

## CHAPTER 5

# RESIDENTIAL BUILDING DESIGN BY COMPONENT PERFORMANCE APPROACH

### SECTION 501 GENERAL

**501.1 Scope.** Residential buildings or portions thereof that enclose conditioned space shall be constructed to meet the requirements of this chapter.

### SECTION 502 BUILDING ENVELOPE REQUIREMENTS

**502.1 General requirements.** The building envelope shall comply with the applicable provisions of Sections 502.1.1 through 502.1.5 regardless of the means of demonstrating envelope compliance as set forth in Section 502.2.

**502.1.1 Moisture control.** The building design shall not create conditions of accelerated deterioration from moisture condensation. In Zone 11, above-grade frame walls, floors and ceilings that are not ventilated to allow moisture to escape shall be required to have an approved vapor retarder. The vapor retarder shall be installed on the warm-in-winter side of the thermal insulation.

**Exceptions:**

1. In construction where moisture or its freezing will not damage the materials.
2. Where other approved means to avoid condensation are provided.

**502.1.2 Masonry veneer.** When insulation is placed on the exterior of a foundation supporting a masonry veneer exterior, the horizontal foundation surface supporting the veneer is not required to be insulated to satisfy any foundation insulation requirement.

**502.1.3 Recessed lighting fixtures.** When installed in the building envelope, recessed lighting fixtures shall meet one of the following requirements:

1. Type IC rated, manufactured with no penetrations between the inside of the recessed fixture and ceiling cavity and sealed or gasketed to prevent air leakage into the unconditioned space.
2. Type IC or non-IC rated, installed inside a sealed box constructed from a minimum 0.5-inch-thick (12.7 mm) gypsum wallboard or constructed from a pre-formed polymeric vapor barrier, or other air-tight assembly manufactured for this purpose, while maintaining required clearances of not less than 0.5 inch (12.7 mm) from combustible material and not less than 3 inches (76 mm) from insulation material.
3. Type IC rated, in accordance with ASTM E 283 admitting no more than 2.0 cubic feet per minute (cfm) (0.944 L/s) of air movement from the conditioned space to the ceiling cavity. The lighting fixture

shall be tested at 1.57 pounds per square foot (psf) (75 Pa) pressure difference and shall be labeled.

**502.1.4 Air leakage.** Provisions for air leakage shall be in accordance with Sections 502.1.4.1 and 502.1.4.2.

**502.1.4.1 Window and door assemblies.** Window and door assemblies installed in the building envelope shall comply with the maximum allowable air leakage rates in Table 502.1.4.1.

**Exception:** Site-constructed windows and doors sealed in accordance with Section 502.1.4.2.

**TABLE 502.1.4.1  
ALLOWABLE AIR LEAKAGE RATES<sup>a, b</sup>**

| WINDOWS<br>(cfm per square foot of window area) | DOORS<br>(cfm per square foot of door area) |                     |
|---|---|---------------------|
|   | Sliding                                     | Swinging            |
| 0.3 <sup>b, d</sup>                             | 0.3 <sup>d</sup>                            | 0.5 <sup>c, d</sup> |

For SI: 1 cfm/ft<sup>2</sup> = 5 L/S · m<sup>2</sup>.

- a. When tested in accordance with ASTM E 283.
- b. See AAMA/WDMA 101/I.S.2.
- c. Requirement based on assembly area.
- d. See NFRC 400.

**502.1.4.2 Caulking and sealants.** All penetrations: site-built windows, doors and skylights; openings between window and door assemblies and their respective jambs and framing; and other sources of air leakage (infiltration and exfiltration) through the building thermal envelope shall be caulked, gasketed, weather-stripped, wrapped or otherwise sealed to limit uncontrolled air movement.

This includes sealing around tubs and showers, at the attic and crawl space panels, at recessed lights and around all plumbing and electrical penetrations. These are openings located in the building envelope between conditioned space and unconditioned space or between the conditioned space and the outside.

**502.1.5 Fenestration solar heat gain coefficient.** The combined solar heat gain coefficient (the area-weighted average) of all glazed fenestration products (including the effects of any permanent exterior solar shading devices) in the building shall not exceed 0.4.

**502.2 Heating and cooling criteria.** The building envelope shall meet the provisions of Table 502.2. Compliance shall be demonstrated in accordance with Section 502.2.1, 502.2.2, 502.2.3, 502.2.4 or 502.2.5, as applicable.

Energy measure tradeoffs utilizing equipment exceeding the requirements of Section 503, 504 or 505 shall only use the compliance methods described in Chapter 4.

**TABLE 502.2  
HEATING AND COOLING CRITERIA<sup>a</sup>**

| ELEMENT                                 | MODE               | DETACHED ONE- AND TWO-FAMILY DWELLINGS | GROUP R-2, R-4 OR TOWNHOUSES |
|---|--------------------|--|------------------------------|
|   |                    | $U_o$                                  | $U_o$                        |
| Walls                                   | Heating or cooling | —                                      | —                            |
| Roof/ceiling                            | Heating or cooling | —                                      | —                            |
| Floors over unheated spaces             | Heating or cooling | —                                      | —                            |
| Heated slab on grade <sup>b,f</sup>     | Heating            | $R$ -value =                           | $R$ -value =                 |
| Unheated slab on grade <sup>c,d,f</sup> | Heating            | $R$ -value =                           | $R$ -value =                 |
| Basement wall <sup>e,f</sup>            | Heating or cooling | $U$ -factor =                          | $U$ -factor =                |
| Crawl space wall <sup>e,f</sup>         | Heating or cooling | $U$ -factor =                          | $U$ -factor =                |

- For SI: 1 Btu/h · ft<sup>2</sup> · °F = 5.678 W/(m<sup>2</sup> · K), °C = [(°F)-32]/1.8.
- Values shall be determined by using the graphs [Figures 502.2(1), 502.2(2), 502.2(3), 502.2(4), 502.2(5) and 502.2(6)] using HDD as specified in Section 302.
  - There are no insulation requirements for heated slabs in locations having less than 500 HDD.
  - There are no insulation requirements for unheated slabs in locations having less than 2,500 HDD.
  - Slab edge insulation is not required for unheated slabs in areas of very heavy termite infestation probability in accordance with Section 502.2.1.4, and as shown in Figure 502.2(7). When horizontal termite inspection, clearance and/or wicking gaps are used, wall insulation for closed crawl spaces is not required for the allowable gap widths listed in Table 502.2(2).
  - Basement and crawl space wall  $U$ -factors shall be based on the wall components and surface air films. Adjacent soil shall not be considered in the determination of the  $U$ -factor.
  - Typical foundation insulation techniques can be found in the DOE *Building Foundation Design Handbook*.

**TABLE 502.2(2)  
WALL INSULATION ALLOWANCES FOR  
TERMITE TREATMENT AND INSPECTION GAPS**

| MAXIMUM GAP WIDTH (inches) | INSULATION LOCATION | GAP DESCRIPTION  |
|----------------------------|---------------------|--|
| 3                          | Outside             | Above-grade inspection between top of insulation and bottom of siding.                                     |
| 6                          | Outside             | Below-grade treatment.   |
| 4 <sup>a</sup>             | Inside              | Wall inspection between top of insulation and bottom of sill.  |
| 4 <sup>a</sup>             | Inside              | Clearance/wicking space between bottom of insulation and top of ground surface, footing or concrete floor. |

- For SI: 1 inch = 25.4 mm.
- No insulation shall be required on masonry wall of 9 inches height or less.

**502.2.1 Compliance by performance on an individual component basis.** Each component of the building envelope shall meet the provisions of Table 502.2 as provided in Sections 502.2.1.1 through 502.2.1.6.

**502.2.1.1 Walls.** The combined thermal transmittance value ( $U_o$ ) of the gross area of exterior walls shall not exceed the value given in Table 502.2. Equation 5-1 shall be used to determine acceptable combinations to meet this requirement:

$$U_o = \frac{(U_w \times A_w) + (U_g \times A_g) + (U_d \times A_d)}{A_o} \tag{Equation 5-1}$$

where:

$U_o$  = The average thermal transmittance of the gross area of the exterior walls.

$A_o$  = The gross area of exterior walls.

$U_w$  = The combined thermal transmittance of the various paths of heat transfer through the opaque exterior wall area.

$A_w$  = Area of exterior walls that are opaque.

$U_g$  = The combined thermal transmittance of all glazing within the gross area of exterior walls.

$A_g$  = The area of all glazing within the gross area of exterior walls.

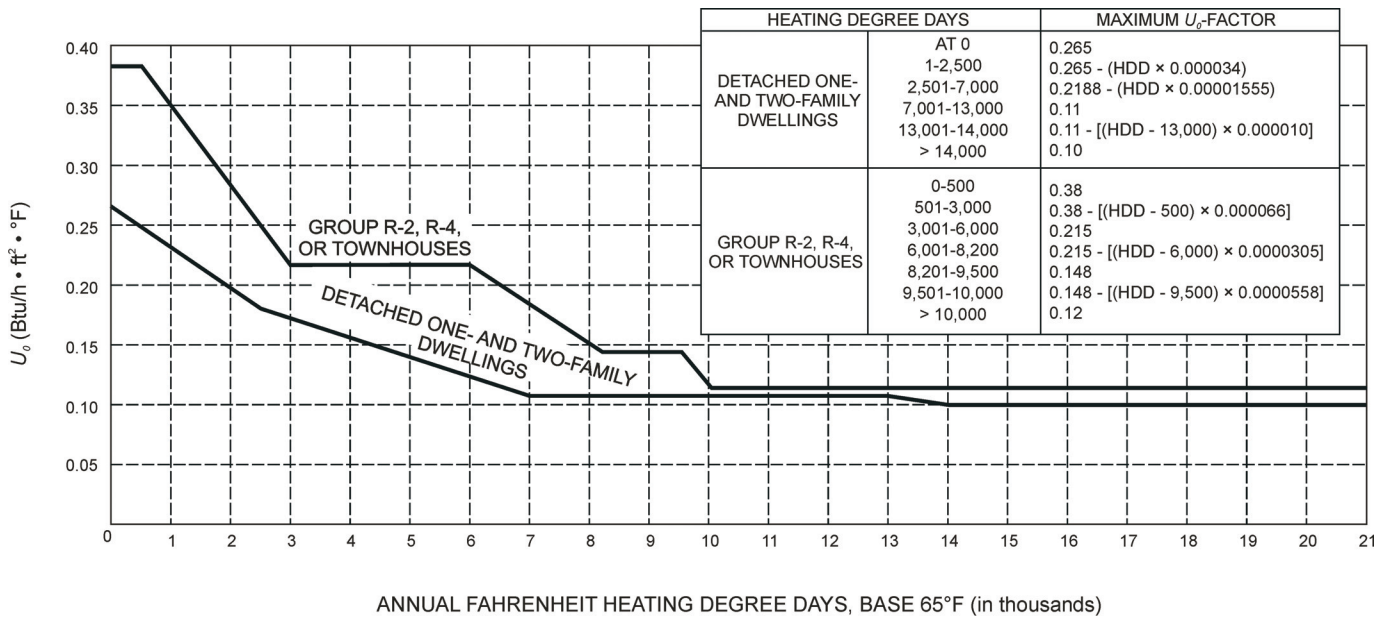
$U_d$  = The combined thermal transmittance of all opaque doors within the gross area of exterior walls.

