development of Simplified Prescriptive Specification for Residential Roof/Ceiling Sections with Truss type and C-Shaped Cold-Formed Steel Framing Members, Owens Corning, Science and Technology Center, Granville, OH, 11 February 2002.

McBride, M., Development of Simplified Prescriptive Specification for Residential Floor Sections with C-Shaped Cold-Formed Steel Framing Members, Owens Corning, Science and Technology Center, Granville, OH, 11 February 2002.

Sections 6 and 7. *This addendum removes the nonmandatory and unenforceable contents of these sections and makes revisions to reflect only requirements essential for a user to design, construct, or inspect a single-family and low-rise multi-family building.*

Section 8. *This section remains essentially intact but is modified to coordinate with the remainder of the standard and to revise the language to mandatory language as necessary. In addition, Sections 8.9.2 and 8.9.4 are modified as a result of the changes to Sections 7 and 9. Section 8.9.2 contains reference changes from climatic data to the inclusion of a table with "Average Annual Outdoor Dry-Bulb Temperature by Cli-*

mate Zone." Section 8.9.4 is modified by removing the reference to Table 7-1 (deleted as part of this addendum) and replacing it with a reference to federally covered equipment.

Section 9. *The format of climatic data for energy codes and standards today is in a state of change. This addendum deletes the existing climate tables and replaces them with a new map and tables of the U.S. that illustrate the 8 primary zones (12 zones overall) presently considered representative of climate zones most applicable for current-day energy standards. The development of this new map was a result of work by the U.S. Department of Energy and Pacific Northwest National Laboratory. The section is also expanded to include international data.*

Section 9–Bibliography:

Briggs, Robert S., Lucas, Robert G., Taylor, Z. Todd. Climate Classifications for Building Energy Codes and Standards: Part 1 - Development Process. ASHRAE Transactions, Vol. 109, Part 1.

Briggs, R. S., Lucas, R. G., Taylor, Z. T. Climate Classifications for Building Energy Codes and Standards: Part 2 - Zone Definitions. ASHRAE Transactions, Vol. 109, Part 1.

Section 10. *As a result of the changes recommended for Sections 5 through 8, modifications to the cited reference standards were necessary as part of a coordinated effort.*

Appendix A. *This appendix has been deleted from the current standard because it does not necessarily serve a purpose due to new regulations and manufactures' processing of insulation materials. Originally it was designed as an informative appendix to provide users of the document with the rule-of-thumb standards for insulation values for ducts since, at the time it was developed, manufacturers did not label their products. Today most duct insulation is labeled; therefore, the guesswork is taken out of applying the appropriate insulation level to ducts.*

Normative Appendix A. *This is a new normative appendix and, as a part of the standard, allows the user the option for compliance with the envelope trade-off procedure as an alternative to the prescriptive envelope requirements in Section 5 or the annual energy cost method in Section 8. It provides the same flexibility in the standard that was previously covered by the existing envelope trade-off procedure but with simpler format and easier application.*

Unless otherwise noted, additions to the current standard (as modified by Addenda b through g) are indicated by underlining and deletions indicated by ~~strikethrough~~. Instructions to the reader are shown in italics.

Addendum *i* to 90.2-2001

(Revise Section 2, Scope, as shown.)

~~**2.3 Two paths are provided for compliance**: the prescriptive requirements method and the annual energy cost method (systems analysis approach).~~

(Delete the following definitions from Section 3.3, Definitions.)

~~***air infiltration retarder:*** fabric or film material or system designed and installed primarily to reduce the movement of air through a wall or into thermal insulation.~~

~~***annual fuel utilization efficiency (AFUE):*** ratio of annual output energy to annual input energy, which includes any non-heating-season pilot input loss, and for gas- or oil-fired furnaces or boilers does not include electrical energy.~~

~~***band joist:*** peripheral edges of frame floors.~~

~~***cardinal orientation:*** four primary compass orientations—north, east, south, and west. North is 0 degrees true, east is 90 degrees, south is 180 degrees, and west is 270 degrees.~~

~~***cooled space:*** enclosed space within a building that is cooled by a cooling system whose sensible capacity exceeds 5 Btu/(h·ft2) or is capable of maintaining a space dry-bulb temperature of 90°F or less at design cooling conditions.~~

~~***cooling degree-hours:*** unit, based upon temperature difference and time, used in estimating cooling loads of residences in summer. For any hour when the dry-bulb temperature is greater than a reference temperature (base 74°F for this standard) there are as many cooling degree-hours as degrees Fahrenheit difference in temperature between the average hourly temperature and the reference temperature.~~

~~***design cooling conditions:*** summer outdoor design conditions listed for selected locations in chapter 24, table 1, column 6 (2.5% values) of the ASHRAE Handbook—Fundamentals.2~~

~~***heated space:*** enclosed space within a building that is heated by a heating system whose output capacity exceeds 10 Btu/(h·ft2) or is capable of maintaining a space dry-bulb temperature of 50°F or more at design heating conditions.~~

~~***heating seasonal performance factor (HSPF):*** 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 (in watt-hours) as determined by Region 4 conditions specified in Reference 3.~~

~~***humid climate:*** climate in which the following conditions occur:~~

~~(a) 67°F or higher wet-bulb outdoor ambient temperature for 3,500 or more hours during the warmest six consecutive months of the year,~~

~~(b) 73°F or higher wet-bulb outdoor ambient temperature for 1,750 or more hours during the warmest six consecutive months of the year.~~

~~***indirectly conditioned space:*** enclosed space within a building that is not heated or cooled space, whose area-weighted heat transfer coefficient to heated or cooled space exceeds that to the outdoors or to unconditioned space, or through which air from heated or cooled space is transferred at a rate exceeding three air changes per hour (see heated space and cooled space).~~

~~***instantaneous water heater:*** one that contains no more than one gallon of water per 4,000 Btu/h of input.~~

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

~~***packaged terminal air conditioner (PTAC):*** factory-selected components, assemblies, or sections for cooling, heating, or both that are intended for application in an individual room or zone.4~~

~~***packaged terminal heat pump:*** PTAC capable of using the refrigeration system in a reverse-cycle or heat pump mode to provide heat.5~~

~~***prescriptive requirements:*** specified values or rules representing the requirements that must be met in order to achieve compliance with the standard.~~

~~***recommend:*** see *should*.~~

~~***seasonal energy efficiency ratio (SEER):*** 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 watt-hours), as determined by conditions specified in Reference 3.~~

~~***should:*** term used to indicate provisions that are not mandatory but which are desirable as good practice.~~

~~***system analysis:*** method to evaluate tradeoffs among envelope components and heating, ventilating, and air-conditioning equipment such that the building's annual energy cost does not exceed a value specified by a building that meets the prescriptive requirements of the standard.~~

~~***thermal mass:*** material with significant heat capacity and surface area that affects building loads by absorbing or releasing heat or both due to the fluctuation of any of the following: (a) interior temperature, (b) interior radiant conditions, (c) exterior temperature, and (d) exterior radiant conditions.~~

~~***thermal mass wall insulation position:***~~

- ~~***exterior insulation position:*** wall having mass thermally coupled directly to the room air and having the entire effective mass layer on the interior of an insulation layer.~~
- ~~***integral insulation position:*** wall having mass thermally coupled to room air and having either insulation and mass materials well mixed, as in wood (logs), or substantially equal amounts of mass material on the interior and exterior of insulation, as in concrete blocks with insulated cores.~~
- ~~***interior insulation position:*** wall having mass located on the exterior of the insulating material(s) or otherwise not meeting either of the above definitions for exterior or integral positions.~~

~~***unheated space:*** space within a building that is not heated space (see heated space).~~

~~***unitary cooling and heating equipment:*** one or more factory-made units that normally include an evaporator or cooling coil or a compressor and condenser combination, and may include a heating function as well.~~

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

~~***wall heat capacity:*** effective wall heat capacity (Btu/ft2·×F) for purposes of calculating thermal mass performance for exterior walls. It is the sum of the products of the mass of each individual material in the wall per unit area of wall surface times its individual specific heat.~~

(Change Section 3.4, Abbreviations, Acronyms, and Symbols, to read as shown)

SYMBOL MEANING

A wall, roof, etc.=area of a specific building component
ACCA = Air Conditioning Contractors of America
ACH = air changes per hour
AEC = annual energy cost
~~AFUE = annual fuel utilization efficiency~~
~~AHAM= Association of Home Appliance Manufacturers~~
ANSI = American National Standards Institute
AR1 = Air-Conditioning and Refrigeration Institute
~~ASME = American Society of Mechanical Engineers~~
ASTM = American Society for Testing and Materials
~~BPCDH74=break point cooling degree-hours base 74°F~~
~~BPHDD65=break point heating degree-days base 65°F~~
C = thermal conductance
~~CDH74= cooling-degree hours base 74°F~~
CFR = Code of Federal Regulations
~~CLF = cooling load factor~~
COP = coefficient of performance
DOE = U.S. Department of Energy
~~EC = combustion efficiency~~
EER = energy efficiency ratio
~~EFFSS= efficiency, steady-state~~
ELA = effective leakage area
~~EXP STA=experimental station~~
~~FAA AP= Federal Aviation Administration (airport)~~
~~HDD65= heating degree-days base 65°F~~
~~HI = Hydronics Institute~~
~~HLF = heating load factor~~
~~HSPF = heating seasonal performance factor~~
HVAC = heating, ventilating, and air conditioning
~~IBR = Institute of Boiler and Radiator Manufacturers, predecessor of Hydronics Institute~~
~~ICDH74= cooling intercept of a specific requirement line from Table 5-3 or Table 5-6~~
~~IHDD65= heating intercept of a specific requirement line from Table 5-3 or Table 5-6~~
IPLV = integrated part-load value
~~LC = load change~~
~~NAHB = National Association of Home Builders~~
~~NAIMA= North American Insulation Manufacturers Association~~
NFPA = National Fire Protection Association
~~NEMA= National Electrical Manufacturers Association~~
NR = no requirement
R = thermal resistance
~~RCR = relative climate ratio~~
~~SEER = seasonal energy efficiency ratio~~
~~SC = shading coefficient~~
~~SMACNA=Sheet Metal and Air Conditioning Contractors National Association~~
~~TAVG = average annual dry-bulb temperature~~
~~TLC = total load change~~
U = thermal transmittance
Uo = overall thermal transmittance
~~W = watts~~
~~WSFO = weather service forecast office~~
~~WSO AP= weather service office (airport)~~

(Delete Section 4 completely, including Figure 4-1, and then replace it with the following new Section 4. As revised by this addendum, Section 4 now consists only of Section 4.1.)

4. COMPLIANCE

4.1 General

This standard provides different methods by which compliance can be determined for low-rise residential buildings — a prescriptive or performance path method (Sections 5, 6, and 7) or an annual energy cost method (Section 8).

(Delete all of Section 5, including figures and tables, except for the following: Sections 5.2.2.1.1 and 5.2.2.1.2, the exception to Section 5.2.2.1.4, Table 5-1, Section 5.3.6, and Figure 17. These sections and this figure and table remain in the revised section although they are changed in numbering or wording by this addendum as shown here. These sections and this figure and table are shown here with any revisions that occurred as a result of Addenda b through g already incorporated (but not indicated here). The rest of Section 5 (besides these specific sections and this figure and table) are new and are therefore indicated here by underlining.

5.1 Prescriptive Path.

5.1.1 General. This section provides thermal performance requirements for the residential building envelope that separates conditioned spaces from either exterior conditions or unconditioned spaces.

5.1.1.1 Single-Family and Multi-family Compliance. For the appropriate climate, the single-family house and multi-family structure envelope shall comply with

1. Prescriptive Path Method in accordance with Sections 5.2 through 5.10, or
2. Envelope Performance Path Trade-off Method in accordance with Section 5.12, or
3. in cases where a systems analysis method of building design is desired, the requirements of Section 8 of this standard.

5.1.1.2 Climate. The climate for the requirements in Chapters 5 and 8 shall be determined based on Chapter 9.

5.2 Prescriptive Path Method. For one- and two-family dwellings and multi-family structures, the thermal resistance of the cavity insulation and the thermal resistance of the continuous insulation uninterrupted by framing, applied to the opaque building envelope components, shall be greater than or equal to the minimum R-values, and the thermal transmittance of all assemblies shall be less than or equal to the maximum U-factors and SHGC of all fenestration assemblies shall be less than or equal to the maximum SHGC criteria, shown in Table 5.2.

~~**5.2.2.1.1**~~ **5.2.1 Thermal Transmittance.** The design thermal transmittance (U) ~~of all above grade envelope components is~~ shall be the variable used to specify the requirements and demonstrate compliance for all doors and fenestration. All design U-factors are air-to-air, including interior and exterior air films. Calculation of design U-factors shall be done in accordance with the procedures in ~~chapters 20, 22, and 27 of~~ the *ASHRAE Handbook—Fundamentals*[2] and account for thermal bridges and anomalies. ~~For example,~~

(a) ~~wood framing members and webs in masonry construction (see chapter 20),~~

(b) ~~metal framing members (see chapter 22, "Zone Method of Calculation," or use Table 5-1), and~~

(c) ~~fenestration (see chapter 27).~~

Table 5-2 Prescriptive Envelope Criteria

Climate Zone	Ceilings				Walls															Floors					Door	Fenestration			
	Attic Space		Without Attic Space (Cathedral or Flat Roof)		Above-Grade Frame				Frame Adjacent to Unconditioned Space				Above-Grade Mass Exterior Insulation	Above-Grade Mass Interior Insulation	Mass Adjacent to Unconditioned Space	Below Grade Exterior Insulation		Below Grade Interior Insulation	Unvented Crawl Space	Frame Over Exterior		Frame Over Unconditioned Space and Vented Crawl Space		Slab-on-Grade	Non-Wood	Vertical Glazed Assemblies		Skylights	
	Wood	Steel	Wood	Steel	Wood		Steel		Wood		Steel		Continuous Insulation	Interior Insulation	Continuous Insulation	Continuous Insulation	Depth Below Grade[a]	Interior Insulation	Interior Insulation	Wood	Steel	Wood	Steel	Perimeter Insulation					
	Cavity	Cavity	Cavity	Cavity	Cavity	Cont. Ins.	Cavity	Cont. Ins.	Cavity	Cont. Ins.	Cavity	Cont. Ins.								Cavity	Cavity	Cavity	Cavity						
No.	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R	R	R	R	R[b]	U	U	SHGC	U	SHGC[b]
1	30	30	13	19	13	0	15	0	0	0	0	0	0	0	0	0	H	0	0	15	22	13	15	NR	0.39	0.67	0.37	1.60	0.4
2	30	30	22	19	15	0	21	0	0	0	0	0	0	0	0	0	H	0	0	19	22	13	15	NR	0.39	0.67	0.37	1.05	0.4
3A,B	30	30	22	22	15	0	15	7.5	0	0	0	0	0	4	0	2.7	H	0	13	19	30	19	30	NR	0.39	0.47	0.40	0.90	0.4
3C	30	30	22	22	15	0	15	7.5	0	0	0	0	0	4	0	2.7	H	0	13	19	30	19	30	NR	0.39	0.47	0.40	0.90	NR
4	38	38	22	22	15	5	15	7.5	0	0	15	0	3	4	0	4	F	0	21	21	38	19	30	NR	0.39	0.35	0.46	0.60	NR
5	43	43	26	30	21	0	21	10	0	0	15	0	3	4	0	5.4	F	0	30	25	38	25	38	NR	0.39	0.35	0.46	0.60	NR
6	49	49	38	38	15	10	21	10	15	0	15	0	6	15	0	8.1	F	0	30	25	38	25	38	NR	0.39	0.35	NR	0.60	NR
7	49	49	38	38	21	10	21	10	15	0	0	10	6	15	0	10.8	F	0	30	38	38	30	38	NR	0.39	0.35	NR	0.60	NR
8	52	52	38	38	21	10	21	10	15	0	15	10	6	21	15	10.8	F	21	30	38	38	30	38	NR	0.39	0.35	NR	0.60	NR

[a] H = Top half of wall insulated, F = Full wall height insulated   [b] NR = No requirement

When more than one assembly is used in an envelope component, the design U-factor for that envelope component shall be calculated using Equation ~~5-1~~ 5.2.1.

$$U = U_1 \times A_1 + U_2 \times A_2 + \ldots + U_n \times A_n / A \quad \text{(Eq. ~~5-1~~ 5.2.1)}$$

where

U = thermal transmittance of the envelope component, Btu/h·ft^2·°F;

A = area of the envelope component, ft^2;

$U_{1\text{-}n}$ = thermal transmittance of the individual component assemblies, Btu/h·ft^2·°F;

$A_{1\text{-}n}$ = area of the individual component assemblies, ft^2.