$A_d$  = The area of all opaque doors within the gross area of exterior walls.

**Notes:** (1) When more than one type of wall, window or door is used, the  $U$  and  $A$  terms for those items shall be expanded into subelements as:

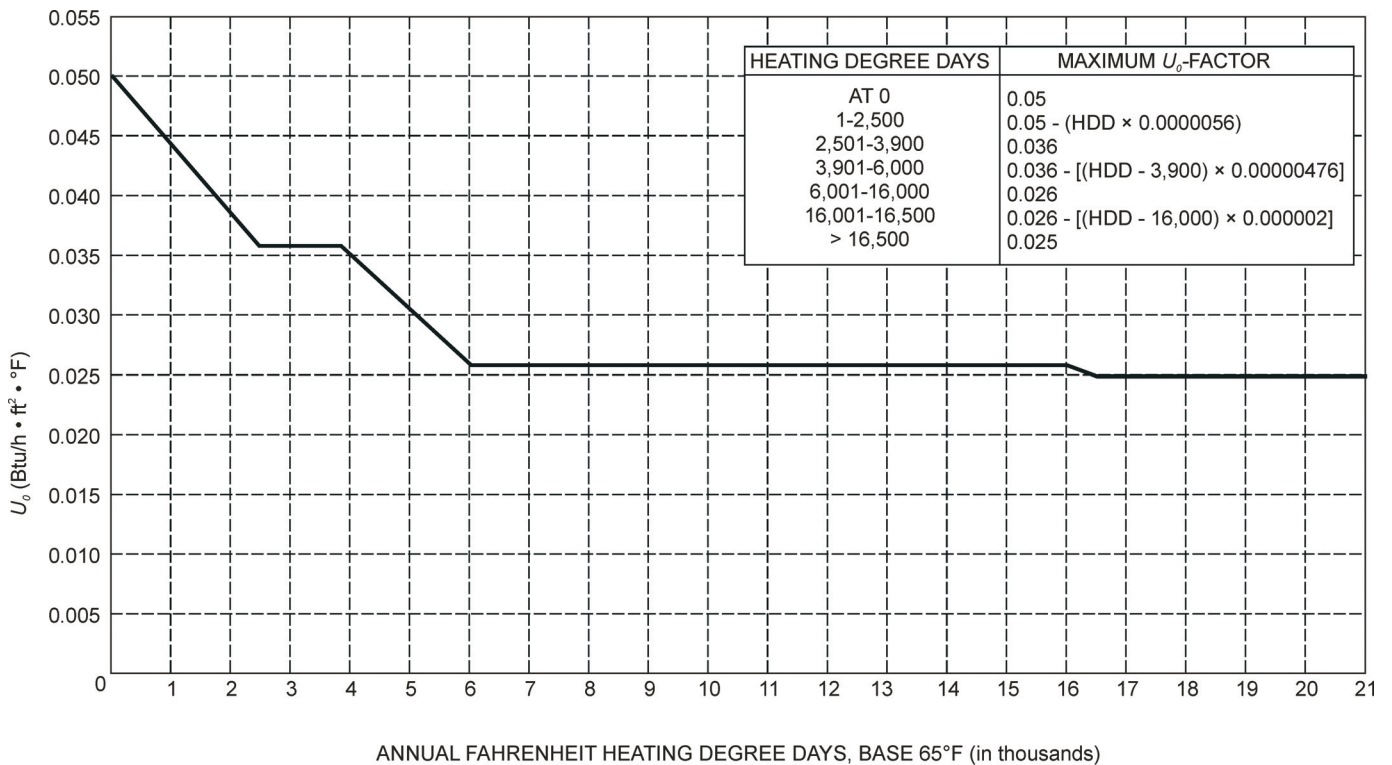
$$(U_{w1} A_{w1}) + (U_{w2} A_{w2}) + (U_{w3} A_{w3}) + \dots \text{ (etc.)} \tag{Equation 5-2}$$

(2) Access doors or hatches in a wall assembly shall be included as a subelement of the wall assembly.



For SI:  $1 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F} = 5.678\text{W}/(\text{m}^2 \cdot \text{K})$ ,  $^\circ\text{C} = [(^\circ\text{F})-32]/1.8$ .

FIGURE 502.2(1)  
 $U_o$ -FACTORS—WALLS: RESIDENTIAL BUILDINGS



For SI:  $1 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F} = 5.678\text{W}/(\text{m}^2 \cdot \text{K})$ ,  $^\circ\text{C} = [(^\circ\text{F})-32]/1.8$ .

FIGURE 502.2(2)  
 $U_o$ -FACTORS—ROOF/CEILINGS

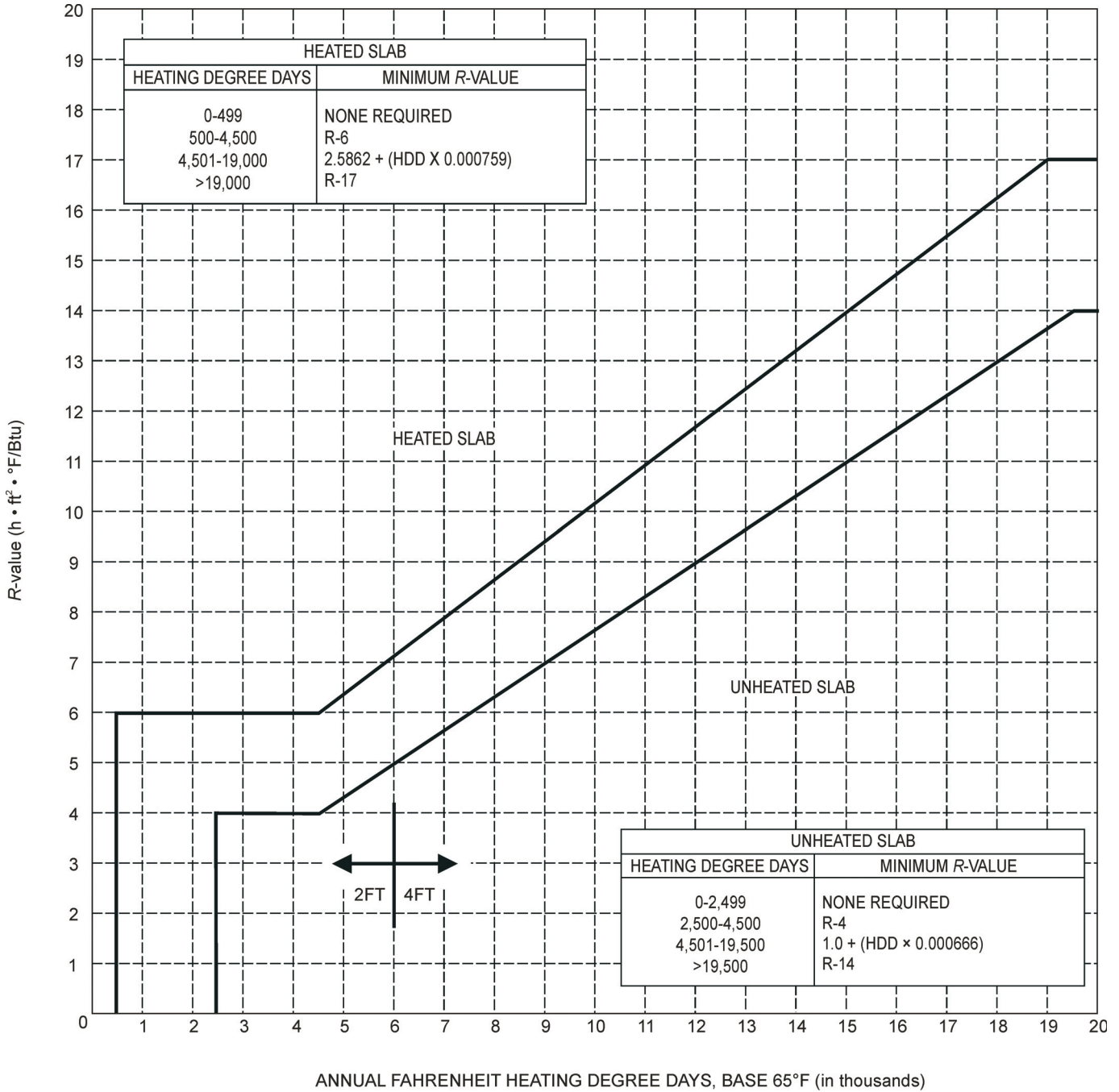
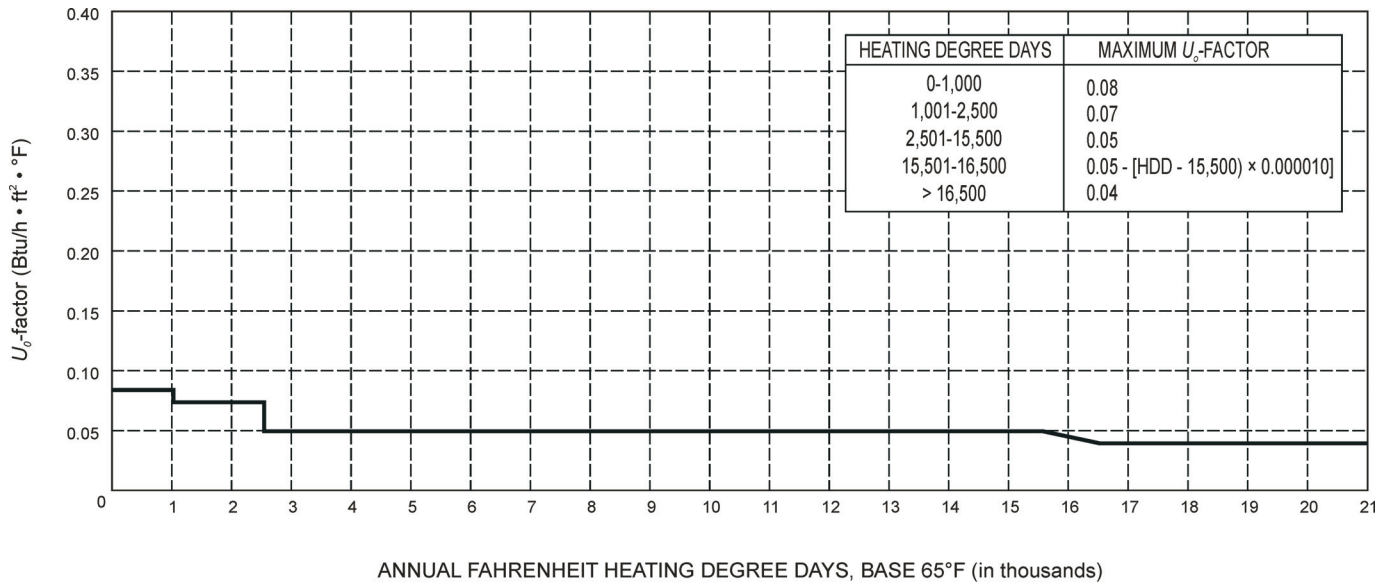


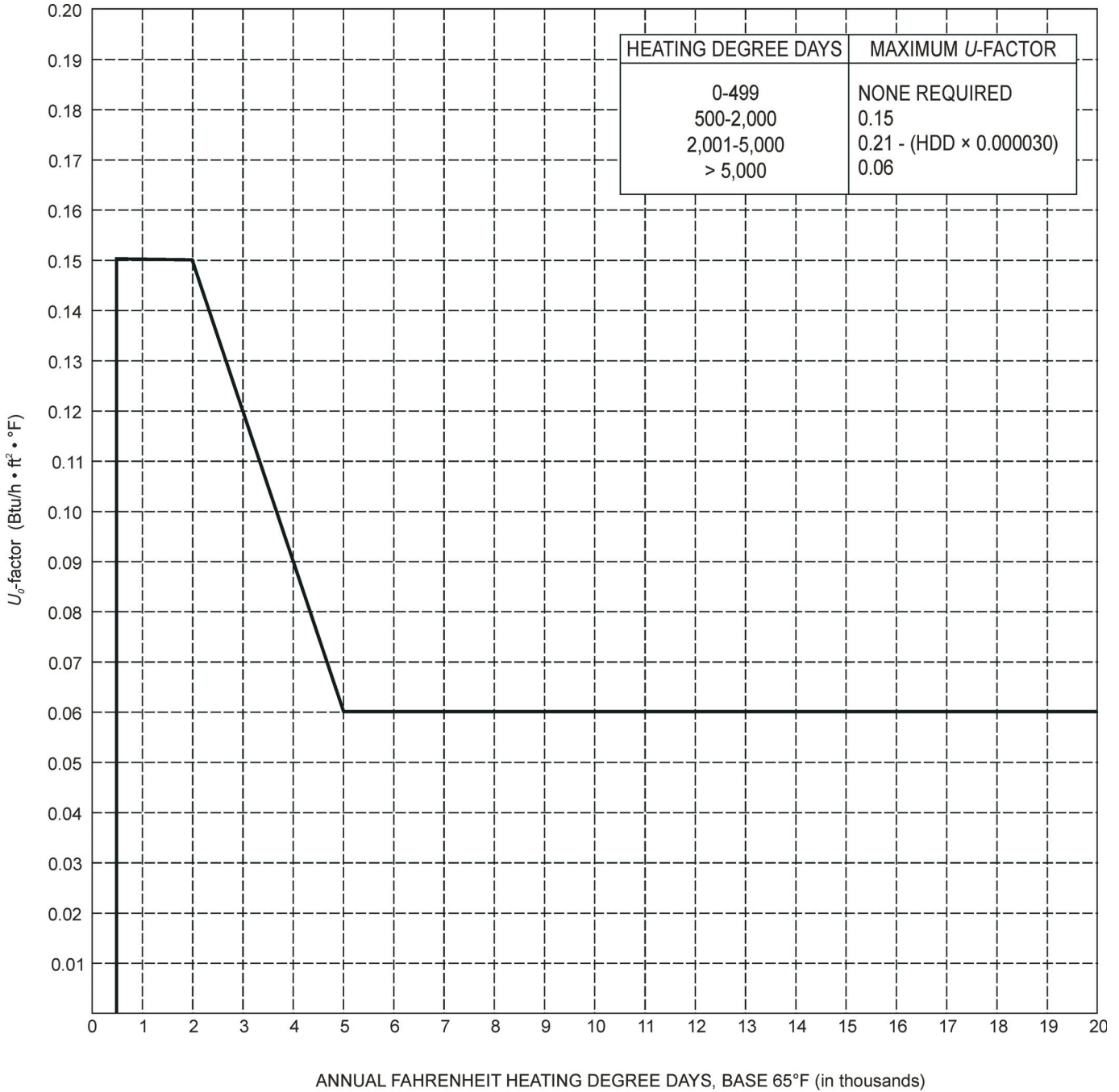
FIGURE 502.2(3)  
R-VALUES—SLAB ON GRADE

For SI: 1 Btu/h · ft<sup>2</sup> · °F = 5.678W/(m<sup>2</sup> · K), °C = [(°F)-32]/1.8.



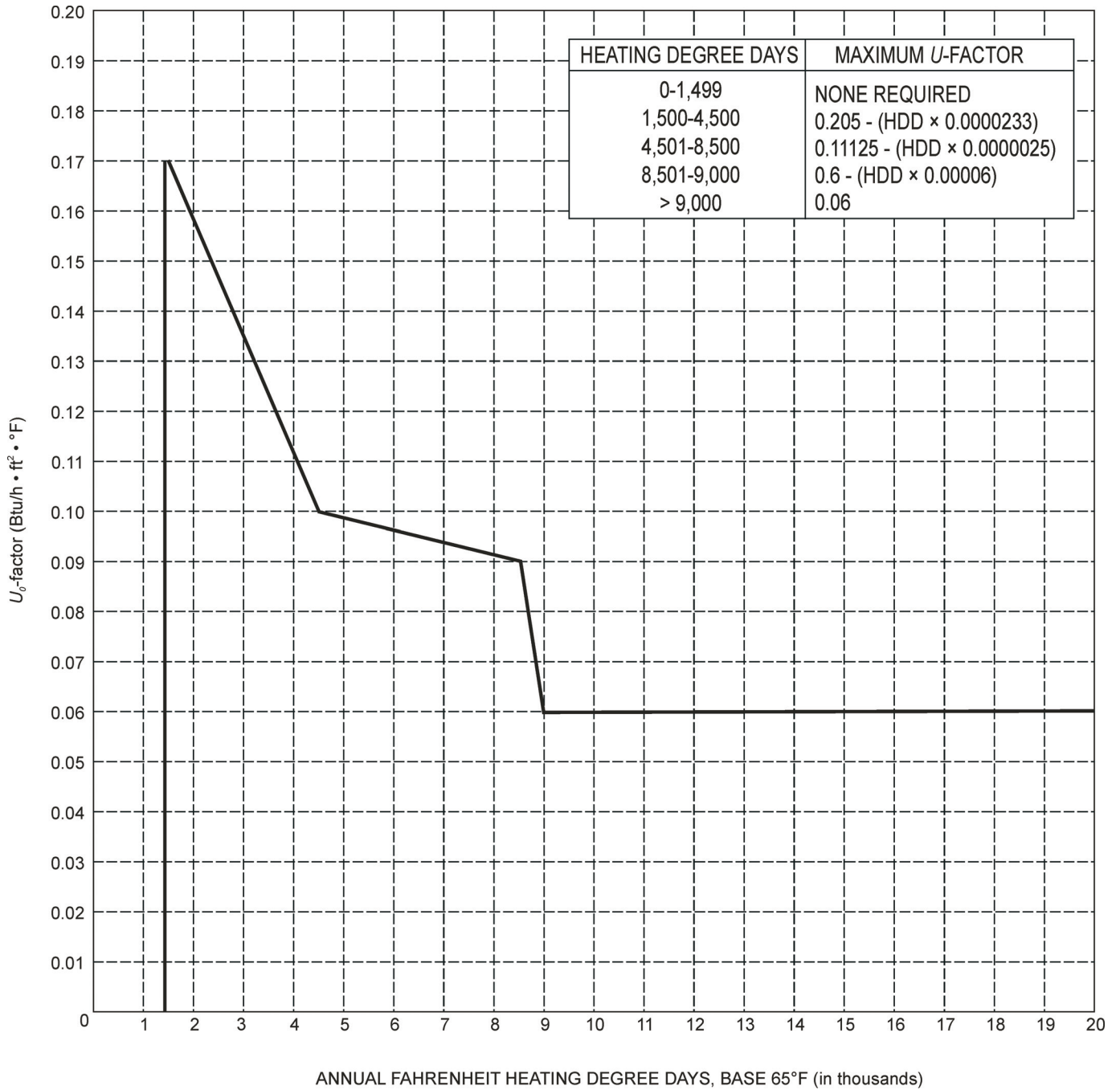
For SI:  $1 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F} = 5.678 \text{ W}/(\text{m}^2 \cdot \text{K})$ ,  $^\circ\text{C} = [(\text{°F}) - 32]/1.8$ .