~~5.2.2.1.2~~ **5.2.2 Thermal Conductance.** The thermal conductance (C) of all below-grade envelope components ~~is~~ shall be the variable used to set the requirements and demonstrate compliance. All C-factors are surface-to-surface, excluding air films and the adjacent ground. Calculation of C-factors shall be done in accordance with the procedures in ~~chapters 20 and 22 of~~ the *ASHRAE Handbook—Fundamentals*[2] and account for thermal bridges and anomalies. ~~For example,~~

~~(a) wood framing members and webs in masonry construction (see chapter 20),~~

~~(b) metal framing members (see chapter 22, "Zone Method of Calculation," or use Table 5-1).~~

When more than one assembly is used in an envelope component, the C-factor for that envelope component shall be calculated using Equation ~~5-2~~ 5.2.2.

$$C = C_1 \times A_1 + C_2 \times A_2 + \ldots + C_n \times A_n / A \quad \text{(Eq. ~~5-2~~ 5.2.2)}$$

where

C = thermal conductance of the envelope component, Btu/h·ft^2·°F;

A = area of the envelope component, ft^2;

$C_{1\text{-}n}$ = thermal conductance of the individual component assemblies, Btu/h·ft^2·°F; and

$A_{1\text{-}n}$ = area of the individual component assemblies, ft^2.

5.3 Mass Walls. When an added R-value of 3.4 or less is required, concrete block walls, in accordance with ASTM C90, with cores filled with material having a maximum thermal conductivity of 0.44 Btu-in./h-ft^2-°F, shall be permitted to be used.

5.4 Envelope Assemblies Containing Steel Framing

(Section 5.2.2.1.4 was revised by Addendum b. This addendum revises this section as shown here.)

~~5.2.2.1.4~~ **5.4.1 Steel Stud Walls.** The thermal transmittance of frame walls that contain steel stud assemblies shall be calculated using a series path procedure that corrects for parallel paths, as presented in Equations ~~5-3 and 5-4~~ 5.4.1(1) and 5.4.1(2).

$$U_i = 1 / R_t \quad \text{(Eq. ~~5-3~~ 5.4.1(1))}$$

$$R_t = (R_i + R_e) \quad \text{(Eq. ~~5-4~~ 5.4.1(2))}$$

where

Ui = total thermal transmittance of the envelope assembly;

R_t = total resistance of the envelope assembly;

R_i = thermal resistance of the series elements (for I = 1 to n), excluding the parallel path element(s);

R_e = equivalent resistance of the element containing the parallel path, as shown in Table 5.4.1(3).

The value of R_e is

$$R_e = (R - \text{value of insulation}) \times Fc \quad \text{(Eq. ~~(5-5)~~ 5.4.1(3))}$$

where

Fc = correction factor from Table ~~5-1~~ 5.4.1

Table ~~5-1~~ 5.4.1 Wall Sections with Steel Studs Parallel Path Equivalent Resistance, R_e

Size of Members (2)	Spacing of Framing	Cavity Insulation R-Value	Correction Factor	Effective Framing/Cavity R-Values, R_e
2 x 4	16 inches o/c	R-11	0.50	R-5.5
		R-13	0.46	R-6.0
		R-15	0.43	R-6.4
	24 inches o/c	R-11	0.60	R-6.6
		R-13	0.55	R-7.2
		R-15	0.52	R-7.8
2 x 6	16 inches o/c	R-19	0.37	R-7.1
		R-21	0.35	R-7.4
	24 inches o/c	R-19	0.45	R-8.6
		R-21	0.43	R-9.0
2 x 8	16 inches o/c	R-25	0.31	R-7.8
	24 inches o/c	R-25	0.38	R-9.6

1. SI Conversions: 1 inch = 25.4 mm
2. Applicable to 0.064 inch (16 gauge) (1.6 mm) thick framing or thinner.

5.4.2 Steel Framing in Ceiling/Roof. When the roof/ceiling assembly contains cold-formed steel truss framing, the U_R value to be used shall be determined by Equations 5.4.2(1), 5.4.2(2), or 5.4.2(3). These equations apply to cold-formed steel truss roof framing spaced at 24 inches (609 mm) on-center and where the penetrations through the cavity insulation do not exceed three (3) penetrations for each 4 foot (1,220 mm) length of the truss.

For constructions without foam between the drywall and bottom chord of the steel truss, use

$$U_R = \frac{1}{0.862 \times R_{ins} + 0.330} \qquad \text{(Eq. 5.4.2(1))}$$

where

R_{ins} = R-value of the cavity insulation, h·ft²·°F/Btu.

For constructions with R-3 foam between the drywall and bottom chord of the steel truss, use

$$U_R = \frac{1}{0.862 \times R_{ins} + 4.994} \qquad \text{(Eq. 5.4.2(2))}$$

For constructions with R-5 foam between the drywall and bottom chord of the steel truss, use

$$U_R = \frac{1}{0.862 x R_{ins} + 7.082} \qquad \text{(Eq. 5.4.2(3))}$$

Exception: When overall system tested U_R values for roof/ceiling assemblies from approved laboratories are available (when such data are acceptable to the building official)

When the roof/ceiling assembly contains conventional C-shaped cold-formed joist/rafter steel framing, the U_R value to be used shall be determined by using Equation 5.4.2(4):

$$U_R = \frac{1}{R_s + (R_{ins} \times F_{cor})} \qquad \text{(Eq. 5.4.2(4))}$$

where

R_s = total thermal resistance of the elements of roof/ceiling construction, in a series along the path of heat transfer, excluding the cavity insulation and the steel framing, h·ft²·°F/Btu;

R_{ins} = R-value of the cavity insulation, h·ft²·°F/Btu;

F_{cor} = correction factor listed in Table 5.4.2, dimensionless.

Exception: When overall system tested U_R values for roof/ceiling assemblies from approved laboratories are available (when such data are acceptable to the building official).

Table 5.4.2 Correction Factors (F_{cor}) for Roof/Ceiling Assemblies

Member Size [a]	Spacing of Framing Members (Inches)	Cavity Insulation R-Value			
		R-19	R-30	R-38	R-49
2x6	16 o.c.	0.70	0.81	0.85	0.88
2x8		0.35	0.65	0.72	0.78
2x10		0.35	0.27	0.62	0.70
2x12		0.35	0.27	0.51	0.62
2x6	24 o.c.	0.78	0.86	0.88	0.91
2x8		0.44	0.72	0.78	0.83
2x10		0.44	0.35	0.69	0.76
2x12		0.44	0.35	0.61	0.69

For SI: 1 in. = 25.4 mm.
a: Applies to steel framing members up to a maximum thickness of 0.064 in.(16 gauge) (1.6 mm).

5.4.3 Steel Framing in Floors Over Unconditioned Spaces. When the floor assembly contains cold-formed steel framing, the value of U_{fn} used shall be recalculated using a series of path procedures to correct for parallel path thermal bridging. The U_{fn} shall be determined as follows using Equation 5.4.3:

$$U_{fn} = \frac{1}{R_{fn} + (R_{ins} \times F_{cor})} \quad \text{(Eq. 5.4.3)}$$

where

R_{fn} = total thermal resistance of the elements of floor construction, in series along the path of heat transfer, excluding the cavity insulation and the steel joist, h·ft²·°F/Btu;

R_{ins} = R-value of the cavity insulation, h·ft²·°F/Btu;

F_{cor} = correction factor listed in Table 5.4.3, dimensionless.

Exception: When overall system tested U_{fn} values for steel-framed floors from approved laboratories are available (when such data are acceptable to the code official).

Table 5.4.3 Correction Factors (F_{cor}) for Steel Floor Assemblies

member Size [a]	spacing of Framing Members (Inches)	cavity Insulation R-Value		
		R-19	R-30	R-38
2x6	16 o.c.	0.70	NA	NA
2x8		0.35	NA	NA
2x10		0.35	0.27	NA
2x12		0.35	0.27	0.24
2x6	24 o.c.	0.78	NA	NA
2x8		0.44	NA	NA
2x10		0.44	0.35	NA
2x12		0.44	0.35	0.32

For SI: 1 in. = 25.4 mm
a: Applies to steel framing members up to a maximum thickness of 0.064 in. (16 gauge) (1.6 mm).

(The exception to Section 5.3.1.1 and Table 5.3.1 was added by Addendum f. This addendum modifies the exception as shown here, making it a section instead of an exception, and replaces the table with a new one.)

~~Exception to 5.3.1.1~~ 5.5 High Albedo Roofs. For roofs where the exterior surface has either of the following:

(a) a minimum total solar reflectance of 0.65 when tested in accordance with ASTM E903 [69] or E1918 [70] and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408 [71] or C1371 [72] or

(b) a minimum solar reflectance index (SRI) of 75 calculated in accordance with ASTM E1980 [73] for medium wind speed conditions,

the U-factor of the proposed ceiling shall be permitted to be adjusted using Equation ~~5-3.1~~ 5.5 for demonstrating compliance.

$$U_{ceiling\ adj} = U_{ceiling\ proposed} \times \text{Multiplier}$$

(Eq. ~~5-3.1~~ 5.5)

where

$U_{ceiling\ adj}$=Adjusted ceiling U-factor for use in demonstrating compliance

$U_{ceiling\ proposed}$=U-factor of the proposed ceiling, as designed

Multiplier=Ceiling U-factor multiplier from Table ~~5.3.1~~5.5

~~Table 5.3.1 Ceiling U-Factor Multiplier~~

~~HDD 65~~	~~(HDD 18)~~	~~Ceilings with Attics~~	~~Ceilings without attics~~
~~0 - 360~~	~~(0 - 200)~~	~~1.50~~	~~1.30~~
~~361 - 900~~	~~(201 - 500)~~	~~1.30~~	~~1.30~~
~~901 - 1800~~	~~(501 - 1000)~~	~~1.20~~	~~1.30~~
~~1801 - 2700~~	~~(1001 - 1500)~~	~~1.15~~	~~1.30~~
~~2701 - 3600~~	~~(1501 - 2000)~~	~~1.10~~	~~1.20~~
~~> 3600~~	~~(> 2000)~~	~~1.00~~	~~1.00~~

Table 5.5 Ceiling U-Factor Multiplier

Zone	Ceilings with Attics	Ceilings without Attics
1	1.50	1.30
2	1.25	1.30
3	1.20	1.20
4	1.15	1.20
5	1.10	1.10
6, 7, 8	1.00	1.00

(Section 5.6 was modified by Addendum d. This addendum revises it as shown here.)

5.6 Floors

~~**5.3.6**~~ **5.6.1 Slab-on-Grade Floors**. All R-values (°F·ft²·h/Btu) refer only to the insulation, excluding the wall constructions and all other elements such as interior finish materials, the floor slab, exterior finish materials, air films, and the adjacent ground. Perimeter insulation shall begin at the top surface of the slab. The insulation length requirement may be satisfied by a combination of vertical and horizontal sections provided they are continuous. Perimeter insulation is not required of areas of very heavy termite infestation probability as shown in Figure ~~5-17~~. 5.6.

5.7 Doors. The requirements shall apply to all door assemblies that permit entry or exit from heated or mechanically cooled spaces or both.

5.7.1 Opaque Portion of Non-Wood Doors. The opaque portion of a non-wood door assembly shall not exceed the maximum U-factor shown in Table 5.2.

5.7.2 Opaque Portion of Wood Doors. The opaque portion of a wood door assembly shall not exceed a maximum U-factor of 0.40 Btu/h·ft²·°F (5.678 W/m²·K).

5.7.3 Glazed Portion of Any Door. The glazed portion of any door assembly shall not exceed a maximum U-factor as shown in the column entitled "fenestration" in Table 5.2.

5.8 Fenestration. The requirements shall apply to all operable or fixed glazed assemblies, including windows, skylights, and glass doors, and shall not exceed the maximum U-factors and SHGC values as shown in Table 5.2. The U-factor (*U*) of fenestration shall be determined in accordance with NFRC *100 Procedures for Determining Fenestration Product U-factors*, and the solar heat gain coefficient (SHGC) of fenestration shall be determined in accordance with *NFRC 200, Procedures for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incident*, by an accredited, independent laboratory, and the fenestration shall be labeled and certified by the manufacturer.