**FIGURE 502.2(4)**  
 **$U_o$ -FACTORS—FLOOR OVER UNHEATED SPACES**



For SI: 1 Btu/h · ft<sup>2</sup> · °F = 5.678W/(m<sup>2</sup> · K), °C = [(°F)-32]/1.8.

FIGURE 502.2(5)  
U-FACTORS—CRAWL SPACE WALLS



For SI: 1 Btu/h · ft<sup>2</sup> · °F = 5.678W/(m<sup>2</sup> · K), °C = [(°F)-32]/1.8.

FIGURE 502.2(6)  
U-FACTORS—BASEMENT WALLS





**502.2.1.1.1 Steel stud framed walls.** When the walls contain steel stud framing, the value of  $U_w$  used in Equation 5-1 shall be recalculated using a series path procedure to correct for parallel path thermal bridging. The  $U_w$  for purposes of Equation 5-1 of steel stud walls shall be determined as follows:

$$U_w = \frac{1}{R_s + (R_{ins} \times F_c)} \quad \text{(Equation 5-3)}$$

where:

$R_s$  = The total thermal resistance of the elements comprising the wall assembly along the path of heat transfer, excluding the cavity insulation and the steel stud.

$R_{ins}$  = The R-value of the cavity insulation.

$F_c$  = The correction factor listed in Table 502.2.1.1.1.

**Exception:** Overall system tested  $U_w$  values for steel stud framed walls from approved laboratories.

**TABLE 502.2.1.1.1  
F<sub>c</sub> VALUES FOR WALL SECTIONS WITH STEEL STUDS  
PARALLEL PATH CORRECTION FACTORS**

| NOMINAL STUD SIZE <sup>a</sup> | SPACING OF FRAMING (inches) | CAVITY INSULATION R-VALUE | CORRECTION FACTOR |
|--------------------------------|-----------------------------|---------------------------|-------------------|
| 2 × 4                          | 16 o.c.                     | R-11                      | 0.50              |
|                                |                             | R-13                      | 0.46              |
|                                |                             | R-15                      | 0.43              |
| 2 × 4                          | 24 o.c.                     | R-11                      | 0.60              |
|                                |                             | R-13                      | 0.55              |
|                                |                             | R-15                      | 0.52              |
| 2 × 6                          | 16 o.c.                     | R-19                      | 0.37              |
|                                |                             | R-21                      | 0.35              |
| 2 × 6                          | 24 o.c.                     | R-19                      | 0.45              |
|                                |                             | R-21                      | 0.43              |
| 2 × 8                          | 16 o.c.                     | R-25                      | 0.31              |
| 2 × 8                          | 24 o.c.                     | R-25                      | 0.38              |

For SI: 1 inch = 25.4 mm.

a. Applies to steel studs up to a maximum thickness of 0.064 inches (16 gage).

**502.2.1.1.2 Mass walls.** When thermal mass credit is desired for an exterior wall having a heat capacity greater than or equal to 6 Btu/ft<sup>2</sup> · °F [1.06 kJ/(m<sup>2</sup> · K)], the  $U_w$  for such a wall shall be less than or equal to the applicable value in Table 502.2.1.1.2(1), 502.2.1.1.2(2) or 502.2.1.1.2(3) based on the  $U_w$  required for an exterior wall having a heat capacity less than 6 Btu/ft<sup>2</sup> · °F [1.06 kJ/(m<sup>2</sup> · K)] as determined by Section 502.2.1.1, Equation 5-1 and Figure 502.2(1).

**Note:** Masonry or concrete walls having a mass greater than or equal to 30 lb/ft<sup>3</sup> (146 kg/m<sup>3</sup>) of exterior wall area and solid wood walls having a

mass greater than or equal to 20 lb/ft<sup>3</sup> (98 kg/m<sup>3</sup>) of exterior wall area have heat capacities equal to or exceeding 6 Btu/ft<sup>2</sup> · °F [1.06 kJ/(m<sup>2</sup> · K)] of exterior wall area.

The heat capacity of the wall shall be determined using Equation 5-4 as follows:

$$HC = w \times c \quad \text{(Equation 5-4)}$$

where:

$HC$  = Heat capacity of the exterior wall, Btu/ft<sup>2</sup> · °F [kJ/(m<sup>2</sup> · K)] of exterior wall area.

$w$  = Mass of the exterior wall, lb/ft<sup>2</sup> (kg/m<sup>2</sup>) of exterior wall area is the density of the exterior wall material, lb/ft<sup>3</sup> (kg/m<sup>3</sup>) multiplied by the thickness of the exterior wall, ft (m).

$c$  = Specific heat of the exterior wall material, Btu/lb · °F [kJ/(kg · K)] of exterior wall area as determined from Chapter 24 of the ASHRAE *Fundamentals Handbook*.

**502.2.1.2 Roof/ceiling.** The combined thermal transmittance value ( $U_o$ ) of the gross area of the roof or ceiling assembly shall not exceed the value given in Table 502.2. Equation 5-5 shall be used to determine acceptable combinations to meet this requirement.

$$U_o = \frac{(U_R \times A_R) + (U_S \times A_S)}{A_o} \quad \text{(Equation 5-5)}$$

where:

$U_o$  = The average thermal transmittance of the gross roof/ceiling area, Btu/h · ft<sup>2</sup> · °F [W/(m<sup>2</sup> · K)].

$A_o$  = The gross area of the roof/ceiling assembly, square feet (m<sup>2</sup>).

$U_R$  = The combined thermal transmittance of the various paths of heat transfer through the opaque roof/ceiling area, Btu/h · ft<sup>2</sup> · °F [W/(m<sup>2</sup> · K)].

$A_R$  = Opaque roof/ceiling assembly area, square feet (m<sup>2</sup>).

$U_s$  = The combined thermal transmittance of the area of all skylight elements in the roof/ceiling assembly (See Section 502.2.1.2.1), Btu/h · ft<sup>2</sup> · °F [W/(m<sup>2</sup> · K)].

$A_s$  = The area (including frame) of all skylights in the roof/ceiling assembly, square feet (m<sup>2</sup>). (see Section 502.2.1.2.1).

**Notes:** (1) When more than one type of roof/ceiling and/or skylight is used, the  $U$  and  $A$  terms for those items shall be expanded into their subelements as in Equation 5-6:

$$(U_{R1} \times A_{R1}) + (U_{R2} \times A_{R2}) + \dots \text{ etc.} \quad \text{(Equation 5-6)}$$

(2) Access doors or hatches in a roof/ceiling assembly shall be included as a subelement of the roof/ceiling assembly.

**TABLE 502.2.1.1.2(1)**  
**REQUIRED  $U_w$  FOR WALL WITH A HEAT CAPACITY EQUAL**  
**TO OR EXCEEDING 6 Btu/ft<sup>2</sup> · °F WITH INSULATION**  
**PLACED ON THE EXTERIOR OF THE WALL MASS**

| HEATING DEGREE DAYS | $U_w$ REQUIRED FOR WALLS WITH A HEAT CAPACITY LESS THAN 6 Btu/ft <sup>2</sup> · °F AS DETERMINED BY USING EQUATION 5-1 AND FIGURE 502.2(1) |      |      |      |      |      |      |      |      |      |      |
|---------------------|--|------|------|------|------|------|------|------|------|------|------|
|                     | 0.24   | 0.22 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |
| 0 - 2,000           | 0.33   | 0.31 | 0.28 | 0.26 | 0.23 | 0.21 | 0.18 | 0.16 | 0.13 | 0.11 | 0.08 |
| 2,001 - 4,000       | 0.32   | 0.30 | 0.27 | 0.25 | 0.22 | 0.20 | 0.17 | 0.15 | 0.13 | 0.10 | 0.08 |
| 4,001 - 5,500       | 0.30   | 0.28 | 0.25 | 0.23 | 0.21 | 0.18 | 0.16 | 0.14 | 0.11 | 0.09 | 0.07 |
| 5,501 - 6,500       | 0.28   | 0.26 | 0.23 | 0.21 | 0.19 | 0.17 | 0.15 | 0.12 | 0.10 | 0.08 | 0.06 |
| 6,501 - 8,000       | 0.26   | 0.24 | 0.22 | 0.19 | 0.17 | 0.15 | 0.13 | 0.11 | 0.09 | 0.07 | 0.05 |
| > 8,000             | 0.24   | 0.22 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |

For SI: °C = [(°F)-32]/1.8, 1 Btu/ft<sup>2</sup> · °F = 0.176 kJ/(m<sup>2</sup> · °K).

**TABLE 502.2.1.1.2(2)**  
**REQUIRED  $U_w$  FOR WALL WITH A HEAT CAPACITY EQUAL**  
**TO OR EXCEEDING 6 Btu/ft<sup>2</sup> · °F WITH INSULATION**  
**PLACED ON THE INTERIOR OF THE WALL MASS**

| HEATING DEGREE DAYS | $U_w$ REQUIRED FOR WALLS WITH A HEAT CAPACITY LESS THAN 6 Btu/ft <sup>2</sup> · °F AS DETERMINED BY USING EQUATION 5-1 AND FIGURE 502.2(1) |      |      |      |      |      |      |      |      |      |      |
|---------------------|--|------|------|------|------|------|------|------|------|------|------|
|                     | 0.24   | 0.22 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |
| 0 - 2,000           | 0.29   | 0.27 | 0.25 | 0.22 | 0.20 | 0.17 | 0.15 | 0.12 | 0.09 | 0.07 | 0.04 |
| 2,001 - 4,000       | 0.28   | 0.26 | 0.24 | 0.21 | 0.19 | 0.16 | 0.14 | 0.12 | 0.09 | 0.07 | 0.04 |
| 4,001 - 5,500       | 0.27   | 0.25 | 0.23 | 0.21 | 0.19 | 0.16 | 0.14 | 0.11 | 0.09 | 0.07 | 0.04 |
| 5,501 - 6,500       | 0.26   | 0.24 | 0.22 | 0.20 | 0.17 | 0.15 | 0.13 | 0.11 | 0.09 | 0.06 | 0.04 |
| 6,501 - 8,000       | 0.25   | 0.23 | 0.21 | 0.19 | 0.17 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |
| > 8,000             | 0.24   | 0.22 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |

For SI: °C = [(°F)-32]/1.8, 1 Btu/ft<sup>2</sup> · °F = 0.176 kJ/(m<sup>2</sup> · °K).

**TABLE 502.2.1.1.2(3)**  
**REQUIRED  $U_w$  FOR WALL WITH A HEAT CAPACITY EQUAL**  
**TO OR EXCEEDING 6 Btu/ft<sup>2</sup> · °F WITH INTEGRAL**  
**INSULATION (INSULATION AND MASS MIXED, SUCH AS A LOG WALL)**

| HEATING DEGREE DAYS | $U_w$ REQUIRED FOR WALLS WITH A HEAT CAPACITY LESS THAN 6 Btu/ft <sup>2</sup> · °F AS DETERMINED BY USING EQUATION 5-1 AND FIGURE 502.2(1) |      |      |      |      |      |      |      |      |      |      |
|---------------------|--|------|------|------|------|------|------|------|------|------|------|
|                     | 0.24   | 0.22 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |
| 0 - 2,000           | 0.33   | 0.31 | 0.28 | 0.25 | 0.23 | 0.20 | 0.17 | 0.15 | 0.12 | 0.09 | 0.07 |
| 2,001 - 4,000       | 0.32   | 0.30 | 0.27 | 0.24 | 0.22 | 0.19 | 0.17 | 0.14 | 0.11 | 0.09 | 0.06 |
| 4,001 - 5,500       | 0.30   | 0.28 | 0.26 | 0.23 | 0.21 | 0.18 | 0.16 | 0.13 | 0.11 | 0.08 | 0.06 |
| 5,501 - 6,500       | 0.28   | 0.26 | 0.24 | 0.21 | 0.19 | 0.17 | 0.14 | 0.12 | 0.10 | 0.08 | 0.05 |
| 6,501 - 8,000       | 0.26   | 0.24 | 0.22 | 0.20 | 0.18 | 0.15 | 0.13 | 0.11 | 0.09 | 0.07 | 0.05 |
| > 8,000             | 0.24   | 0.22 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 | 0.06 | 0.04 |

For SI: °C = [(°F)-32]/1.8, 1 Btu/ft<sup>2</sup> · °F = 0.176 kJ/(m<sup>2</sup> · °K).

(3)When the roof/ceiling assembly contains cold-formed steel truss framing, the  $U_R$  value to be used in Equation 5-5 shall be determined by Equation 5-7, 5-8, or 5-9. These equations apply to cold-formed steel truss roof framing spaced at 24 inches (609 mm) on-center and where the penetrations of the truss members through the cavity insulation do not exceed three penetrations for each 4-foot (1220 mm) length of the truss.

For constructions without foam between the drywall and bottom chord of the steel truss use Equation 5-7:

$$U_R = \frac{1}{(0.864 \times R_{ins}) + 0.330} \quad \text{(Equation 5-7)}$$

where:

$R_{ins}$  = The  $R$ -value of the cavity insulation,  $h \cdot \text{ft}^2 \cdot \text{°F/Btu}$ .

For constructions with R-3 foam between the drywall and bottom chord of the steel truss use Equation 5-8:

$$U_R = \frac{1}{(0.864 \times R_{ins}) + 4.994} \quad \text{(Equation 5-8)}$$

For constructions with R-5 foam between the drywall and bottom chord of the steel truss use Equation 5-9:

$$U_R = \frac{1}{(0.864 \times R_{ins}) + 7.082} \quad \text{(Equation 5-9)}$$

**Exception:** Overall system tested  $U_R$  values for roof/ceiling assemblies from approved laboratories, when such data are acceptable to the code official.

(4)When the roof/ceiling assembly contains conventional C-shaped cold-formed joist/rafter steel framing, the  $U_R$  value to be used in equation 5-5 shall be determined Equation 5-10 as follows:

$$U_R = \frac{1}{R_s + (R_{ins} \times F_{cor})} \quad \text{(Equation 5-10)}$$

where:

$R_s$  = The 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,  $h \cdot \text{ft}^2 \cdot \text{°F/Btu}$ .

$R_{ins}$  = The  $R$ -value of the cavity insulation,  $h \cdot \text{ft}^2 \cdot \text{°F/Btu}$ .

$F_{cor}$  = The correction factor listed in Table 502.2.1.2, dimensionless.

**Exception:** Overall system tested  $U_R$  values for roof/ceiling assemblies from approved laboratories, when such data are acceptable to the code official.

**502.2.1.2.1 Skylights.** Skylight shafts, 12 inches (305 mm) in depth and greater, shall be insulated to no less than R-13 in climates 0 - 4,000 HDD and R-19 in climates greater than 4,000 HDD. The skylight shaft thermal performance shall not be included in the roof thermal transmission coefficient calculation.

**502.2.1.3 Floors over unheated spaces.** The combined thermal transmittance factor ( $U_o$ ) of the gross area of floors over unheated spaces shall not exceed the value given in Table 502.2. For floors over outdoor air (i.e., overhangs),  $U_o$ -factors shall not exceed the value for roofs given in Table 502.2. Equation 5-11 shall be used to determine acceptable combinations to meet this requirement.

$$U_o = \frac{(U_{f1} \times A_{f1}) + (U_{f2} \times A_{f2}) + \dots + (U_{fn} \times A_{fn})}{A_o} \quad \text{(Equation 5-11)}$$

TABLE 502.2.1.2  
CORRECTION FACTORS ( $F_{cor}$ ) FOR ROOF/CEILING ASSEMBLIES

| MEMBER SIZE <sup>a</sup> | SPACING OF FRAMING MEMBERS <sup>b</sup> (INCHES) | CAVITY INSULATION R-VALUE |      |      |      |
|--------------------------|--|---------------------------|------|------|------|
|                          |  | R-19                      | R-30 | R-38 | R-49 |
| 2 × 4                    | 16 o.c.  | 0.90                      | 0.94 | 0.95 | 0.96 |
| 2 × 6                    |  | 0.70                      | 0.81 | 0.85 | 0.88 |
| 2 × 8                    |  | 0.35                      | 0.65 | 0.72 | 0.78 |
| 2 × 10                   |  | 0.35                      | 0.27 | 0.62 | 0.70 |
| 2 × 12                   |  | 0.35                      | 0.27 | 0.51 | 0.62 |
| 2 × 4                    | 24 o.c.  | 0.95                      | 0.96 | 0.97 | 0.97 |
| 2 × 6                    |  | 0.78                      | 0.86 | 0.88 | 0.91 |
| 2 × 8                    |  | 0.44                      | 0.72 | 0.78 | 0.83 |
| 2 × 10                   |  | 0.44                      | 0.35 | 0.69 | 0.76 |
| 2 × 12                   |  | 0.44                      | 0.35 | 0.61 | 0.69 |

For SI: 1 inch = 25.4 mm.

a. Applies to steel framing members up to a maximum thickness of 0.064 inches (16 gage).

b. Linear interpolation for determining correction factors which are intermediate between those given in the table is permitted.

where:

$U_o$  = The average thermal transmittance of the gross floor area, Btu/h · ft<sup>2</sup> · °F [W/(m<sup>2</sup> · K)].

$A_o$  = The gross area of the different floor assemblies, square feet (m<sup>2</sup>).

$U_{fn}$  = The combined thermal transmittance of the various paths of heat transfer through the  $n^{\text{th}}$  floor assembly, Btu/h · ft<sup>2</sup> · °F [W/(m<sup>2</sup> · K)].

$A_{fn}$  = The area associated with the  $n^{\text{th}}$  floor assembly, square feet (m<sup>2</sup>).

**Note:** Access doors or hatches in a floor assembly shall be included as a subelement of the floor assembly.

**Exceptions:** When the floor assembly contains C-shaped, cold-formed steel framing, the value of  $U_{fn}$  used in Equation 5-11 shall be recalculated using a series of path procedure to correct for parallel path thermal bridging. The  $U_{fn}$  for purposes of Equation 5-11 for C-shaped, cold-formed steel-framing construction shall be determined using Equation 5-12 as follows:

$$U_{fn} = \frac{1}{R_{fn} + (R_{ins} \times F_{cor})} \quad \text{(Equation 5-12)}$$

where:

$R_{fn}$  = The 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 · ft<sup>2</sup> · °F/Btu.

$R_{ins}$  = The  $R$ -value of the cavity insulation, h · ft<sup>2</sup> · °F/Btu.

$F_{cor}$  = The correction factor listed in Table 502.2.1.3, dimensionless.

**Exception:** Overall system tested  $U_{fn}$  values for steel-framed floors from approved laboratories, when such data are acceptable to the code official.

**502.2.1.4 Slab-on-grade floors.** The thermal resistance of the insulation around the perimeter of the floor shall not be less than the value given in Table 502.2. Where insulation is not required in accordance with Footnote d to Table 502.2, building envelope compliance shall be demonstrated by using Section 502.2.2 or Chapter 4 with the actual slab insulation  $R$ -value in Table 502.2; or using Section 502.2.4.

Insulation shall be of an approved type, and placed on the outside of the foundation or on the inside of a foundation wall. In climates below 6,000 annual Fahrenheit HDD, the insulation shall extend downward from the elevation of the top of the slab for a minimum distance of 24 inches (610 mm) or downward to at least the bottom of the slab and then horizontally to the interior or exterior for a minimum total distance of 24 inches (610 mm). In all climates equal to or greater than 6,000 HDD, the insulation shall extend downward from the elevation of the top of the slab for a minimum of 48 inches (1219 mm) or downward to at least the bottom of the slab and then horizontally to the interior or exterior for a minimum total distance of 48 inches (1219 mm). In all climates, horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10 inches (254 mm) thick. The top edge of the insulation installed between the exterior wall and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.8 rad) angle away from the exterior wall.