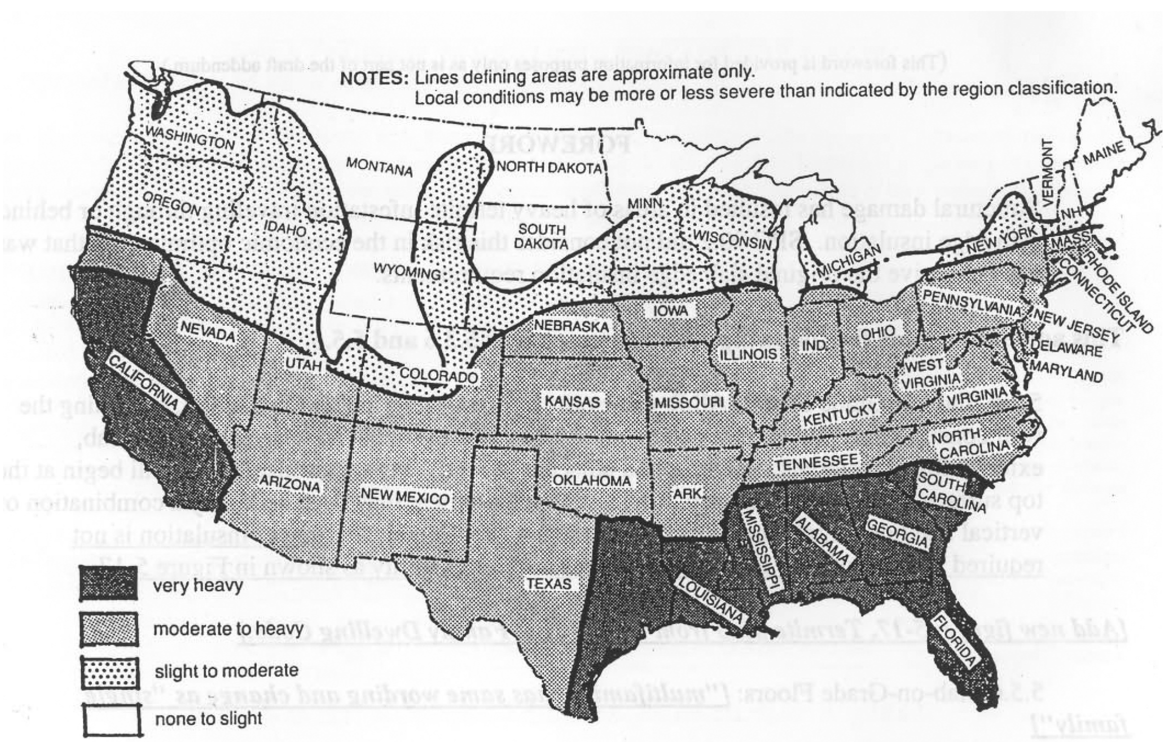
Exception 1 to Section 5.8: Skylight area, including frames, less than or equal to 1 percent of the total floor space utilized for living, sleeping, eating, cooking, bathing, washing, and sanitation purposes is exempt from this requirement provided the skylight U-factor is less than 0.8.

Exception 2 to Section 5.8: Fenestration that can be thermally separated from the conditioned space (such as sunrooms, solariums, and greenhouses) shall be excluded from the prescriptive U- value, SHGC, and area requirements provided it is separated by envelope components that meet this standard.

5.9 Air Leakage. The building envelope shall meet the provisions of Sections 5.9.1 through 5.9.4 or shall comply with ASHRAE 119.[1]

5.9.1 Windows and Doors. Window and door assemblies shall comply with Table 5.9.1.

5.9.2 Access openings. Access openings in the building envelope, other than sliding and swinging doors and win-



~~Figure 5-17~~ Figure 5.6 Termite Infestation Probability Map.

Table 5.9.1 Maximum Allowable Air Infiltration Rates [2], Windows and Doors

Description	Air Infiltration Limit	Reference Standard
Aluminum windows and sliding doors	0.37	ANSI/AAMA/NWWDA-101/I.S.2 [3]
PVC windows and sliding doors	0.37	ANSI/AAMA/NWWDA-101/I.S.2 [3]
Wood windows and sliding doors	0.34	ANSI/AAMA/NWWDA-101/I.S.2 [3]
Wood doors	0.34	ANSI/AAMA/NWWDA-101/I.S.2 [3]
Windows not covered above	0.34 cfm/ft of sash crack	
Fixed windows	0.34 cfm/ft^2 of window area	
Swinging Doors	0.50 cfm/ft^2 of door area	

1. SI Conversions: 1 cfm/ft = 66.89 m^3/h·m; 1 cfm/ft^2 = 18.29 m^3/h·m^2
2. Air infiltration as determined in accordance with ASTM E283 at a pressure differential of 1.57 lb/ft^2 (75 Pa).
3. For windows the limit is cfm/ft of sash crack and for sliding doors the limit is cfm/ft^2 of door area.

dows, shall be sealed using weatherstripping and be provided with a latch or some other positive means of closure. The level of insulation provided with the access openings shall be equivalent to that of the building envelope assembly in which it is installed.

5.9.3 Foundations. Foundation walls, crawlspace walls, and other building envelope walls below grade shall have all cracks and the intersection of above-grade construction assemblies with below-grade construction materials sealed.

5.9.4 Joints and penetrations. Joints and penetrations in the building envelope that are sources of air leakage shall be sealed with caulking, gasketing, weather stripping, or other materials compatible with the construction materials, location, and anticipated conditions.

5.10 Water Vapor Retarders and Moisture Barriers.

5.10.1 A durable continuous moisture barrier at least 6 mil thick shall be placed over exposed soils in crawlspaces and extend 1 ft (305 mm) up the crawlspace walls. Joints in the moisture barrier shall overlap a minimum of 1 ft (305 mm).

5.10.2 A moisture barrier shall be installed beneath a heated slab.

5.11 Envelope Performance Path Trade-off Method. The building envelope complies with the standard if the proposed building satisfies the provisions of Section 5.2 and the envelope performance factor of the proposed building is less than or equal to the annual heating and cooling energy costs for the envelope of the prescriptive path building. The annual heating and cooling energy cost considers only the building envelope components. Heating, ventilating, and air-conditioning systems and equipment and service water heating shall be the same for both the proposed building and the prescriptive. The envelope performance factor shall be calculated using the procedures of Normative Appendix A.

Table 5-11 Performance Path Envelope Criteria

Climate Zone	Ceilings				Walls											Floors					Doors	Fenestration			
	Attic Space		Without Attic Space (Cathedral or Flat Roof)		Above-Grade Frame		Frame Adjacent to Unconditioned Space		Above-Grade Mass Exterior Insulation	Above-Grade Mass Interior Insulation	Mass Adjacent to Unconditioned Space	Below Grade Exterior Insulation		Below Grade Interior Insulation	Unvented Crawl Space	Frame Over Exterior		Frame Over Unconditioned Space and Vented Crawl Space		Slab-on-Grade (Perimeter Insulation	Non-Wood	Vertical Glazed Assemblies		Skylights	
	Wood	Steel	Wood	Steel	Wood	Steel	Wood	Steel					Depth Below Grade[a]			Wood	Steel	Wood	Steel						
No.	U	U	U	U	U	U	U	U	U	U	U	U		U	U	U	U	U	U	R	U	U	SHGC	U	SHGC[b]
1	0.036	0.038	0.063	0.084	0.089	0.118	0.274	0.442	0.261	0.261	0.244	0.633	H	0.630	0.412	0.060	0.089	0.066	0.090	0	0.39	0.67	0.37	1.60	0.4
2	0.036	0.038	0.041	0.084	0.083	0.090	0.274	0.442	0.261	0.261	0.244	0.633	H	0.630	0.412	0.051	0.089	0.066	0.090	0	0.39	0.67	0.37	1.05	0.4
3A,B	0.036	0.038	0.041	0.080	0.083	0.063	0.274	0.442	0.261	0.181	0.244	0.234	H	0.630	0.065	0.051	0.078	0.051	0.071	0	0.39	0.47	0.40	0.90	0.4
3C	0.036	0.038	0.041	0.080	0.083	0.063	0.274	0.442	0.261	0.181	0.244	0.234	H	0.630	0.065	0.051	0.078	0.051	0.071	0	0.39	0.47	0.40	0.90	NR
4	0.026	0.030	0.041	0.080	0.058	0.063	0.094	0.155	0.153	0.181	0.244	0.179	F	0.630	0.043	0.046	0.070	0.051	0.071	0	0.39	0.35	0.46	0.60	NR
5	0.023	0.027	0.041	0.071	0.058	0.047	0.081	0.155	0.153	0.181	0.244	0.143	F	0.630	0.031	0.039	0.070	0.039	0.064	0	0.39	0.35	0.46	0.60	NR
6	0.021	0.023	0.026	0.064	0.044	0.047	0.081	0.155	0.115	0.073	0.244	0.103	F	0.630	0.031	0.039	0.070	0.039	0.064	0	0.39	0.35	NR	0.60	NR
7	0.021	0.230	0.026	0.064	0.035	0.047	0.081	0.100	0.115	0.073	0.244	0.081	F	0.630	0.031	0.026	0.070	0.033	0.064	0	0.39	0.35	NR	0.60	NR
8	0.020	0.022	0.026	0.064	0.035	0.047	0.055	0.061	0.115	0.053	0.071	0.081	F	0.056	0.031	0.026	0.070	0.033	0.064	0	0.39	0.35	NR	0.60	NR

[a] H = Top half of wall insulated, F = Full height of wall insulated

[b] NR = No requirement

(Delete Section 6 entirely and then replace it with the following new Section 6.)

6. HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC) SYSTEMS AND EQUIPMENT

6.1 General. This section provides performance requirements for heating, venting, air-conditioning, and service water heating equipment for one- and two-family houses and multi-family structures.

6.2 Heating, Ventilating, and Air-Conditioning Systems and Equipment. This section shall regulate only equipment using single-phase electric power, air conditioners and heat pumps with rated cooling capacities less than 65,000 Btu/h (19 kW), warm air furnaces with rated heating capacities less than 225,000 Btu/h (66 kW), boilers less than 300,000 Btu/h (88 kW) input, and heating-only heat pumps with rated heating capacities less than 65,000 Btu/h (19 kW).

6.3 Balancing. The air distribution system design, including outlet grilles, shall provide a means for balancing the air distribution system unless the design procedure provides a system intended to operate within plus or minus 10 percent of design air quantities.

6.4 Insulation for Ducts. All portions of the air distribution system installed in or on buildings for heating and cooling shall be R-8. When the mean outdoor dew-point temperature in any month exceeds 60°F (15°C), vapor retarders shall be installed on conditioned-air supply ducts. Vapor retarders shall have a water vapor permeance not exceeding 0.5 perm (0.003 µg/Pa•s•m^2) when tested in accordance with Procedure A in *ASTM E96, Standard Test Method for Water Vapor Transmission of Materials*.

Insulation is not required when the ducts are within the conditioned space.

6.5 Insulation for Piping. HVAC system piping installed to serve buildings and within buildings shall be thermally insulated in accordance with Table 6.5.

Table 6.5 Minimum Pipe Insulation Thickness (in inches)[a, e]

Fluid Design Operating Temp. Range (°F)	Insulation Conductivity		Nominal Pipe Diameter (in.)				
	Conductivity Btu·in./(h·ft^2·°F)	Mean Rating Temp.°F	≤1	1 to 1-1/4	1-1/2 to 3-1/2	4 to 6	Equal to or greater than 8
Heating Systems (Steam, Steam Condensate, and Hot Water)[b,c]							
201-250	0.27-0.30	150	1.5	1.5	2.0	2.0	2.0
141-200	0.25-0.29	125	1.0	1.0	1.0	1.5	1.5
105-140	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
Cooling Systems (Chilled Water, Brine, and Refrigerant)[d]							
40-55	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
Below 40	0.22-0.28	100	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-ft^2-°F), and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

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

[c] Piping insulation is not required between the control valve and coil on run-outs when the control valve is located within 4 ft of the coil and the pipe size is 1 in. or less.

[d] These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders and/or additional insulation.

[e] For piping exposed to outdoor air, increase insulation thickness by 0.5 inch. The outdoor air is defined as any portion of insulation that is exposed to outdoor air. For example, attic spaces and crawlspaces are considered exposed to outdoor air.

6.6 Ventilation and Combustion Air

6.6.1 Ventilation Air. The building shall be designed to have the capability to provide the ventilation air specified in Table 6.6.1. Mechanical ventilation shall be calculated in accordance with Equation 6.6.1.

$$\text{Mechanical Ventilation} = ((0.35 - \text{Summer}) \times \text{Volume}) / 60 \qquad \text{(Equation 6.6.1)}$$

where

mechanical ventilation = required mechanical ventilation rate to supplement summer infiltration, cfm,

summer = summer design infiltration rate, ACH.

volume = volume of conditioned space, ft^3,

6.6.2 Combustion Air. Combustion air for fossil fuel heating equipment shall be in accordance with the locally adopted code or with one of the following: natural gas and propane heating equipment, ANSI Z223.1/NFPA 54, *National Fuel Gas Code;* oil heating equipment, NFPA 31, *Standard for the Installation of Oil Equipment;* solid fuel burning equipment, NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances.*

Table 6.6.1 Ventilation Air [1]

Category	Minimum Requirement	Conditions
Mechanical ventilation (2)	50 cfm outdoor air	When summer design infiltration rate calculated in accordance with reference standard "A" or "B" is less than 0.35 ACH (3)
Kitchen exhaust	100 cfm intermittent	All conditions
Bath exhaust	50 cfm intermittent	All conditions

Notes:
1. SI Conversion: 1 cfm = 0.00047 m^3/s
2. Calculate in accordance with Equation 6.6.1.
3. Reference standards:
   A. Residential Load Calculation, *Manual J*[27]
   B. *Cooling and Heating Load Calculation Manual*, ASHRAE[28]

6.7 Electric Heating Systems.

Electric heating systems shall be installed in accordance with the following requirements.

6.7.1 Wall, Floor, or Ceiling Electric Resistance Heating. When wall, floor, or ceiling electric-resistance heating units are used, the structure shall be zoned and heaters installed in each zone in accordance with the heat loss of that zone. Where living and sleeping zones are separate, the minimum number of zones shall be two. If two or more heaters are installed in any one room, they shall be controlled by one thermostat.

6.7.2 Electric Central Warm Air Heating. When electric central warm air heating is to be installed, an electric heat pump or an off-peak electric heating system with thermal storage shall be used.

Exception 1: Electric resistance furnaces where the ducts are located inside the conditioned space and a minimum of two zones are provided where the living and sleeping zones are separate.

Exception 2: Packaged air-conditioning units with supplemental electric heat.

6.8 Bath Ceiling Units.

Bath ceiling units providing any combination of heat, light, or ventilation shall be provided with controls permitting separate operation of the heating function.

6.9 HVAC Equipment, Rated Combinations.

HVAC system equipment and system components shall be furnished with the input(s), output(s), and the value of the appropriate performance descriptor of HVAC products in accordance with federal law or as specified in Table 6.9, as applicable. These shall be based on newly produced equipment or components. Manufacturers' recommended maintenance instructions shall be furnished with and attached to the equipment. The manufacturer of electric resistance heating equipment shall furnish full-load energy input over the range of voltages at which the equipment is intended to operate.

Table 6.9 Minimum Requirements for Non-Federally Covered HVAC Equipment

Groundwater * source heat pump	Cooling mode	11.0 EER @ 70°F Ent. Water 11.5 EER @ 50°F Ent. Water	ARI-325-85
	Heating mode	3.4 COP @ 70°F Ent. Water 3.0 COP @ 50°F Ent. Water	ARI-325-85
Unitary A/C	Water-cooled split system	9.3 EER @ 85°F Ent. Water 8.3 IPLV @ 75°F Ent. Water	ARI 210/240-89
	Evaporatively cooled split system	9.3 EER @ 95°F Out. Amb. 8.5 IPLV @ 80°F Out. Amb.	ARI 210/240-89

* Performance for electrically powered equipment with capacity less than 65,000 Btu/h when rated in accordance with ARI Standard 325-85, *Ground Water-Source Heat Pumps*, Air-Conditioning and Refrigeration Institute, Arlington, VA 22209.

6.10 Controls

6.10.1 Temperature Control. Each system or each zone within a system shall be provided with at least one thermostat capable of being set from 55°F (13°C) to 85°F (29°C) and capable of operating the system's heating and cooling. The thermostat or control system, or both, shall have an adjustable deadband, the range of which includes a setting of 10°F (5.6 °C) between heating and cooling when automatic changeover is provided. Wall-mounted temperature controls shall be mounted on an inside wall.

6.10.2 Ventilation Control. Each mechanical ventilation system (supply or exhaust or both) shall be equipped with a readily accessible switch or other means for shutoff. Manual or automatic dampers installed for the purpose of isolating outside air intakes and exhausts from the air distribution system shall be designed for tight shutoff.

6.10.3 Humidity Control

6.10.3.1 Heating. If additional energy-consuming equipment is provided for adding moisture to maintain specific selected relative humidities in spaces or zones, a humidistat shall be provided. This device shall be capable of being set to prevent energy from being used to produce relative humidity within the space above 30%.

6.10.3.2 Cooling. If additional energy-consuming equipment is provided for reducing humidity, it shall be equipped with controls capable of being set to prevent energy from being used to produce a relative humidity within the space below 50% during periods of human occupancy and below 60% during unoccupied periods.

6.10.3.3 Other Controls. When setback, zoned, humidity and cooling controls and equipment are provided, they shall be designed and installed in accordance with Section 6.10.

(Delete Section 7 entirely, except for Section 7.1.3, which was added by Addendum e. Add the following new sections as shown and revise Section 7.1.3 as shown to create the following new Section 7.)

7. SERVICE WATER HEATING

7.1 Application. Residential-type water heaters, pool heaters, and unfired water heater storage tanks shall meet the minimum performance requirements specified by federal law. Unfired storage water heating equipment shall have a heat loss through the tank surface area of less than 6.5 Btu/h·ft^2.

7.2 Pump Operation. Circulating hot water systems shall be arranged so that the circulating pump(s) can be turned off (automatically or manually) when the hot water system is not in operation.

~~7.1.3~~ **7.3 Central Water Heating Equipment**. Service water heating equipment (central systems) that does not fall under the requirements for residential-type service water heating equipment addressed in 7.1 shall meet the applicable requirements for service water-heating equipment found in ASHRAE Standard 90.1-~~1999~~2001.

7.4 Swimming Pools, Hot Tubs, and Spas

7.4.1 Pool Covers. Heated pools shall be equipped with a pool cover.

7.4.2 Covers. Outdoor pools deriving over 70% of the energy for heating (computed over an operating season) from nondepletable sources or from recovery of energy that would otherwise be wasted shall not be required to have pool covers.

7.4.3 Time Clock. Time clocks shall be installed so that the pump can be set to run in the off-peak electric demand period and can be set for the minimum time necessary to maintain the water in a clear and sanitary condition in keeping with applicable health standards.

7.4.3.1 Pumps. Pumps used to operate solar pool heating systems are not required to have time clocks installed.

7.5 Heat Traps. Heat traps shall be installed on both the inlet and outlet of water heaters that have vertical pipe risers connected to the top of the heater unless the water heater is equipped with an integral heat trap or is part of a circulating system. The heat trap shall be installed as close as possible to the inlet and the outlet fitting. The heat trap may be an arrangement of piping and fittings, such as elbows, or a commercially available heat trap that prevents the thermosiphoning of the hot water during standby periods.

(Revise Section 8 of Standard 90.2-2001 (as modified by Addenda b through g) as shown here. Only sections that are revised by this addendum are shown. Those sections that are not shown remain unchanged from the 90.2-2001 edition (unless they have been changed by Addenda b through g).

8. ANNUAL ENERGY COST METHOD

8.1.1 Compliance. This section provides a compliance path for a proposed design based on calculated annual energy cost (AEC). The procedure consists of a comparison of the AEC of the proposed design with the AEC of a prescriptive design that meets the requirements of Sections 5, 6, and 7 and whose characteristics are defined in this section. If the AEC of the proposed design is less than or equal to the AEC of the prescriptive design, then the proposed design complies with the standard and need not comply with the specific requirements of Sections 5, 6, and 7. The intent is to allow flexibility in the design process while ensuring that the AEC of the proposed design is no more than is allowed under the prescriptive path. ~~This compliance path provides an opportunity to account for the benefits of innovative designs, materials, and equipment (such as active and passive solar heating and cooling, heat recovery, air-to-air heat exchangers, innovative foundation systems, advanced controls, high-efficiency equipment, radiant barriers, thermal mass, operable shading and insulation, and thermal storage) when they cannot be evaluated adequately under the prescriptive procedures.~~

Informative Note: This compliance path provides an opportunity to account for the benefits of innovative designs, materials, and equipment (such as active and passive solar heating and cooling, heat recovery, air-to-air heat exchangers, innovative foundation systems, advanced controls, high-efficiency equipment, radiant barriers, thermal mass, operable shading and insulation, and thermal storage) when they cannot be evaluated adequately under the prescriptive procedures.

This section also provides a procedure for estimating the annual energy cost for building designs under standard conditions. In addition to providing compliance calculations, this procedure is intended to be used by designers for estimating energy costs of proposed designs. These estimates are based on reasonable assumptions for average conditions and may be used by designers, owners, financiers, and others in evaluating and comparing building designs. This procedure is intended to predict the AEC under average conditions. However, the AEC of any specified building may differ due to variations in construction, occupancy, operation, maintenance, and weather. Energy use for unusual equipment that is not included in the procedure (for example, swimming pools, hot tubs, saunas, engine block heaters, or well pumps) may also be a significant factor. Simplified calculation methods may be used to calculate the impact of certain design parameters; however, dynamic simulations using hourly weather data are recommended.

8.2 Scope

~~Annual energy cost compliance analysis is not required for designs that meet the prescriptive requirements of this standard.~~ Annual energy cost compliance is applicable to energy use for space conditioning only. Energy for other uses, such as domestic hot water, cooking, lighting, and appliances, is included for total energy cost estimates but is not a variable between the proposed design and prescriptive design for compliance with this standard. Capital costs, replacement costs, maintenance costs, financing charges, and other construction or equipment costs are not included. Although space-conditioning, domestic hot water heating, and appliance energy costs are calculated together, no compliance trade-offs are allowed between them.

8.4.1 Professional Judgment. The modeling techniques and assumptions prescribed in this standard shall be used where specified ~~and no professional judgment is required~~. However, professional judgment is required where the standard does not prescribe specific modeling techniques and assumptions. Two rules shall be used when applying professional judgment. First, the proposed design and prescriptive design shall both be analyzed using the same techniques and assumptions except where differences in conservation features require a different approach. Second, simplifying assumptions that may reduce the energy use of the proposed design in relation to the prescriptive design shall not be used. ~~AEC calculations should be performed by a licensed professional with appropriate training, if the design of the building requires a design professional.~~

8.6 Proposed Design. The analysis of the proposed design shall take into account all qualities, details, and characteristics of the design that significantly affect energy use and cost. These ~~may~~ include construction, geometry, orientation, exposure, materials, equipment, and renewable energy sources. The characteristics and all significant energy conservation features shall be documented in the construction documents.

8.6.3.1 Unit-by-Unit Calculations. For unit-by-unit calculations, an AEC is calculated separately for each proposed living unit plan according to one of the two approaches in ~~8.5.1~~ 8.6.1. Top-floor, mid-floor, and bottom-floor units shall be considered separate living unit plans. Walls and other surfaces that separate living units from other living units shall be assumed to have no heat transfer.

8.6.3.2 Whole-Building Calculations. For whole-building calculations, a single AEC shall be determined by one of the following methods.

(a) Calculate the AEC for the entire building as a single zone. Conditioned common spaces such as corridors and lobbies shall be included.

(b) If each living unit meets the requirements of 8.8.4.2(a), (b), and (c), the AEC may be calculated for the entire building as two zones by aggregating all the living spaces of all units into one zone and all of the sleeping spaces into another. Sleeping spaces shall include bedrooms and associated bathrooms, dressing rooms, closets, and hallways. All other conditioned spaces shall be considered living spaces. Common spaces such as corridors and lobbies, if conditioned, shall be treated as living spaces.

(c) Calculate the AEC for the entire building as the sum of the AECs of each living unit calculated separately. The AEC of conditioned common spaces shall be calculated and included in the building's total AEC.

(Section 8.7.1 was revised in Addendum c. This addendum modifies the section as shown here.)

8.7.1 Ducts. Ducts in the prescriptive design, if any, shall be assumed to be completely in unconditioned spaces. Single-family prescriptive designs shall comply with ~~part B of~~ the provisions for ducts outside the conditioned space for each prescriptive envelope requirement.

8.7.7 Fenestration. The total vertical fenestration area of the prescriptive design shall be equal to the total fenestration area of the proposed design (including skylights)~~, or the prescriptive glazing allowance, whichever is less. The prescriptive glazing allowance is 18% of the floor area or 125 ft2 per living unit, whichever is greater.~~ One-fourth of the fenestration area in the prescriptive design shall be located vertically on each orientation. The prescriptive design shall have no skylights.

8.8.2 Internal Thermal Mass. Both the prescriptive design and proposed design shall have the same occupancy thermal mass (furniture and contents). The value shall be 8 lb/ft^2 of the conditioned floor area. This is based on 2-in. wood with a specific heat of 0.39 Btu/lb·°F and a conductivity of 1.0 Btu·in/(h·ft^2·°F). To account for structural mass (such as partition walls), a value of 5.0 lb/ft^2 of the conditioned floor area shall be used for the prescriptive design. This is based on the thermal properties of l/2-in. gypsum board. The proposed design ~~with nonstandard construction features may use~~ shall use the same value as the prescriptive design or a different structural mass assumption if detailed calculations are documented. Calculation methods that assume massless exterior walls and a combined interior thermal mass node shall use 3.5 Btu/ºF per square foot of conditioned floor area total mass in the prescriptive design and in the proposed design unless additional structural thermal mass is documented in the proposed design.

(The following note was added in Addendum f. This addendum modifies it as shown here.)

8.8.3.1 Note: For low absorptivity roofs, the reference house is permitted to employ ~~Exceptions 5.3.1.1 or 5.3.1.2 or 5.5.1.1 or 5.5.1.2~~ the values in Section 5.4.

8.8.3.2 Window Internal Shading. Fenestration shall be assumed to be internally shaded for both the prescriptive and the proposed design cooling load calculations. Such shading shall be assumed to reduce the fenestration shading coefficient by 30% of its value without internal shading but shall have no effect on window U-factor. Credit ~~may~~ shall be taken for higher performance shading and insulation systems in the proposed design that demonstrate significantly higher performance. All operable shading and drapes shall be closed when the air conditioner is running to meet a cooling load and closed at night but open during the rest of the day.

8.8.3.4 Infiltration. One of the three methods of calculating infiltration effects listed in 8.8.3.4.2 shall be used. For the first two methods, infiltration rates for both proposed design and prescriptive design are identical and the prescriptive infiltration requirements of ~~5.6~~ 5.10 shall be met in the proposed design.

8.8.3.4.2 Infiltration shall be calculated for both proposed design and prescriptive design based on the effective leakage area (ELA) and site conditions for the proposed design plus an allowance for occupancy. The ELA shall be determined using methods described in ~~chapter 23 of~~ the *ASHRAE Handbook—Fundamentals*,[2] ANSI/ASHRAE 119[68] using a standard pressure of 4 Pa, or from standard test methods such as ANSI/ASTM E283.[18] The determination of the energy loss from infiltration shall be based upon the hourly calculation of specific infiltration as described in ~~chapter 23 of~~ the *ASHRAE Handbook—Fundamentals*,[2] ANSI/ASHRAE 119,[68] or an equivalent method. A constant of 0.15 ACH shall be added to the calculated leakage to account for occupancy-caused infiltration through door openings, exhaust fans, etc.

8.8.4.1 8.8.4.1 General. The annual energy cost of the proposed design shall be calculated using the HVAC equipment specified. The same fuel source shall be used in the proposed design and the prescriptive design. Equipment of the same DOE product class shall be used in the proposed design and prescriptive design except for the following:

(a) For an electric central warm air system without thermal storage, the prescriptive design shall have an air-source heat pump.

(b) For any electric heating system without thermal storage in climates greater than 2,000 heating degree-days (base 65°F), the prescriptive design shall have an air-source heat pump.

The mechanical systems in the prescriptive design shall meet the minimum requirements specified in Section 6. If the system specified in the design is not directly categorized in Section 6, then the system from Section 6 that uses the same fuel type and that is most similar to the design shall be selected. If a design uses more than one fuel type for one purpose, such as a combination of electricity and gas for space heating, the prescriptive design shall utilize the same fuel sources for that purpose in the same proportions as the proposed design. In no case shall the energy cost comparison between prescriptive design and proposed design include changes from one fuel type to another for the same purpose, except ~~that~~ where the proposed design ~~may~~ utilizes renewable sources not included in the prescriptive design.

8.8.4.2 Zoning. The prescriptive design shall have one thermal zone. If electric resistance is modeled in the prescriptive design as specified in 6.4.3.2.3, then one of two options shall be used for modeling the proposed design. The first option is to model ~~both~~ the ~~prescriptive and~~ proposed design ~~shall be modeled~~ as a single thermal zone. ~~Otherwise~~ The second option is to model two thermal zones—a living zone and a sleeping zone~~—may be simulated~~ in each living unit when calculating the AEC of the proposed design if the following three conditions are met:

(a) Each zone has its own thermostat that controls the supply of heating and cooling to the zone.

(b) The total nonclosable opening area between adjacent zones in a living unit is less than 40 ft^2, and all remaining zonal boundary areas are separated by permanent walls or operable doors (or both) that are capable of restricting free air movement in the closed position.

(c) For forced-air systems, conditioned air flows into, through, and out of a zone only when a zone requires conditioning. No measurable amount of air ~~may~~ shall be discharged into any zone through damper leakage or as a bypass for system control. Each zone shall have its own return register located in the zone, but return dampers are not required.

8.8.4.4 Equipment Efficiency. Calculation of energy consumption shall be based on the data collected in the DOE-mandated test procedure for the equipment specified. The efficiency descriptor used to set minimum efficiency requirements in Section 6 shall be used to calculate energy consumption based on loads for methods in which a single efficiency is required. The same method of calculation shall be used in both the proposed design and the prescriptive design.