**502.2.1.5 Crawl space walls.** If the floor above a crawl space does not meet the requirements of Section 502.2.1.3 and the crawl space does not have ventilation openings

TABLE 502.2.1.3  
CORRECTION FACTORS ( $F_{cor}$ ) FOR STEEL FLOOR ASSEMBLIES

| MEMBER SIZE <sup>a</sup> | SPACING OF FRAMING MEMBERS <sup>b</sup> (INCHES) | CAVITY INSULATION R-VALUE |                |                |
|--------------------------|--|---------------------------|----------------|----------------|
|                          |  | R-19                      | R-30           | R-38           |
| 2 × 6                    | 16 o.c.  | 0.70                      | Not Applicable | Not Applicable |
| 2 × 8                    |  | 0.35                      | Not Applicable | Not Applicable |
| 2 × 10                   |  | 0.35                      | 0.27           | Not Applicable |
| 2 × 12                   |  | 0.35                      | 0.27           | 0.24           |
| 2 × 6                    | 24 o.c.  | 0.78                      | Not Applicable | Not Applicable |
| 2 × 8                    |  | 0.44                      | Not Applicable | Not Applicable |
| 2 × 10                   |  | 0.44                      | 0.35           | Not Applicable |
| 2 × 12                   |  | 0.44                      | 0.35           | 0.32           |

For SI: 1 inch = 25.4 mm.

a. Applies to steel framing members up to a maximum thickness of 0.064 inches (16 gage).

b. Linear interpolation is permitted for determining correction factors which are between those given in the table.

that communicate directly with the outside air, then the exterior walls of the crawl space shall have a thermal transmittance value not exceeding the value given in Table 502.2. Where the inside ground surface is less than 12 inches (305 mm) below the outside finish ground level or the vertical wall insulation stops less than 12 inches (305 mm) below the outside finish ground, crawl space wall insulation shall extend vertically and horizontally a minimum total distance of 24 inches (610 mm) linearly from the outside finish ground level [see Appendix Detail 502.2.1.5(1), 502.2.1.5(2), 502.2.1.5(3) and the DOE *Foundation Design Handbook*].

**502.2.1.6 Basement walls.** The exterior walls of conditioned basements shall have a transmittance value not exceeding the value given in Table 502.2 from the top of the basement wall to a depth of 10 feet (3048 mm) below the outside finish ground level, or to the level of the basement floor, whichever is less.

**502.2.2 Compliance by total building envelope performance.** The building envelope design of a proposed building shall be permitted to deviate from the  $U_o$ -factors,  $U$ -factors, or  $R$ -values specified in Table 502.2, provided the total thermal transmission heat gain or loss for the proposed building envelope does not exceed the total heat gain or loss resulting from the proposed building's conformance to the values specified in Table 502.2. For basement and crawl space walls that are part of the building envelope, the  $U$ -factor of the proposed foundation shall be adjusted by the  $R$ -value of the adjacent soil where the corresponding  $U$ -factor in Table 502.2 is similarly adjusted. Heat gain or loss calculations for slab edge and basement or crawl space wall foundations shall be determined using methods consistent with the ASHRAE *Fundamentals Handbook*.

**502.2.3 Compliance by acceptable practice on an individual component basis.** Each component of the building envelope shall meet the provisions of Table 502.2 as provided in Sections 502.2.3.1 through 502.2.3.6. The various walls, roof and floor assemblies described in Section 502.2.3 are typical and are not intended to be all inclusive. Other assemblies shall be permitted, provided documentation is submitted indicating the thermal transmittance value of the opaque section. Documentation shall be in accordance with accepted engineering practice.

**502.2.3.1 Walls.** The  $U_o$  of the exterior wall shall be determined in accordance with Equation 5-13.

$$U_o = \frac{(U_f \times A_f) + U_w \times (100 - A_f)}{100} \quad \text{(Equation 5-13)}$$

where:

$U_o$  = The overall thermal transmittance of the gross exterior wall area.

$U_f$  = The average thermal transmittance of the glazing area.

$$A_f = \frac{\text{Glazing Area}}{\text{Gross Exterior Wall Area} \times 100}$$

(Equation 5-14)

$U_w$  = The average thermal transmittance of the opaque exterior wall area.

The  $U$ -factor for the opaque portion of the exterior wall ( $U_w$ ) shall meet the provisions of Table 502.2 as determined by Equation 5-13, and be selected from Table 502.2.3.1(1), 502.2.3.1(2) or 502.2.3.1(3) listed in the Appendix. The glazing  $U$ -factor ( $U_f$ ) and the percentage of glazing area ( $A_f$ ) shall consist of all glazed surfaces in the building envelope measured using the rough opening and including the sash, curbing and other framing elements that enclose conditioned spaces. The value of  $U_f$  shall be determined in accordance with Section 102.5.2. Opaque doors in the building envelope shall have a maximum  $U$ -factor of 0.35. One door shall be exempt from this requirement.

**Exceptions:**

1. When the exterior wall(s) is comprised of steel stud framing members, the procedure contained in Section 502.2.1.1.1 shall be used to adjust the  $U$ -factor of the opaque sections of such walls prior to selection of the appropriate acceptable practice(s) from Appendix Table 502.2.3.1(1).
2. When the thermal mass of the exterior building walls is considered, the procedure contained in Section 502.2.1.1.2 shall be used to adjust the  $U$ -factor of the opaque sections of such walls prior to the selection of the appropriate acceptable practice(s) from Table 502.2.3.1(2) or 502.2.3.1(3) listed in the Appendix.

**502.2.3.2 Roof/ceiling.** The roof/ceiling assembly shall be selected from Appendix Table 502.2.3.2 for a thermal transmittance value not exceeding the value specified for roofs/ceilings in Table 502.2.

**Exception:** When the roof/ceiling is comprised of assemblies containing truss type or C-shaped, cold-formed steel-framing members, the procedure outlined in Section 502.2.1.2 shall be used to adjust the roof/ceiling  $U$ -factor before selecting a roof/ceiling assembly from Appendix Table 502.2.3.2.

**502.2.3.3 Floors over unheated spaces.** The floor section over an unheated space shall be selected from Appendix Table 502.2.3.3 for the overall thermal transmittance factor ( $U_o$ ) not exceeding the value specified for floors over unheated spaces in Table 502.2. For floors over outdoor air (i.e., overhangs),  $U_o$ -factors for heating shall meet the same requirement as shown for roofs/ceilings in Table 502.2.

**Exception:** When the floor is comprised of C-shaped, cold-formed steel-framing members, the procedure outlined in Section 502.2.1.3 shall be used to adjust the floor  $U$ -factor before selecting a floor assembly from Appendix Table 502.2.3.3.

**502.2.3.4 Slab-on-grade floors.** Slab-on-grade floors shall meet the provisions of Table 502.2 as determined by Section 502.2.1.4.

**502.2.3.5 Closed crawl space walls.** Where the floor above a closed crawl space is not insulated, the exterior crawl space walls shall be insulated. The exterior walls shall have a thermal transmittance value not exceeding the value given in Table 502.2(1). The *U*-factor for the wall shall be determined by selecting the *U*-factor for the appropriate crawl space wall section from Appendix Table 502.2.3.5.

Wall insulation can be located on any combination of the outside and inside wall surfaces and within the structural cavities or materials of the wall system. Wall insulation requires that the exterior wall band joist area of the floor frame be insulated. Wall insulation shall begin 3 inches (76 mm) below the top of the masonry foundation wall and shall extend down to 3 inches (76 mm) above the top of the footing or concrete floor, 3 inches (76 mm) above the interior ground surface or 24 inches (610 mm) below the outside finished ground level, whichever is less [see Appendix Details 502.2.1.5(1), 502.2.1.5(2) and 502.2.1.5(3)].

Termite inspection, clearance and/or wicking gaps are allowed in wall insulation systems [see Appendix Details 502.2.1.5(4) and 502.2.1.5(5)]. Insulation may be deleted in the gap area without energy penalty. The allowable insulation gap widths are listed in Table 502.2(2). If gap widths exceed the allowances, one of the following energy compliance options shall be met:

1. Wall insulation is not allowed and the required insulation value shall be provided in the floor system.
2. Compliance shall be demonstrated with energy trade-off methods provided by MecCheck version 3.0 or higher, or the North Carolina Energy Conservation Code Chapter 4 or 5.

**502.2.3.6 Basement walls.** The exterior walls of conditioned basements shall have a thermal transmittance value not exceeding the value given in Table 502.2 from the top of the basement wall to a depth of 10 feet (3048 mm) below grade, or to the level of the basement floor, whichever is less. The *U*-factor of the wall shall be determined by selecting the *U*-factor for the wall section from Appendix Table 502.2.3.6.

**502.2.4 Compliance by prescriptive specification on an individual component basis.** The thermal resistance of insulation applied to the opaque building envelope components shall be greater than or equal to the minimum *R*-values, and the area-weighted average thermal transmittance (*U*-factor) of all fenestration assemblies (other than opaque doors which are governed by Section 502.2.4.6) shall be less than or equal to the maximum *U*-factors shown in Table 502.2.4(3) or 502.2.4(8), as applicable. Sections 502.2.4.1 through 502.2.4.19 shall apply to the use of these tables.

**TABLE 502.2.4(1)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS,  
DETACHED ONE- AND TWO-FAMILY DWELLINGS  
WINDOW AREA 8 PERCENT OF GROSS EXTERIOR WALL AREA**  
Deleted.

**TABLE 502.2.4(2)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS,  
DETACHED ONE- AND TWO-FAMILY DWELLINGS  
WINDOW AREA 12 PERCENT OF  
GROSS EXTERIOR WALL AREA**

Deleted.

**TABLE 502.2.4(4)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS,  
DETACHED ONE- AND TWO-FAMILY DWELLINGS  
WINDOW AREA 18 PERCENT  
OF GROSS EXTERIOR WALL AREA**

Deleted.

**TABLE 502.2.4(5)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS,  
DETACHED ONE- AND TWO-FAMILY DWELLINGS  
WINDOW AREA 20 PERCENT  
OF GROSS EXTERIOR WALL AREA**

Deleted.