Informative Note: The use of more sophisticated calculations, which take any combination of ambient temperature, part load, sizing, or other effects into account, is encouraged. ~~The same method of calculation shall be used in both proposed design and prescriptive design.~~

8.8.4.6 Equipment Capacity and Redundant Equipment. For calculation methods where equipment capacity does not affect energy consumption, the capacity of the equipment in the proposed design ~~may~~ shall be ignored. Otherwise, actual equipment capacities and types shall be used in calculations unless the actual capacity is not adequate to meet the calculated load. In that case, for the purpose of calculating the AEC, the equipment capacity shall be increased to meet the load. If more than one type of equipment is assigned to the load, the capacity of the one with the highest energy cost shall be increased. For example, if a heat pump system with resistance backup heat is too small to meet the heating load, the resistance heater capacity shall be increased. The proposed design and the prescriptive design shall have equipment sized in a consistent manner but not necessarily the same capacity if, for example, the design loads are different. However, heat pump compressors for the prescriptive-design AEC calculation shall be sized to meet the smaller of the heating load or 125% of the cooling load at the respective design conditions.

Redundant equipment, emergency equipment, or both need not be included if it is controlled such that it will not operate under normal conditions.

8.8.5 The Calculation Tool. The same calculation tool shall be used to calculate the AEC of both the prescriptive design and the proposed design. The calculation tool shall be appropriate for the design parameters that are being analyzed. The calculation tool shall estimate the annual energy cost impact of each energy conservation feature of the proposed design that deviates from the prescriptive design. ~~Simplified calculation methods may be used to calculate the impact of certain design parameters; however, dynamic simulations using hourly weather data are recommended.~~

Hand calculation analyses shall include a written documentation of the assumptions made. Computer analysis shall be performed using programs that utilize scientifically justifiable techniques and procedures for modeling building loads, systems, and equipment. Computer program documentation shall state what methods are used and which conservation methods are accurately modeled.

Energy consumption for occupant energy uses shall be calculated according to Equations 8-15 and 8-16. The energy consumption for these end uses shall be added to those calculated for heating and cooling for both the prescriptive design and the proposed design before annual energy costs are calculated.

One of the calculation methods addressed in 8.8.5.1 through 8.8.5.4 shall be used.

8.8.5.1 Simplified Calculation Methods. Annual heating and cooling energy shall be calculated using variable-base degree-days.[2] Passive solar effects shall be calculated using the solar load ratio method as specified in Reference 10. These methods ~~may be used for~~ are applicable for calculations for the following conservation measures in climates with less than 8,000 cooling degree-hours base 74°F (CDH74):

(a) envelope and glazing U-factor and area,
(b) equipment efficiency, and
(c) passive solar effects.

8.8.5.2 Bin Calculation Method. Calculation techniques for this method are specified in simplified energy calculations.[2,52] This procedure ~~may be used~~ is applicable for the following measures in any climate:

(a) envelope and glazing U-factor and areas,
(b) equipment efficiency, and
(c) evaporative and ventilative cooling.

8.8.5.3 Correlation Methods. Heating and cooling energies are calculated through correlation to a database generated for representative configurations using detailed hourly transient analysis. The database results are then translated into simplified algorithms that can be presented as tables, nomographs, or microcomputer programs. Correlation methods ~~may be used if~~ are allowed if it is shown that the construction variables to be analyzed are adequately quantified by the simulation program used to generate the database and that the results are reliably re-created by the simplified algorithms. Correlation methods shall not be used for analysis of weather or construction variables not covered by or outside the range of the database. The methodology used to generate the database, the correlation techniques, and their comparison to the basic data shall be well documented.

8.8.5.4 Transient Analysis Using Hourly Weather Data. This method uses calculation techniques as specified in ~~chapter 28 of~~ the *ASHRAE Handbook—Fundamentals*.[2] The method uses transfer functions, finite differences, or other methods to calculate the transient responses of the building to hourly weather data for a typical year. ASHRAE WYEC[53,54] or TMY weather[55] data sets or the equivalent shall be used. If weather data for an entire year are not used, the weather data used must represent the full range of climatic variation for the full year in the chosen location. Documentation shall include the building location and weather station used in the analysis. ~~Weather data may be adjusted~~ Documentation shall also include adjustments made to compensate for microclimatic differences between the building site and the weather station. ~~Programs based on this methodology that include algorithms for computing shading and other solar effects plus algorithms for computing the psychrometrics of air systems may be used to evaluate all building and equipment variables.~~

(Note: The following sections, Sections 8.9.1 through 8.9.5, were revised and/or added in Addendum e. This addendum revises all but one of these sections, Section 8.9.3, as shown here.)

8.9.1 General. Domestic hot water shall be assumed to be supplied to all living units. Both the proposed design and the prescriptive design shall use the domestic water heating system designed for the proposed application. ~~, including high-efficiency equipment, waste heat use, off-peak storage, and renewable energy sources.~~

8.9.2 Domestic Hot Water Load. The total domestic hot water load used to calculate the annual energy consumption (AEC) shall be the same for the prescriptive design and the proposed design. It shall be determined using Equation 8-10.

$$DHWL = AGPD \times 8.28 \times (1.35\ Tinlet) \qquad \text{(Eq. 8-10)}$$

where

DHWL = domestic hot water load of the living unit (Btu/day),

AGPD = average gallons per day of hot water consumption, determined using the procedure described in Section 8.9.3, and

Tinlet = inlet mean water temperature, which shall be assumed to be equal to the average annual outdoor dry-bulb air temperature for ~~the location~~ the climate zone from Table 8-4 or 40ºF, whichever is higher ~~(see Section 9 for climatic).~~

Table 8-4 Average Annual Outdoor Dry-Bulb Temperature by Climate Zone

Climate Zone	Average Annual Outdoor Dry-Bulb Temperature - °F
1	78
2	69
3 A,B	62
3 C	60
4	55
5	49
6	44
7	38
8	24

8.9.4 Energy Consumption. The daily average electric energy consumption of federally covered residential electric water heaters shall be determined by Equation 8-12 ~~if the equipment is listed in Table 7-1; otherwise Equation 8-14 shall be used~~. For federally covered commercial electric water heating equipment, Equation 8-14 shall be used. The daily average gas consumption of federally covered residential gas water heaters shall be determined by Equation 8-13 ~~if the equipment is listed in Table 7-1; otherwise Equation 8-15 shall be used~~. For federally covered commercial gas water heating equipment, Equation 8-15 shall be used. The daily average energy use of domestic water heaters using other fuels (such as fuel oil) shall be determined using appropriate conversion factors.

(Eq. 8-12) *(No change)*

(Eq. 8-13) *(No change)*

(Eq. 8-14) *(No change)*

(Eq. 8-15) *(No change)*

8.9.5 Hourly Domestic Hot Water Fraction. Where hourly hot water load is required, it shall be distributed over the day according to the profile in Table ~~8-4~~ 8-5. The hourly hot water load is DHWL multiplied by the factor for the hour.

(Revise the number of Table 8-4 in 90.2-2001, with no changes to table except the change to the table note shown.)

Table ~~8-4~~ 8-5, Daily Domestic Hot Water Load Profile

Note: These hourly values include a large diversity factor and ~~should~~ shall not be used to calculate peak loads for equipment sizing.

(Delete Section 9 completely and then replace it with the following new Section 9.)

9. CLIMATIC DATA

9.1 Scope. The climatic data contained in this section shall apply to Chapters 5, 6, 7, and 8 for a given geographic location.

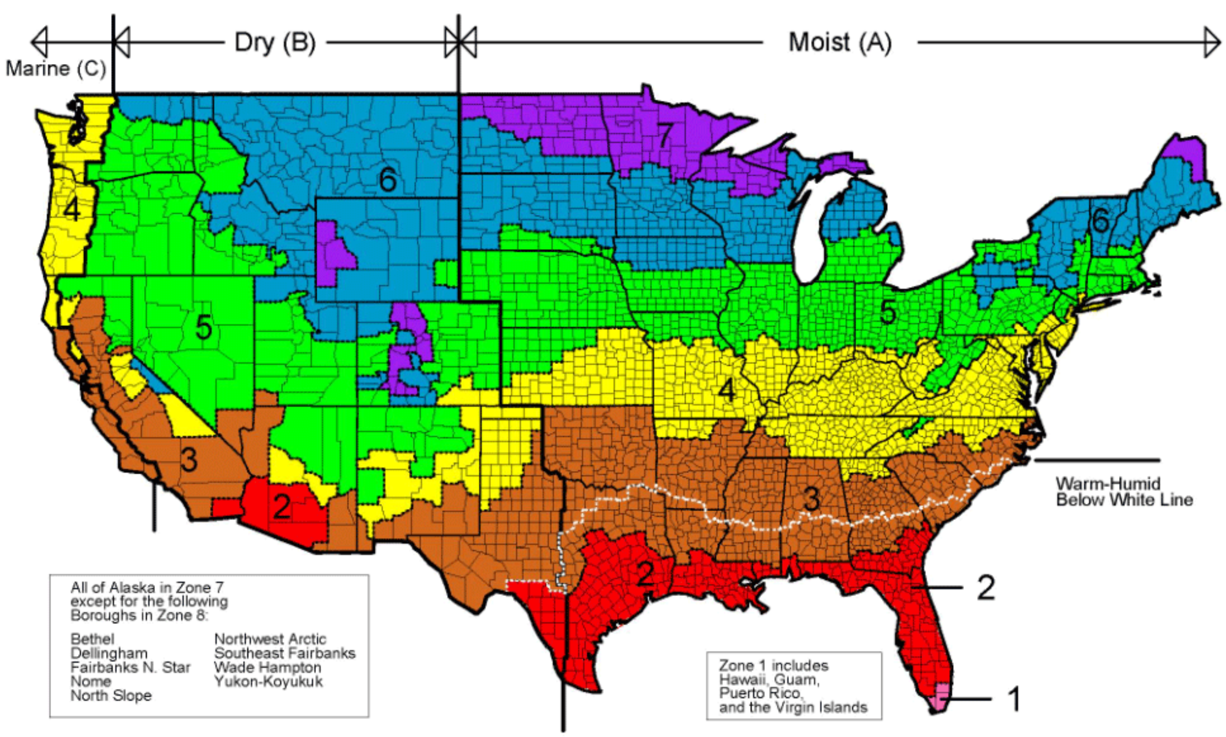


Figure 9.1 Climate Zones for United States Locations.

TABLE 9.1 Climate Zones—United States

State County	Zone
Alabama (AL)	
Zone 3A,B Except	
Baldwin	2
Mobile	2
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 Fair-banks (CA)	8
Wade Hampton (CA)	8
Yukon-Koyukuk (CA)	8
Arizona (AZ)	
Zone 3A,B Except	
La Paz	2
Maricopa	2
Pima	2
Pinal	2
Yuma	2
Gila	4
Yavapai	4
Apache	5
Coconino	5
Navajo	5
Arkansas (AR)	
Zone 3A,B Except	
Baxter	4
Benton	4
Boone	4
Carroll	4
Fulton	4
Izard	4
Madison	4
Marion	4
Newton	4
Searcy	4
Stone	4
Washington	4
California (CA)	
Zone 3A,B Except	
Imperial	2
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	4
Calaveras	4
Del Norte	4
El Dorado	4
Humboldt	4
Inyo	4
Lake	4
Mariposa	4
Trinity	4
Tuolumne	4
Lassen	5
Modoc	5
Nevada	5
Plumas	5
Sierra	5
Siskiyou	5
Alpine	6
Mono	6
Colorado (CO)	
Zone 5 Except	
Baca	4
Las Animas	4
Otero	4
Alamosa	6
Archuleta	6
Chaffee	6
Conejos	6
Costilla	6
Custer	6
Dolores	6
Eagle	6
Moffat	6
Ouray	6
Rio Blanco	6
Saguache	6
San Miguel	6
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
Summit	7
Connecticut (CT)	
Zone 5	
Delaware (DE)	
Zone 4	
District of Columbia (DC)	
Zone 4	
Florida (FL)	
Zone 2 Except	
Broward	1
Miami-Dade	1
Monroe	1
Georgia (GA)	
Zone 3A,B Except	
Appling	2
Atkinson	2
Bacon	2
Baker	2
Berrien	2
Brantley	2
Brooks	2
Bryan	2
Camden	2
Charlton	2
Chatham	2
Clinch	2
Colquitt	2
Cook	2
Decatur	2
Echols	2
Effingham	2
Evans	2
Glynn	2
Grady	2
Jeff Davis	2
Lanier	2
Liberty	2
Long	2
Lowndes	2
McIntosh	2
Miller	2
Mitchell	2
Pierce	2
Seminole	2
Tattnall	2
Thomas	2
Toombs	2
Ware	2
Wayne	2
Banks	4
Catoosa	4
Chattooga	4
Dade	4
Dawson	4
Fannin	4
Floyd	4
Franklin	4
Gilmer	4
Gordon	4
Habersham	4
Hall	4
Lumpkin	4
Murray	4
Pickens	4
Rabun	4

State	
County	Zone
Stephens	4
Towns	4
Union	4
Walker	4
White	4
Whitfield	4
Hawaii (HI)	
Zone 1	
Idaho (ID)	
Zone 6 Except	
Ada	5
Benewah	5
Canyon	5
Cassia	5
Clearwater	5
Elmore	5
Gem	5
Gooding	5
Idaho	5
Jerome	5
Kootenai	5
Latah	5
Lewis	5
Lincoln	5
Minidoka	5
Nez Perce	5
Owyhee	5
Payette	5
Power	5
Shoshone	5
Twin Falls	5
Washington	5
Illinois (IL)	
Zone 5 Except	
Alexander	4
Bond	4
Christian	4
Clay	4
Clinton	4
Crawford	4
Edwards	4
Effingham	4
Fayette	4
Franklin	4

State	
County	Zone
Gallatin	4
Hamilton	4
Hardin	4
Jackson	4
Jasper	4
Jefferson	4
Johnson	4
Lawrence	4
Macoupin	4
Madison	4
Monroe	4
Montgomery	4
Perry	4
Pope	4
Pulaski	4
Randolph	4
Richland	4
Saline	4
Shelby	4
St. Clair	4
Union	4
Wabash	4
Washington	4
Wayne	4
White	4
Williamson	4
Indiana (IN)	
Zone 5 Except	
Brown	4
Clark	4
Crawford	4
Daviess	4
Dearborn	4
Dubois	4
Floyd	4
Gibson	4
Greene	4
Harrison	4
Jackson	4
Jefferson	4
Jennings	4
Knox	4
Lawrence	4
Martin	4

State	
County	Zone
Monroe	4
Ohio	4
Orange	4
Perry	4
Pike	4
Posey	4
Ripley	4
Scott	4
Spencer	4
Sullivan	4
Switzerland	4
Vanderburgh	4
Warrick	4
Washington	4
Iowa (IA)	
Zone 5 Except	
Allamakee	6
Black Hawk	6
Bremer	6
Buchanan	6
Buena Vista	6
Butler	6
Calhoun	6
Cerro Gordo	6
Cherokee	6
Chickasaw	6
Clay	6
Clayton	6
Delaware	6
Dickinson	6
Emmet	6
Fayette	6
Floyd	6
Franklin	6
Grundy	6
Hamilton	6
Hancock	6
Hardin	6
Howard	6
Humboldt	6
Ida	6
Kossuth	6
Lyon	6
Mitchell	6

State	
County	Zone
O'Brien	6
Osceola	6
Palo Alto	6
Plymouth	6
Pocahontas	6
Sac	6
Sioux	6
Webster	6
Winnebago	6
Winneshiek	6
Worth	6
Wright	6
Kansas (KS)	
Zone 4 Except	
Cheyenne	5
Cloud	5
Decatur	5
Ellis	5
Gove	5
Graham	5
Greeley	5
Hamilton	5
Jewell	5
Lane	5
Logan	5
Mitchell	5
Ness	5
Norton	5
Osborne	5
Phillips	5
Rawlins	5
Republic	5
Rooks	5
Scott	5
Sheridan	5
Sherman	5
Smith	5
Thomas	5
Trego	5
Wallace	5
Wichita	5
Kentucky (KY)	
Zone 4	
Louisiana (LA)	

State	
County	**Zone**
Zone 2 Except	
Bienville	3A,B
Bossier	3A,B
Caddo	3A,B
Caldwell	3A,B
Catahoula	3A,B
Claiborne	3A,B
Concordia	3A,B
De Soto	3A,B
East Carroll	3A,B
Franklin	3A,B
Grant	3A,B
Jackson	3A,B
La Salle	3A,B
Lincoln	3A,B
Madison	3A,B
Morehouse	3A,B
Natchitoches	3A,B
Ouachita	3A,B
Red River	3A,B
Richland	3A,B
Sabine	3A,B
Tensas	3A,B
Union	3A,B
Vernon	3A,B
Webster	3A,B
West Carroll	3A,B
Winn	3A,B
Maine (ME)	
Zone 6 Except	
Aroostook	7
Maryland (MD)	
Zone 4 Except	
Garrett	5
Massachusetts (MA)	
Zone 5	
Michigan (MI)	
Zone 5 Except	
Alcona	6
Alger	6
Alpena	6
Antrim	6
Arenac	6
Benzie	6

State	
County	**Zone**
Charlevoix	6
Cheboygan	6
Clare	6
Crawford	6
Delta	6
Dickinson	6
Emmet	6
Gladwin	6
Grand Traverse	6
Huron	6
Iosco	6
Isabella	6
Kalkaska	6
Lake	6
Leelanau	6
Manistee	6
Marquette	6
Mason	6
Mecosta	6
Menominee	6
Missaukee	6
Montmorency	6
Newaygo	6
Oceana	6
Ogemaw	6
Osceola	6
Oscoda	6
Otsego	6
Presque Isle	6
Roscommon	6
Sanilac	6
Wexford	6
Baraga	7
Chippewa	7
Gogebic	7
Houghton	7
Iron	7
Keweenaw	7
Luce	7
Mackinac	7
Ontonagon	7
Schoolcraft	7
Minnesota (MN)	
Zone 6 Except	

State	
County	**Zone**
Aitkin	7
Becker	7
Beltrami	7
Carlton	7
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 Tail	7
Pennington	7
Pine	7
Polk	7
Red Lake	7
Roseau	7
St. Louis	7
Wadena	7
Wilkin	7
Mississippi (MS)	
Zone 3A,B Except	
Hancock	2
Harrison	2
Jackson	2
Pearl River	2
Stone	2
Missouri (MO)	
Zone 4 Except	
Adair	5
Andrew	5
Atchison	5
Buchanan	5
Caldwell	5

State	
County	**Zone**
Chariton	5
Clark	5
Clinton	5
Daviess	5
Gentry	5
Grundy	5
Harrison	5
Holt	5
Knox	5
Lewis	5
Linn	5
Livingston	5
Macon	5
Marion	5
Mercer	5
Nodaway	5
Pike	5
Putnam	5
Ralls	5
Schuyler	5
Scotland	5
Shelby	5
Sullivan	5
Worth	5
Montana (MT)	
Zone 6	
Nebraska (NE)	
Zone 5	
Nevada (NV)	
Zone 5 Except	
Clark	3A,B
New Hampshire (NH)	
Zone 6 Except	
Cheshire	5
Hillsborough	5
Rockingham	5
Strafford	5
New Jersey (NJ)	
Zone 4 Except	
Bergen	5
Hunterdon	5
Mercer	5
Morris	5
Passaic	5

State	
County	**Zone**
Somerset	5
Sussex	5
Warren	5
New Mexico (NM)	
Zone 5 Except	
Chaves	3A,B
Dona Ana	3A,B
Eddy	3A,B
Hidalgo	3A,B
Lea	3A,B
Luna	3A,B
Otero	3A,B
Bernalillo	4
Curry	4
DeBaca	4
Grant	4
Guadalupe	4
Lincoln	4
Quay	4
Roosevelt	4
Sierra	4
Socorro	4
Union	4
Valencia	4
New York (NY)	
Zone 5 Except	
Bronx	4
Kings	4
Nassau	4
New York	4
Queens	4
Richmond	4
Suffolk	4
Westchester	4
Allegany	6
Broome	6
Cattaraugus	6
Chenango	6
Clinton	6
Delaware	6
Essex	6
Franklin	6
Fulton	6
Hamilton	6

State	
County	**Zone**
Herkimer	6
Jefferson	6
Lewis	6
Madison	6
Montgomery	6
Oneida	6
Otsego	6
Schoharie	6
Schuyler	6
St. Lawrence	6
Steuben	6
Sullivan	6
Tompkins	6
Ulster	6
Warren	6
Wyoming	6
North Carolina (NC)	
Zone 4 Except	
Anson	3A,B
Beaufort	3A,B
Bladen	3A,B
Brunswick	3A,B
Cabarrus	3A,B
Camden	3A,B
Carteret	3A,B
Chowan	3A,B
Columbus	3A,B
Craven	3A,B
Cumberland	3A,B
Currituck	3A,B
Dare	3A,B
Davidson	3A,B
Duplin	3A,B
Edgecombe	3A,B
Gaston	3A,B
Greene	3A,B
Hoke	3A,B
Hyde	3A,B
Johnston	3A,B
Jones	3A,B
Lenoir	3A,B
Martin	3A,B
Mecklenburg	3A,B
Montgomery	3A,B

State	
County	**Zone**
Moore	3A,B
New Hanover	3A,B
Onslow	3A,B
Pamlico	3A,B
Pasquotank	3A,B
Pender	3A,B
Perquimans	3A,B
Pitt	3A,B
Randolph	3A,B
Richmond	3A,B
Robeson	3A,B
Rowan	3A,B
Sampson	3A,B
Scotland	3A,B
Stanly	3A,B
Tyrrell	3A,B
Union	3A,B
Washington	3A,B
Wayne	3A,B
Wilson	3A,B
Alleghany	5
Ashe	5
Avery	5
Mitchell	5
Watauga	5
Yancey	5
North Dakota (ND)	
Zone 7 Except	
Adams	6
Billings	6
Bowman	6
Burleigh	6
Dickey	6
Dunn	6
Emmons	6
Golden Valley	6
Grant	6
Hettinger	6
LaMoure	6
Logan	6
McIntosh	6
McKenzie	6
Mercer	6
Morton	6

State	
County	**Zone**
Oliver	6
Ransom	6
Richland	6
Sargent	6
Sioux	6
Slope	6
Stark	6
Ohio (OH)	
Zone 5 Except	
Adams	4
Brown	4
Clermont	4
Gallia	4
Hamilton	4
Lawrence	4
Pike	4
Scioto	4
Washington	4
Oklahoma (OK)	
Zone 3A,B Except	
Beaver	4
Cimarron	4
Texas	4
Oregon (OR)	
Zone 4 Except	
Baker	5
Crook	5
Deschutes	5
Gilliam	5
Grant	5
Harney	5
Hood River	5
Jefferson	5
Klamath	5
Lake	5
Malheur	5
Morrow	5
Sherman	5
Umatilla	5
Union	5
Wallowa	5
Wasco	5
Wheeler	5
Pennsylvania (PA)	

State	
County	**Zone**
Zone 5 Except	
Bucks	4
Chester	4
Delaware	4
Montgomery	4
Philadelphia	4
York	4
Rhode Island (RI)	
Zone 5	
South Carolina (SC)	
Zone 3A,B	
South Dakota (SD)	
Zone 6 Except	
Bennett	5
Bon Homme	5
Charles Mix	5
Clay	5
Douglas	5
Gregory	5
Hutchinson	5
Jackson	5
Mellette	5
Todd	5
Tripp	5
Union	5
Yankton	5
Tennessee (TN)	
Zone 4 Except	
Chester	3A,B
Crockett	3A,B
Dyer	3A,B
Fayette	3A,B
Hardeman	3A,B
Hardin	3A,B
Haywood	3A,B
Henderson	3A,B
Lake	3A,B
Lauderdale	3A,B
Madison	3A,B
McNairy	3A,B
Shelby	3A,B
Tipton	3A,B
Texas (TX)	
Zone 3A,B Except	

State	
County	**Zone**
Anderson	2
Angelina	2
Aransas	2
Atascosa	2
Austin	2
Bandera	2
Bastrop	2
Bee	2
Bell	2
Bexar	2
Bosque	2
Brazoria	2
Brazos	2
Brooks	2
Burleson	2
Caldwell	2
Calhoun	2
Cameron	2
Chambers	2
Cherokee	2
Colorado	2
Comal	2
Coryell	2
DeWitt	2
Dimmit	2
Duval	2
Edwards	2
Falls	2
Fayette	2
Fort Bend	2
Freestone	2
Frio	2
Galveston	2
Goliad	2
Gonzales	2
Grimes	2
Guadalupe	2
Hardin	2
Harris	2
Hays	2
Hidalgo	2
Hill	2
Houston	2
Jackson	2

State	
County	**Zone**
Jasper	2
Jefferson	2
Jim Hogg	2
Jim Wells	2
Karnes	2
Kenedy	2
Kinney	2
Kleberg	2
La Salle	2
Lavaca	2
Lee	2
Leon	2
Liberty	2
Limestone	2
Live Oak	2
Madison	2
Matagorda	2
Maverick	2
McLennan	2
McMullen	2
Medina	2
Milam	2
Montgomery	2
Newton	2
Nueces	2
Orange	2
Polk	2
Real	2
Refugio	2
Robertson	2
San Jacinto	2
San Patricio	2
Starr	2
Travis	2
Trinity	2
Tyler	2
Uvalde	2
Val Verde	2
Victoria	2
Walker	2
Waller	2
Washington	2
Webb	2
Wharton	2

State	
County	**Zone**
Willacy	2
Williamson	2
Wilson	2
Zapata	2
Zavala	2
Armstrong	4
Bailey	4
Briscoe	4
Carson	4
Castro	4
Cochran	4
Dallam	4
Deaf Smith	4
Donley	4
Floyd	4
Gray	4
Hale	4
Hansford	4
Hartley	4
Hockley	4
Hutchinson	4
Lamb	4
Lipscomb	4
Moore	4
Ochiltree	4
Oldham	4
Parmer	4
Potter	4
Randall	4
Roberts	4
Sherman	4
Swisher	4
Yoakum	4
Utah (UT)	
Zone 5 Except	
Washington	3A,B
Box Elder	6
Cache	6
Carbon	6
Daggett	6
Duchesne	6
Morgan	6
Rich	6
Summit	6

State	
County	Zone
Uintah	6
Wasatch	6
Vermont (VT)	
Zone 6	
Virginia (VA)	
Zone 4	
Washington (WA)	
Zone 5 Except	
Clallam	4
Clark	4
Cowlitz	4
Grays Harbor	4
Jefferson	4
King	4
Kitsap	4
Lewis	4
Mason	4
Pacific	4
Pierce	4
Skagit	4
Snohomish	4
Thurston	4
Wahkiakum	4

State	
County	Zone
Whatcom	4
Ferry	6
Okanogan	6
Pend Oreille	6
Stevens	6
West Virginia (WV)	
Zone 5 Except	
Berkeley	4
Boone	4
Braxton	4
Cabell	4
Calhoun	4
Clay	4
Gilmer	4
Jackson	4
Jefferson	4
Kanawha	4
Lincoln	4
Logan	4
Mason	4
McDowell	4
Mercer	4
Mingo	4

State	
County	Zone
Monroe	4
Morgan	4
Pleasants	4
Putnam	4
Ritchie	4
Roane	4
Tyler	4
Wayne	4
Wirt	4
Wood	4
Wyoming	4
Wisconsin (WI)	
Zone 6 Except	
Ashland	7
Bayfield	7
Burnett	7
Douglas	7
Florence	7
Forest	7
Iron	7
Langlade	7
Lincoln	7
Oneida	7

State	
County	Zone
Price	7
Sawyer	7
Taylor	7
Vilas	7
Washburn	7
Wyoming (WY)	
Zone 6 Except	
Goshen	5
Platte	5
Lincoln	7
Sublette	7
Teton	7
Pacific Rim (PR)	
Zone 1 Except	
Barranquitas 2 SSW	2
Cayey 1 E	2
Pacific Islands (PI)	
Zone 1 Except	
Midway Sand Island	2
Virgin Islands (VI)	
Zone 1	

TABLE 9.2 Canadian Climate Zones

Province / City	Zone
Alberta (AB)	
Calgary International A	7
Edmonton International A	7
Grande Prairie A	7
Jasper	7
Lethbridge A	6
Medicine Hat A	6
Red Deer A	7
British Columbia (BC)	
Dawson Creek A	7
Ft Nelson A	8
Kamloops	5
Nanaimo A	5
New Westminster BC Pen	5
Penticton A	5
Prince George	7
Prince Rupert A	6
Vancouver International A	5
Victoria Gonzales Hts	5
Manitoba (MB)	
Brandon CDA	7
Churchill A	8
Dauphin A	7
Flin Flon	7
Portage La Prairie A	7
The Pas A	7
Winnipeg International A	7
New Brunswick (NB)	
Chatham A	7
Fredericton A	6
Moncton A	6
Saint John A	6
Newfoundland (NF)	
Corner Brook	6
Gander International A	7
Goose A	7
St John's A	6
Stephenville A	6
Northwest Territories (NW)	
Ft Smith A	8
Inuvik A	8
Resolute A	8
Yellowknife A	8
Nova Scotia (NS)	
Halifax International A	6
Kentville CDA	6
Sydney A	6
Truro	6
Yarmouth A	6