**TABLE 502.2.4(6)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS,  
DETACHED ONE- AND TWO-FAMILY DWELLINGS  
WINDOW AREA 25 PERCENT  
OF GROSS EXTERIOR WALL AREA**

Deleted.

**TABLE 502.2.4(7)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS, GROUP  
R-2, R-4 OR TOWNHOUSE RESIDENTIAL BUILDINGS  
WINDOW AREA 20 PERCENT  
OF GROSS EXTERIOR WALL AREA**

Deleted.

**TABLE 502.2.4(9)  
PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS, GROUP  
R-2, R-4 OR TOWNHOUSE RESIDENTIAL BUILDINGS  
WINDOW AREA 30 PERCENT  
OF GROSS EXTERIOR WALL AREA**

Deleted.

**502.2.4.1 Walls.** The sum of the thermal resistance of cavity insulation plus insulating sheathing (if used) shall meet or exceed the “Exterior wall *R*-value.”

**502.2.4.2 Wood construction only.** The tables shall only be used for wood construction.

**502.2.4.3 Window area.** The actual window area of a proposed design shall be computed using the rough opening area of all skylights, above-grade windows and, where the basement is conditioned space, any basement windows.

**502.2.4.4 Window area, exempt.** Fifteen square feet (1.4 m<sup>2</sup>) of the total window area computed under Section 502.2.4.3 shall be exempt from the “Glazing *U*-factor” requirement. In addition, impact glazing in wind-borne debris regions meeting the requirements of the Large Missile Test of ASTM E 1996 and of ASTM E 1886 shall be exempt from the “Glazing *U*-Factor” requirements.

**502.2.4.5 Truss/rafter construction.** “Ceiling *R*-value” assumes standard truss or rafter construction. Where raised-heel trusses or other construction techniques are employed to obtain the full height of ceiling insulation over the exterior wall top plate, R-30 shall be permitted to be used where R-38 is required in the table, and R-38 shall be permitted to be used where R-49 is required.

**TABLE 502.2.4(3)**  
**PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS, DETACHED ONE- AND TWO-FAMILY DWELLINGS**

| ZONE | HEATING DEGREE DAYS | MAXIMUM          | MINIMUM         |                       |               |                       |                                  |                          |
|------|---------------------|------------------|-----------------|-----------------------|---------------|-----------------------|----------------------------------|--------------------------|
|      |                     | Glazing U-factor | Ceiling R-value | Exterior wall R-value | Floor R-value | Basement wall R-value | Slab perimeter R-value and depth | Crawl space wall R-value |
| 1    | 0 - 499             | Any              | R-13            | R-11                  | R-11          | R-0                   | R-0                              | R-0                      |
| 2    | 500 - 999           | 0.90             | R-19            | R-11                  | R-11          | R-0                   | R-0                              | R-4                      |
| 3    | 1,000 - 1,499       | 0.75             | R-19            | R-11                  | R-11          | R-0                   | R-0                              | R-5                      |
| 4    | 1,500 - 1,999       | 0.75             | R-26            | R-13                  | R-11          | R-5                   | R-0                              | R-5                      |
| 5    | 2,000 - 2,499       | 0.65             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-6                      |
| 6    | 2,500 - 2,999       | 0.40             | R-30            | R-13                  | R-19          | R-6                   | R-0                              | R-7                      |
| 7    | 3,000 - 3,499       | 0.40             | R-30            | R-13                  | R-19          | R-7                   | R-0                              | R-8                      |
| 8    | 3,500 - 3,999       | 0.40             | R-30            | R-13                  | R-19          | R-8                   | R-5, 2 ft.                       | R-10                     |
| 9    | 4,000 - 4,499       | 0.40             | R-38            | R-13                  | R-19          | R-8                   | R-5, 2 ft.                       | R-11                     |
| 10   | 4,500 - 4,999       | 0.45             | R-38            | R-16                  | R-19          | R-9                   | R-6, 2 ft.                       | R-17                     |
| 11   | 5,000 - 5,499       | 0.40             | R-38            | R-18                  | R-19          | R-9                   | R-6, 2 ft.                       | R-17                     |
| 12   | 5,500 - 5,999       | 0.40             | R-38            | R-18                  | R-21          | R-10                  | R-9, 2 ft.                       | R-19                     |
| 13   | 6,000 - 6,499       | 0.35             | R-38            | R-18                  | R-21          | R-10                  | R-9, 4 ft.                       | R-20                     |
| 14   | 6,500 - 6,999       | 0.35             | R-49            | R-21                  | R-21          | R-11                  | R-11, 4 ft.                      | R-20                     |
| 15   | 7,000 - 8,499       | 0.35             | R-49            | R-21                  | R-21          | R-11                  | R-13, 4 ft.                      | R-20                     |
| 16   | 8,500 - 8,999       | 0.35             | R-49            | R-21                  | R-21          | R-18                  | R-14, 4 ft.                      | R-20                     |
| 17   | 9,000 - 12,999      | 0.35             | R-49            | R-21                  | R-21          | R-19                  | R-18, 4 ft.                      | R-20                     |

For SI: 1 foot = 304.8 mm.

**TABLE 502.2.4(8)**  
**PRESCRIPTIVE BUILDING ENVELOPE REQUIREMENTS, GROUP R-2, R-4 OR TOWNHOUSE RESIDENTIAL BUILDINGS**

| ZONE | HEATING DEGREE DAYS | MAXIMUM          | MINIMUM         |                       |               |                       |                                  |                          |
|------|---------------------|------------------|-----------------|-----------------------|---------------|-----------------------|----------------------------------|--------------------------|
|      |                     | Glazing U-factor | Ceiling R-value | Exterior wall R-value | Floor R-value | Basement wall R-value | Slab perimeter R-value and depth | Crawl space wall R-value |
| 1    | 0 - 499             | Any              | R-13            | R-11                  | R-11          | R-0                   | R-0                              | R-0                      |
| 2    | 500 - 999           | Any              | R-19            | R-11                  | R-11          | R-0                   | R-0                              | R-5                      |
| 3    | 1,000 - 1,499       | Any              | R-19            | R-11                  | R-11          | R-0                   | R-0                              | R-5                      |
| 4    | 1,500 - 1,999       | 0.85             | R-19            | R-11                  | R-11          | R-5                   | R-0                              | R-5                      |
| 5    | 2,000 - 2,499       | 0.70             | R-19            | R-11                  | R-11          | R-5                   | R-0                              | R-5                      |
| 6    | 2,500 - 2,999       | 0.40             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-5                      |
| 7    | 3,000 - 3,499       | 0.40             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-5                      |
| 8    | 3,500 - 3,999       | 0.40             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-5                      |
| 9    | 4,000 - 4,499       | 0.40             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-5                      |
| 10   | 4,500 - 4,999       | 0.53             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-6                      |
| 11   | 5,000 - 5,499       | 0.40             | R-30            | R-13                  | R-11          | R-5                   | R-0                              | R-6                      |
| 12   | 5,500 - 5,999       | 0.51             | R-30            | R-13                  | R-11          | R-6                   | R-0                              | R-6                      |
| 13   | 6,000 - 6,499       | 0.51             | R-30            | R-13                  | R-19          | R-10                  | R-7, 4 ft.                       | R-16                     |
| 14   | 6,500 - 6,999       | 0.45             | R-30            | R-13                  | R-19          | R-10                  | R-7, 4 ft.                       | R-16                     |
| 15   | 7,000 - 8,499       | 0.35             | R-38            | R-16                  | R-19          | R-11                  | R-9, 4 ft.                       | R-18                     |
| 16   | 8,500 - 8,999       | 0.35             | R-38            | R-16                  | R-19          | R-17                  | R-10, 4 ft.                      | R-18                     |
| 17   | 9,000 - 12,999      | Note a           | Note a          | Note a                | Note a        | Note a                | Note a                           | Note a                   |

For SI: 1 foot = 304.8 mm.

a. See Section 502.2.4.13

**502.2.4.6 Doors.** Opaque doors in the building envelope shall have a maximum  $U$ -factor of 0.35. One door shall be exempt from this requirement.

**502.2.4.7 Ceilings.** “Ceiling  $R$ -value” shall be required for flat or “cathedral” (inclined) ceilings.

**502.2.4.8 Floors.** “Floor  $R$ -value” shall apply to floors over unconditioned spaces. A floor over outside air shall meet the requirement for “Ceiling  $R$ -value.”

**502.2.4.9 Basement walls.** Basement wall insulation shall be installed in accordance with Section 502.2.1.6.

**502.2.4.10 Unheated slabs.** Slab perimeter insulation shall be installed in accordance with Section 502.2.1.4.

**502.2.4.11 Heated slabs.**  $R-2$  shall be added to the “Slab perimeter  $R$ -value” where the slab is heated.

**502.2.4.12 Closed crawl space walls.** “Crawl space wall  $R$ -value” shall apply to closed crawl spaces only. Crawl space insulation shall be installed in accordance with Section 502.2.1.5.

**502.2.4.13 Tables not applicable.** The particular climate range indicated by Note a in Tables 502.2.4(4), 502.2.4(6), 502.2.4(7), 502.2.4(8) and 502.2.4(9) shall not be used with the indicated envelope component(s) to demonstrate compliance under Section 502.2.4.

**502.2.4.14 Climates greater than 13,000 HDD.** These tables shall not be used for climates greater than or equal to 13,000 HDD.

**502.2.4.15 Fenestration solar heat gain coefficient.** Fenestration products shall also meet the requirements of Section 502.1.5. Fifteen square feet (1.4 m<sup>2</sup>) of total glazed fenestration shall be exempt from the SHGC requirement. In addition, all glazing in doors shall be exempt from the SHGC requirement.

**502.2.4.16 Steel-framed wall construction.** Where steel framing is used in wall construction, the wall assembly shall meet the equivalent wall cavity and sheathing  $R$ -values in Table 502.2.4.16(1) or 502.2.4.16(2), based on the “on-center” (o.c.) dimension of the steel studs and the required  $R$ -value for wood-framed walls determined in accordance with Section 502.2.4, and utilizing any combination of cavity and sheathing insulation set off by commas in Table 502.2.4.16(1) or 502.2.4.16(2).