Province / City	Zone
Ontario (ON)	
Belleville	6
Cornwall	6
Hamilton RBG	5
Kapuskasing A	7
Kenora A	7
Kingston A	6
London A	6
North Bay A	7
Oshawa WPCP	6
Ottawa International A	6
Owen Sound MOE	6
Peterborough	6
St Catharines	5
Sudbury A	7
Thunder Bay A	7
Timmins A	7
Toronto Downsview A	6
Windsor A	5
Prince Edward Island (PE)	
Charlottetown A	6
Summerside A	6
Quebec (PQ)	
Bagotville A	7
Drummondville	6
Granby	6
Montreal Dorval International A	6
Quebec A	7
Rimouski	7
Sept-Iles A	7
Shawinigan	7
Sherbrooke A	7
St Jean de Cherbourg	7
St Jerome	7
Thetford Mines	7
Trois Rivieres	7
Val d'Or A	7
Valleyfield	6
Saskatchewan (SK)	
Estevan A	7
Moose Jaw A	7
North Battleford A	7
Prince Albert A	7
Regina A	7
Saskatoon A	7
Swift Current A	7
Yorkton A	7
Yukon Territory (YT)	
Whitehorse A	8

TABLE 9.3 International Climate Zones

Country / City	Province/Region	Zone
Argentina		
Buenos Aires/Ezeiza		3 A,B
Cordoba		3 A,B
Tucuman/Pozo		2
Australia		
Adelaide	SA	3 C
Alice Springs	NT	2
Brisbane	QL	2
Darwin Airport	NT	1
Perth/Guildford	WA	3 A,B
Sydney/K Smith	NSW	3 A,B
Azores		
Lajes	Terceira	3 A,B
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		3 C
Punta Arenas/Chabunco		6
Santiago/Pedahuel		3 C
China		
Shanghai/Hongqiao		3 A,B
Cuba		
Guantanamo Bay NAS	Ote	1
Cyprus		
Akrotiri		3 A,B
Larnaca		3 A,B
Paphos		3 A,B
Czech Republic (Former Czechoslovakia)		
Prague/Libus		5
Dominican Republic		
Santo Domingo		1
Egypt		
Cairo		2
Luxor		1
Finland		
Helsinki/Seutula		7
France		
Lyon/Satolas		4
Marseille		3 C
Nantes		4
Nice		3 C
Paris/Le Bourget		4
Strasbourg		5
Germany		
Berlin/Schoenfeld		5
Hamburg		5
Hannover		5
Mannheim		5
Greece		
Souda	Crete	3 A,B
Thessalonika/Mikra		3 C
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 A,B
Tel Aviv Port		2
Italy		
Milano/Linate		4
Napoli/Capodichino		3 C
Roma/Fiumicino		3 C

Country City	Province/Region	Zone
Jamaica		
Kingston/Manley		1
Montego Bay/ Sangster		1
Japan		
Fukaura		5
Sapporo		5
Tokyo		3 A,B
Jordan		
Amman		3 A,B
Kenya		
Nairobi Airport		3 A,B
Korea		
Pyongyang		5
Seoul		4
Malaysia		
Kuala Lumpur		1
Mexico		
Guadalajara	Jalisco	1
Merida	Yucatan	1
Mexico City	Distrito Federal	3 A,B
Monterrey	Nuevo Laredo	3 A,B
Tampico	Tamaulipas	1
Veracruz	Veracruz	3 C
Netherlands		
Amsterdam/Schiphol		5
New Zealand		
Auckland Airport		3 C
Christchurch		4
Wellington		3 C
Norway		
Bergen/Florida		5
Oslo/Fornebu		6
Pakistan		
Karachi Airport		1
Papua New Guinea		
Port Moresby		1
Paraguay		
Asuncion/Stroessner		1
Peru		
Lima-Callao/Chavez		2
San Juan de Marcona		2
Talara		2
Philippines		
Manila Airport	Luzon	1
Poland		
Krakow/Balice		5
Puerto Rico		
San Juan/Isla Verde WSFO		1
Romania		
Bucuresti/Bancasa		5
Russia (Former Soviet Union)		
Kaliningrad	East Prussia	5

Country City	Province/Region	Zone
Krasnoiarsk		7
Moscow Observatory		6
Petropavlovsk		7
Rostov-Na-Donu		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		3 A,B
Johannesburg		3 C
Pretoria		3 A,B
Spain		
Barcelona		3 C
Madrid		4
Valencia/Manises		3 A,B
Sweden		
Stockholm/Arlanda		6
Switzerland		
Zurich		5
Syria		
Damascus Airport		3 A,B
Taiwan		
Tainan		1
Taipei		2
Tanzania		
Dar es Salaam		1
Thailand		
Bangkok		1
Tunisia		
Tunis/El Aouina		3 A,B
Turkey		
Adana		3 A,B
Ankara/Etimesgut		4
Istanbul/Yesilkoy		3 C
United Kingdom		
Birmingham	England	5
Edinburgh	Scotland	5
Glasgow Apt	Scotland	5
London/Heathrow	England	4
Uruguay		
Montevideo/Carrasco		3 A,B
Venezuela		
Caracas/Maiquetia		1
Vietnam		
Hanoi/Gialam		1

(Add the following new references to Section 10.)

ANSI/AAMA/NEWWDA-101/I.S.-2-1997, *Voluntary Specifications for Aluminum, Vinyl (PVC) and Wood Windows and Glass Doors*, Window and Door Manufacturers Association, Des Plaines, IL, 1997.

ANSI Z223.1/NFPA 54-02 *National Fuel Gas Code*, National Fire Protection Association, Quincy, MA, 2002.

NFPA 31- 01, *Standard for the Installation of Oil Equipment;* Solid fuel burning equipment, National Fire Protection Association, Quincy, MA, 2001.

NFPA 211-00 *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, National Fire Protection Association, Quincy, MA, 2000.

NFRC 200-01, Procedures for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incident, National Fenestration Rating Council, Silver Spring, Md. 2001.

(Change the following reference standards in Section 10 to read as shown)

2 – ~~1993~~ 2001 ASHRAE *Handbook – Fundamentals.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

26 - ASHRAE/IESNA Standard 90.1-~~1989~~ 2001, Energy Standard for Building Except Low-Rise Residential Buildings. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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(Delete the following references in Section 10 without substitution)

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~~4 - ARl Standard 380-93 for packaged terminal air-conditioners and heat pumps. Arlington, Va.: Air-Conditioning and Refrigeration Institute.~~

~~6 - ANSI/AHAM RAC-I-1982, Room air conditioners. Chicago: Association of Home Appliance Manufacturers.~~

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~~11- ASTM C 177-93, Standard test method for steady-state heat flux measurements and thermal transmission properties by means of the guarded-hot-plate apparatus. Philadelphia: American Society for Testing and Materials.~~

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~~13 - ASTM C 236-89, Standard test method for steady-state thermal performance of building assemblies by means of a guarded-hot-box. Philadelphia: American Society for Testing and Materials.~~

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~~21 - ASTM D 4099-89, Standard specification for poly (vinyl chloride) (PVC) prime windows. Philadelphia: American Society for Testing and Materials.~~

~~22 - ANSI/NWW DA I. S. 2-87, Industry standard for wood window units. Des Plains, Ill.: National Wood Window & Door Association.~~

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(Delete informative Appendix A and replace it with the entirely new normative Appendix A that follows.)

~~(This appendix is not a part of this standard but is included for information purposes only.)~~

~~APPENDIX A Typical Duct Insulation Levels~~

~~Level~~	~~Type~~
~~R-2~~	~~Installed insulation thermal conductance (C)= 0.48 Btu/h×ft^2×°F (R = 2.1)~~
	~~· 1 in., minimum 0.6 lb/ft^3 glass fiber blanket (wrap)~~
	~~· 0.5 in., 2- to 3-lb/ft^3 glass fiber blanket or board (duct liner)~~
	~~· 0.5 in., 3- to 10-lb/ft^3 glass fiber board~~
	~~· Flexible duct insulated with a glass fiber blanket having a l in. nominal wall thickness~~
~~R-4~~	~~Installed insulation thermal conductance (C) = 0.24 Btu/h×ft^2×°F (R = 4.2)~~
	~~· 2 in., minimum 0.6 lb/ft^3 glass fiber blanket (wrap)~~
	~~· 1 in., 1.5- to 3-lb/ft^3 glass fiber blanket or board (duct liner)~~
	~~· 1 in., 3- to 10-lb/ft^3 glass fiber board~~
	~~· Flexible duct insulated with a glass fiber blanket having a 1.25-in. wall thickness~~
~~R-6~~	~~Installed insulation thermal conductance (C) = 0.16 Btu/h×ft^2×°F (R = 6.3)~~
	~~· 3 m., minimum 0.6 lb/ft^3 glass fiber blanket (wrap)~~
	~~· 1.5 in., 1.5- to 3-lb/ft^3 glass fiber blanket or board (duct liner)~~
	~~· 1.5 in., 3- to 10-lb/ft^3 glass fiber board~~
	~~· Flexible duct insulated with a glass fiber blanket having a 1.75-in. wall thickness~~

~~Notes:~~

~~All insulation values are determined by using flat specimens to determine thermal conductance(C) using the relationship C = k/t, where t is the installed thickness in inches and k (Btu×in./h×ft^2×°F) is determined for the insulation using ASTM C518-85 or C177-85 and measured at a mean temperature of 75°F.~~

~~Duct wrap shall be tested at 75% of its nominal thickness, and the installed thickness value shall also be assumed to be 75% of the nominal thickness. For rigid board and duct liner products, the nominal value shall be used for thickness. Air films are not to be included in any calculations.~~

~~For flexible ducts, t is equal to the installed wall thickness determined by measuring the inner and outer circumferences of the duct, calculating the resultant inside and outside diameters, subtracting the inside diameter from the outside diameter and dividing the difference by 2.~~

~~Insulation examples listed in this appendix are suggested as combinations which may yield the required conductance value. If higher density materials are used, thickness may be decreased in some cases. Conversely, by increasing thickness, lighter density materials may be used to give the required thermal performance. Manufacturers data shall be utilized to make these determinations.~~

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX A
ENVELOPE PERFORMANCE PATH TRADE-OFF METHOD

A1 Scope. This section shall be used to evaluate envelope trade-off options by the performance path methodology to demonstrate compliance. This section shall not be used to evaluate envelope trade-off options against HVAC equipment types or efficiencies, heating and cooling distribution system efficiencies, air infiltration performance, or domestic water heating equipment performance.

A2 Methodology. The methodology is to calculate total heating and cooling energy costs of the proposed envelope design options and compare those to the energy costs of the prescriptive envelope criteria from Section 5.1. Compliance is achieved when the proposed envelope energy costs (PEC) are less than or equal to the prescriptive criteria energy costs (CEC).

A2.1 Basic Assumptions. All of the basic assumptions used in calculating the energy costs are identical to those used in developing the prescriptive envelope criteria. The specific assumptions relate to the type and efficiencies of the HVAC equipment for heating and cooling, the air distribution system efficiencies, heating and cooling energy prices, and economic variables. All of these assumptions are imbedded in the constants listed for each climate zone in Table A-1. These assumptions are intended to predict the energy costs under average conditions. However, the energy costs of any specified building may differ due to variations in construction, occupancy, operation, maintenance, HVAC systems, and weather.

A2.2 Proposed Envelope Design Assumptions. The analyses of the proposed envelope design options shall take into account all qualities, details, and characteristics of the design that significantly affect energy use and cost. The geometry, orientation, and exposure of each envelope trade-off option must be the same for the proposed envelope design and the design that meets the prescriptive criteria. The characteristics and all significant energy conservation features shall be documented in the construction documents.

A2.3 Mandatory Requirements. The proposed envelope design shall comply with the requirements for calculations, testing, and rating specified in Section 5. The proposed envelope design shall also comply with all other requirements of Section 5 if the effect of the requirements on the energy costs of the prescriptive design is not fully and accurately included in the calculations performed in this section.

A2.4 Professional Judgment. The modeling techniques and assumptions prescribed in this standard shall be used where specified and no professional judgment is required. However, professional judgment is required where the standard does not prescribe specific modeling techniques and assumptions. Two rules shall be used when applying professional judgment. First, the proposed design and prescriptive design shall both be analyzed using the same techniques and assumptions except where differences in conservation features require a different approach. Second, simplifying assumptions that reduce the energy use of the proposed design in relation to the prescriptive design shall not be used.

A3 Weighted Average Thermal Performance Factors (U-Factors, C-Factors, SHGC). When more than one type of construction for an envelope component is present, a weighted value shall be used to demonstrate compliance.

A3.1 Thermal Properties of Envelope Options. Thermal properties of envelope options shall be determined using the procedures contained in ASHRAE Standard 90.1-2001 or from Normative Appendix A in the same standard, "Assembly U-factor, C-factor, and F-factor Determination."

A3.2 Area-Weighted U-Factors (Above-Grade Ceilings, Walls, Floors, and Fenestration). When the criteria are expressed in terms of U-factors, the area-weighted U-factor (U_o) is determined by Equation A-1.

$$U_o = (U_1 \cdot A_1 + U_2 \cdot A_2 + \ldots + U_n A_n)/(A_1 + A_2 + \ldots + A_n) \qquad \text{(Eq. A-1)}$$

where

U_o = overall area-weighted U-factor, Btu/h·ft^2·°F
U_1 = U-factor of first construction type, Btu/h·ft^2·°F
U_2 = U-factor of second construction type, Btu/h·ft^2·°F
U_n = U-factor of nth construction type, Btu/h·ft^2·°F
A_1 = area of first construction type, ft^2
A_2 = area of second construction type, ft^2
A_n = area of nth construction type, ft^2

A3.3 Area-Weighted R-Values (Doors). The criteria for doors are presented as R-values. The R-values are converted into an area-weighted U-factor (U_o) by Equation A-2 for use in the envelope trade-off analysis.

$$U_o = (A_1/(0.85+R_1) + A_2/(0.85+R_2) + \ldots + A_n/(0.85+R_n)) / (A_1 + A_2 + \ldots + A_n) \qquad \text{(Eq. A-2)}$$

where

U_o = overall area-weighted U-factor, Btu/h·ft^2·°F
R_1 = R-value of first door construction type, h·ft^2·°F/Btu
R_2 = R-value of second door construction type, h·ft^2·°F/Btu
R_n = R-value of nth door construction type, h·ft^2·°F/Btu
A_1 = area of first door construction type, ft^2
A_2 = area of second door construction type, ft^2
A_n = area of nth door construction type, ft^2

A3.4 Area-Weighted Average SHGC. When more than one fenestration construction type is present, the area-weighted SHGC is determined by Equation A-3.

$$SHGC_o = (SHGC_1 \cdot A_1 + SHGC_2 \cdot A_2 + \ldots + SHGC_n \cdot A_n)/(A_1 + A_2 + \ldots + A_n) \qquad \text{(Eq. A-3)}$$

where

$SHGC_o$ = overall area-weighted SHGC, dimensionless
$SHGC_1$ = SHGC of first fenestration construction type, dimensionless
$SHGC_2$ = SHGC of second fenestration construction type, dimensionless
$SHGC_n$ = SHGC of nth fenestration construction type, dimensionless
A_1 = area of first fenestration construction type, ft^2
A_2 = area of second fenestration construction type, ft^2
A_n = area of nth fenestration construction type, ft^2

A3.5 Perimeter-Weighted C-Factors (Basement and Crawlspace Walls). When the criteria are expressed in terms of C-factors, the perimeter-weighted C-factor (C_o) is determined by Equation A-4.

$$C_o = (C_1 \cdot P_1 + C_2 \cdot P_2 + \ldots + C_n \cdot P_n)/(P_1 + P_2 + \ldots + P_n) \qquad \text{(Eq. A-4)}$$

where

C_o = overall perimeter-weighted C-factor, Btu/h·ft·°F
C_1 = C-factor of first envelope construction type, Btu/h·ft·°F
C_2 = C-factor of second envelope construction type, Btu/h·ft·°F
C_n = C-factor of nth envelope construction type C-factor, Btu/h·ft·°F
P_1 = perimeter of first envelope construction type, ft
P_2 = perimeter of second envelope construction type, ft
P_n = perimeter of nth envelope construction type, ft

A3.6 Perimeter-Weighted Average R-Values (Slabs). The criteria for slabs are presented as R-values. The R-values are converted into an area-weighted U-factor (U_o) by Equation A-5 for use in the envelope trade-off analysis.

$$U_o = (P_1/(1 + R_1) + P_2/(1 + R_2) + \ldots + P_n/(1 + R_n))/(P_1 + P_2 + \ldots + P_n) \qquad \text{(Eq. A-5)}$$

where

U_o = overall perimeter-weighted U-factor, Btu/h·ft^2·°F
R_1 = R-value of first slab construction type, h·ft^2·°F/Btu
R_2 = R-value of second slab construction type, h·ft^2·°F/Btu
R_n = R-value of nth slab construction type, h·ft^2·°F/Btu
P_1 = perimeter of first slab construction type, ft
P_2 = perimeter of second slab construction type, ft
P_n = perimeter of nth slab construction type, ft

A4 Equations for Envelope Trade-off Calculations. The equations presented in this subsection shall be used in all building envelope trade-off calculations. The total heating and cooling energy costs (EC) are determined using Equation A-6.

$$EC = HEAT + COOL \quad \text{(Eq. A-6)}$$

where

EC = total heating and cooling energy costs for an envelope construction option, \$/yr

HEAT = heating energy cost for an envelope construction option, \$/yr

COOL = cooling energy cost for an envelope construction option, \$/yr

Equation A-6 shall be used to determine the total energy costs for the proposed envelope options (PEC) and the total energy costs for the prescriptive envelope criteria options (CEC).

A4.1 Above-Grade Opaque Envelope Options. The analysis of above-grade opaque envelope options shall use the following equations.

$$HEAT = U_o \cdot A \cdot HECM \quad \text{(Eq. A-7)}$$

where

U_o = overall area-weighted thermal transmittance, Btu/h·ft^2·°F

A = total surface area of above-grade opaque constructions, ft^2

HECM = heating energy cost multiplier for a specific climate zone, see Table A-1

and

$$COOL = U_o \cdot A \cdot CECM \quad \text{(Eq. A-8)}$$

where

CECM = cooling energy cost multiplier for a specific climate zone (see Table A-1)

A4.1.1 Ceilings with Attics. Ceilings with attics separate conditioned space from exterior weather conditions with a ventilated attic space above the insulation. The ceilings can be horizontal surfaces, sloped surfaces, or tray type construction. The framing can be truss or rafter construction made of wood or cold-formed steel.

A4.1.2 Ceilings without Attics. Ceilings without attics separate conditioned space from exterior weather conditions without an attic space above the insulation. Cathedral ceilings or flat roofs do not have a ventilated attic space above the insulation but may have a small (one-inch) air space for moisture removal. The framing can be truss or rafter construction made of wood or cold-formed steel.

A4.1.3 Above-Grade Frame Walls and Band Joists. Above-grade walls frame walls are exterior walls that separate conditioned space from exterior weather conditions. The framing construction can be wood or cold-formed steel.

A4.1.4 Above-Grade Concrete, Masonry, or Log Walls. Above-grade concrete, masonry, or log walls are exterior walls that separate conditioned space from exterior weather conditions. The walls shall be modeled as exterior or integral insulation assemblies or as interior insulation assemblies depending upon the location of the insulation relative to the mass of the walls. The insulation positions are reflected in the heating and cooling energy costs multipliers in Table A-1.

A4.1.5 Doors. Doors separate conditioned space from exterior weather conditions, enclosed garages, and enclosed porches. The construction can be any material.

A4.1.6 Floors Over Exterior Ambient Conditions. Floors over exterior ambient conditions separate conditioned space from exterior weather conditions. Examples of exterior ambient conditions include overhangs, carports, enclosed garages, and enclosed porches. The framing construction can be wood or cold-formed steel.

A4.1.7 Floors Over Unconditioned Spaces. Floors over unconditioned spaces separate conditioned space from unconditioned space. Examples of unconditioned space include vented crawlspace and basement. The framing construction can be wood or cold-formed steel.

A4.1.8 Walls Adjacent to Unconditioned Spaces. Walls adjacent to unconditioned spaces separate conditioned space from unconditioned space. Examples of interior walls that separate conditioned space from unconditioned space include vented crawlspace, basement, and mechanical rooms. The framing construction can be any material.

A4.2 Vertical Fenestration Envelope Options. Vertical fenestration separates conditioned space from exterior weather conditions. The analysis of vertical fenestration options shall use the following equations. These equations assume that the fenestration is uniformly distributed on the four cardinal orientations No restrictions on the fenestration area are allowed.

$$HEAT = U_{fo} \cdot A \cdot HECM + SHGC_{fo} \cdot A \cdot HECM \quad \text{(Eq. A-9)}$$

where

A = area of all fenestration, ft^2

U_{fo} = overall area-weighted fenestration thermal transmittance, Btu/h·ft^2·°F

$SHGC_{fo}$ = overall area-weighted solar heat gain coefficient for fenestration, dimensionless

and

$$COOL = U_{fo} \cdot A \cdot CECM + SHGC_{fo} \cdot A \cdot CECM \quad \text{(Eq. A-10)}$$

A4.3 Skylight Options. The analysis of skylight options shall use the following equations. These equations assume that the skylights are uniformly distributed on the four cardinal orientations. This analysis shall be used when the skylight area exceeds the one percent of the conditioned floor area allowed under the prescriptive criteria in Section 5.2. When the skylight area exceeds the one percent limit, the ceiling area shall be reduced to reflect the increased area of the skylights and the ceiling shall be included in the envelope trade-off analysis.

$$HEAT = U_{so} \cdot A \cdot HECM + SHGC_{so} \cdot A \cdot HECM \quad \text{(Eq. A-11)}$$

where

A = area of all skylights, ft^2

U_{so} = overall area-weighted skylight thermal transmittance, Btu/h·ft^2·°F

$SHGC_{so}$ = overall area-weighted solar heat gain coefficient for skylights, dimensionless and

$$COOL = U_{so} \cdot A \cdot CECM + SHGC_{so} \cdot A \cdot CECM \quad \text{(Eq. A-12)}$$

A4.4 Below-Grade Envelope Options. The analysis of below-grade envelope options shall use the following equations. The thermal conductance of the below-grade envelope options shall exclude the interior and exterior air film coefficients and the surrounding soil.

$$HEAT = C_o \cdot P \cdot HECM \quad \text{(Eq. A-12)}$$

where

C_o = overall perimeter-weighted thermal conductance, Btu/h·ft^2·°F

P = total perimeter of below-grade constructions, ft

and

$$COOL = C_o \cdot P \cdot CECM \quad \text{(Eq. A-14)}$$

A4.4.1 Basement Walls. Basement walls separate conditioned space from exterior weather conditions. The wall construction can be concrete, masonry, or wood and the depth of the basement wall below grade can vary as can the depth of the insulation used. All of these variables are reflected in the heating and cooling energy cost multipliers in Table A-1.

A4.3.2 Crawl Space Walls. Crawlspace walls separate the crawlspace from exterior weather conditions. The wall constructions can be masonry, concrete, or wood, which are reflected in the heating and cooling energy cost multipliers in Table A-1

A4.5 Slab-on-Grade Envelope Options. The analysis of slab-on-grade envelope options shall use the following equations. The depth of the slab edge insulation is reflected in the heating and cooling energy cost multipliers in Table A-1.

$$HEAT = U_o \cdot P \cdot HECM \quad \text{(Eq. A-15)}$$

where

U_o = perimeter-weighted thermal transmittance of the slab edge insulation, Btu/h·ft·°F

P = total perimeter of insulated slab edge, ft

and

$$COOL = U_o \cdot P \cdot CECM \quad \text{(Eq. A-16)}$$

Table A-1 Heating and Cooling Energy Cost Multipliers for Envelope Trade-off Analysis

No.	Item
1	Ceilings with Attics
2	Ceilings without Attics
3	Above Grade Frame Wall and Band Joists
4	Above-grade Concrete, Masonry or Log walls - Exterior or Integral Insulation
5	Above-grade Concrete, Masonry or Log walls - Interior Insulation
6	Walls Adjacent to Unconditioned Space
7	Doors
8	Fenestration - Vertical Glazing - U-factors
9	Fenestration - Vertical Glazing - SHGC
10	Skylights - U-factors
11	Skylights - SHGC
12	Floors over Exterior Ambient Conditions
13	Floors over Unconditioned Spaces
14	Basement Walls - Concrete or Masonry - Deep - 1 ft above, 7 ft below grade - Top Half Insulated
15	Basement Walls - Concrete or Masonry - Deep - 1 ft above, 7 ft below grade - Entire Wall Insulated
16	Basement Walls - concrete or masonry - Shallow 4 ft above, 4 ft below grade - Entire wall insulated
17	Slab-on-grade - 2 ft
18	Slab-on-grade - 4 ft
19	Crawl Space Walls - Concrete or masonry
20	Crawl Space Walls - Wood
21	Basement Walls - Wood - Deep - 1 ft above, 7 ft below grade
22	Basement Walls - Wood - Shallow – 4 ft above, 4 ft below grade

Table A-1 (continued)
Heating and Cooling Energy Cost Multipliers for Envelope Trade-off Analysis

Heating Energy Cost Multipliers (HECM) by Climate Zones									
No.	1	2	3A,B	3C	4	5	6	7	8
1	0.41	2.25	4.77	5.34	8.51	11.43	14.45	18.33	25.67
2	0.36	1.99	4.22	4.72	7.53	10.11	12.78	16.21	22.71
3	0.33	1.82	3.85	4.31	6.88	9.23	11.67	14.80	20.74
4	0.33	1.82	3.85	4.31	6.88	9.23	11.67	14.80	20.74
5	0.33	1.82	3.85	4.31	6.88	9.23	11.67	14.80	20.74
6	0.09	0.47	0.99	1.11	1.77	2.37	3.00	3.81	5.33
7	0.33	1.82	3.85	4.31	6.88	9.23	11.67	14.80	20.74
8	0.32	1.73	3.67	4.11	6.55	8.79	11.11	14.10	19.75
9	–0.20	–1.09	–2.32	–2.60	–4.14	–5.56	–7.03	–8.91	–12.48
10	0.32	1.73	3.67	4.11	6.55	8.79	11.11	14.10	19.75
11	–1.55	–2.87	–4.69	–5.10	–7.38	–9.48	–11.65	–14.45	–19.74
12	0.33	1.82	3.85	4.31	6.88	9.23	11.67	14.80	20.74
13	0.09	0.47	0.99	1.11	1.77	2.37	3.00	3.81	5.33
14	0.41	2.25	4.77	5.34	8.51	11.43	14.45	18.33	25.67
15	0.57	3.12	6.60	7.40	11.79	15.83	20.00	25.38	35.55
16	0.88	4.85	10.27	11.50	18.34	24.62	31.11	39.47	55.30
17	0.06	0.30	0.64	0.72	1.15	1.54	1.94	2.47	3.46
18	0.07	0.39	0.83	0.92	1.47	1.98	2.50	3.17	4.44
19	0.37	2.03	4.31	4.83	7.70	10.33	13.06	16.56	23.20
20	0.51	2.77	5.87	6.57	10.48	14.07	17.78	22.56	31.60
21	0.81	4.41	9.36	10.48	16.70	22.42	28.34	35.95	50.36
22	1.39	7.62	16.14	18.08	28.82	38.69	48.89	62.03	86.89

Cooling Energy Cost Multipliers (CECM) by Climate Zones									
No.	1	2	3A,B	3C	4	5	6	7	8
1	2.94	2.39	1.66	1.24	1.01	0.89	0.78	0.44	0.32
2	2.50	2.04	1.41	1.05	0.86	0.76	0.66	0.38	0.27
3	1.47	1.20	0.83	0.62	0.51	0.44	0.39	0.22	0.16
4	1.20	0.98	0.68	0.51	0.42	0.36	0.32	0.18	0.13
5	1.16	0.95	0.65	0.49	0.40	0.35	0.31	0.18	0.13
6	0.59	0.48	0.33	0.25	0.20	0.18	0.16	0.09	0.06
7	1.47	1.20	0.83	0.62	0.51	0.44	0.39	0.22	0.16
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	5.48	4.46	3.09	2.31	1.89	1.66	1.45	0.83	0.60
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	23.84	17.69	11.24	8.53	7.39	6.83	6.39	5.36	5.10
12	1.47	1.20	0.83	0.62	0.51	0.44	0.39	0.22	0.16
13	0.59	0.48	0.33	0.25	0.20	0.18	0.16	0.09	0.06
14	0.59	0.48	0.33	0.25	0.20	0.18	0.16	0.09	0.06
15	0.88	0.72	0.50	0.37	0.30	0.27	0.23	0.13	0.10
16	2.06	1.68	1.16	0.87	0.71	0.62	0.54	0.31	0.23
17	0.44	0.36	0.25	0.19	0.15	0.13	0.12	0.07	0.05
18	0.44	0.36	0.25	0.19	0.15	0.13	0.12	0.07	0.05
19	1.47	1.20	0.83	0.62	0.51	0.44	0.39	0.22	0.16
20	2.79	2.27	1.58	1.17	0.96	0.84	0.74	0.42	0.31
21	2.64	2.15	1.49	1.11	0.91	0.80	0.70	0.40	0.29
22	5.29	4.31	2.98	2.23	1.82	1.60	1.40	0.80	0.58

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.