**502.2.4.17 High-mass wall construction.** Exterior walls constructed of high-mass materials having heat capacity greater than or equal to 6 Btu/ ft<sup>2</sup> · °F [1.06 kJ/(m<sup>2</sup> · K)] of exterior wall area shall meet the equivalent insulation  $R$ -values in Table 502.2.4.17(1) or 502.2.4.17(2), based on the placement of the insulation, the HDD of the building location, and the required  $R$ -value for wood-framed walls determined in accordance with Section 502.2.4.

**502.2.4.18 Steel-framed roof/ceiling construction.** When truss-type, cold-formed steel framing is used in roof/ceiling construction, the roof/ceiling assembly shall meet the equivalent insulation  $R$ -values in Table 502.2.4.18(1).

When C-shaped, cold-formed steel framing is used in roof/ceiling construction, the steel roof/ceiling assembly shall meet the equivalent wood framed  $U_R$ -factors in Table 502.2.4.18(2).

**TABLE 502.2.4.16(1)  
16-INCH O.C. STEEL-FRAMED WALL EQUIVALENT  $R$ -VALUES**

| WOOD-FRAMED WALL $R$ -VALUE <sup>a</sup> | EQUIVALENT STEEL-FRAMED WALL CAVITY $R$ -VALUE PLUS SHEATHING $R$ -VALUE |
|--|--|
| R-11                                     | R-0+R-9, R-11+R-4, R-15+R-3, R-21+R-2                                    |
| R-13                                     | R-11+R-5, R-15+R-4, R-21+R-3   |
| R-14                                     | R-11+R-6, R-13+R-5, R-19+R-4   |
| R-15                                     | R-11+R-6, R-15+R-5, R-19+R-4   |
| R-16                                     | R-11+R-8, R-15+R-7, R-21+R-6   |
| R-17                                     | R-11+R-9, R-13+R-8, R-19+R-7   |
| R-18                                     | R-11+R-9, R-15+R-8, R-21+R-7   |
| R-19                                     | R-11+R-10, R-13+R-9, R-19+R-8, R-25+R-7                                  |
| R-20                                     | R-11+R-10, R-13+R-9, R-19+R-8  |
| R-21                                     | R-13+R-10, R-19+R-9, R-25+R-8  |
| R-22                                     | R-13+R-10, R-19+R-9  |
| R-24                                     | R-19+R-10, R-25+R-9  |
| R-25                                     | R-19+R-10  |
| R-26                                     | R-19+R-11, R-21+R-10   |

For SI: 1 inch = 25.4 mm.

a. As required by Section 502.2.4 and the tabular entry for “Exterior wall  $R$ -value” shown in Tables 502.2.4(1) through 502.2.4(9), as applicable.

**TABLE 502.2.4.16(2)  
24-INCH O.C. STEEL-FRAMED WALL EQUIVALENT  $R$ -VALUES**

| WOOD-FRAMED WALL $R$ -VALUE <sup>a</sup> | EQUIVALENT STEEL-FRAMED WALL CAVITY $R$ -VALUE PLUS SHEATHING $R$ -VALUE |
|--|--|
| R-11                                     | R-0+R-9, R-11+R-3, R-15+R-2, R-25+R-0                                    |
| R-13                                     | R-11+R-4, R-15+R-3, R-19+R-2   |
| R-14                                     | R-11+R-5, R-13+R-4, R-15+R-3, R-21+R-2                                   |
| R-15                                     | R-11+R-5, R-13+R-4, R-19+R-3, R-21+R-2                                   |
| R-16                                     | R-11+R-7, R-13+R-6, R-19+R-5, R-25+R-4                                   |
| R-17                                     | R-11+R-8, R-13+R-7, R-15+R-6, R-21+R-5                                   |
| R-18                                     | R-11+R-8, R-13+R-7, R-19+R-6, R-25+R-5                                   |
| R-19                                     | R-11+R-9, R-13+R-8, R-15+R-7, R-21+R-6                                   |
| R-20                                     | R-11+R-9, R-13+R-8, R-19+R-7, R-21+R-6                                   |
| R-21                                     | R-11+R-9, R-15+R-8, R-21+R-7   |
| R-22                                     | R-11+R-10, R-13+R-9, R-19+R-8, R-21+R-7                                  |
| R-24                                     | R-11+R-10, R-15+R-9, R-19+R-8  |
| R-25                                     | R-13+R-10, R-19+R-9, R-21+R-8  |
| R-26                                     | R-15+R-10, R-19+R-9, R-25+R-8  |

For SI: 1 inch = 25.4 mm.

a. As required by Section 502.2.4 and the tabular entry for “Exterior wall  $R$ -value” shown in Tables 502.2.4(1) through 502.2.4(9), as applicable.



**TABLE 502.2.4.17(1)**  
**HIGH-MASS WALL EQUIVALENT R-VALUES INSULATION PLACED ON**  
**THE EXTERIOR OF THE WALL OR WITH INTEGRAL INSULATION**

| WOOD-FRAMED WALL R-VALUE <sup>a</sup> | EQUIVALENT HIGH-MASS WALL R-VALUE |                   |                   |                   |                   |             |
|---------------------------------------|-----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------|
|                                       | HDD 0 - 1,999                     | HDD 2,000 - 3,999 | HDD 4,000 - 5,499 | HDD 5,500 - 6,499 | HDD 6,500 - 8,499 | HDD ≥ 8,500 |
| R-11                                  | R-6                               | R-6               | R-7               | R-8               | R-9               | R-10        |
| R-13                                  | R-6                               | R-6               | R-8               | R-9               | R-10              | R-11        |
| R-14                                  | R-6                               | R-7               | R-8               | R-9               | R-10              | R-11        |
| R-15                                  | R-7                               | R-7               | R-8               | R-9               | R-10              | R-12        |
| R-16                                  | R-7                               | R-7               | R-8               | R-9               | R-11              | R-12        |
| R-17                                  | R-7                               | R-7               | R-9               | R-10              | R-11              | R-13        |
| R-18                                  | R-7                               | R-7               | R-9               | R-10              | R-11              | R-13        |
| R-19                                  | R-8                               | R-9               | R-10              | R-11              | R-13              | R-15        |
| R-20                                  | R-8                               | R-9               | R-10              | R-11              | R-13              | R-16        |
| R-21                                  | R-8                               | R-9               | R-10              | R-12              | R-14              | R-16        |
| R-22                                  | R-8                               | R-9               | R-10              | R-12              | R-14              | R-17        |
| R-23                                  | R-9                               | R-9               | R-11              | R-12              | R-14              | R-17        |
| R-24                                  | R-9                               | R-9               | R-11              | R-12              | R-14              | R-17        |
| R-25                                  | R-9                               | R-10              | R-11              | R-13              | R-15              | R-18        |
| R-26                                  | R-9                               | R-10              | R-11              | R-13              | R-15              | R-18        |

a. As required by Section 502.2.4 and the tabular entry for “Exterior wall R-value” shown in Tables 502.2.4(1) through 502.2.4(9), as applicable.

**TABLE 502.2.4.17(2)**  
**HIGH-MASS WALL EQUIVALENT R-VALUES**  
**INSULATION PLACED ON THE INTERIOR OF THE WALL**

| WOOD-FRAMED WALL R-VALUE <sup>a</sup> | EQUIVALENT HIGH-MASS WALL R-VALUE |                   |                   |                   |                   |             |
|---------------------------------------|-----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------|
|                                       | HDD 0 - 1,999                     | HDD 2,000 - 3,999 | HDD 4,000 - 5,499 | HDD 5,500 - 6,499 | HDD 6,500 - 8,499 | HDD ≥ 8,500 |
| R-11                                  | R-10                              | R-10              | R-11              | R-11              | R-12              | R-12        |
| R-13                                  | R-11                              | R-11              | R-12              | R-12              | R-14              | R-14        |
| R-14                                  | R-12                              | R-12              | R-12              | R-13              | R-15              | R-15        |
| R-15                                  | R-13                              | R-13              | R-13              | R-14              | R-15              | R-15        |
| R-16                                  | R-13                              | R-13              | R-13              | R-15              | R-15              | R-15        |
| R-17                                  | R-14                              | R-14              | R-14              | R-15              | R-16              | R-16        |
| R-18                                  | R-15                              | R-15              | R-15              | R-19              | R-16              | R-16        |
| R-19                                  | R-16                              | R-16              | R-16              | R-20              | R-19              | R-19        |
| R-20                                  | R-16                              | R-16              | R-16              | R-21              | R-20              | R-20        |
| R-21                                  | R-17                              | R-17              | R-17              | R-21              | R-21              | R-21        |
| R-22                                  | R-17                              | R-17              | R-17              | R-22              | R-21              | R-21        |
| R-23                                  | R-18                              | R-18              | R-18              | R-22              | R-22              | R-22        |
| R-24                                  | R-19                              | R-19              | R-19              | R-22              | R-22              | R-22        |
| R-25                                  | R-20                              | R-20              | R-20              | R-22              | R-22              | R-22        |
| R-26                                  | R-21                              | R-21              | R-21              | R-23              | R-23              | R-23        |

a. As required by Section 502.2.4 and the tabular entry for “Exterior wall R-value” shown in Tables 502.2.4(1) through 502.2.4(9), as applicable.

**TABLE 502.2.4.18(1)**  
**TRUSS TYPE COLD-FORMED STEEL ROOF/CEILING**  
**EQUIVALENT R-VALUES<sup>a</sup>**

| WOOD-FRAMED ROOF/CEILING R-VALUE <sup>b</sup> | TRUSS TYPE COLD-FORMED STEEL CAVITY AND CONTINUOUS INSULATION R-VALUE, 24 INCHES ON CENTER <sup>c</sup> |
|---|---|
| R-13  | R-19, R-13 + R-3  |
| R-19  | R-26, R-19 + R-3  |
| R-26  | R-38, R-26 + R-3  |
| R-30  | R-38, R-30 + R-3  |
| R-38  | R-49, R-38 + R-5  |
| R-49  | Not applicable  |

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

- a. This table applies to cold-formed, steel-truss roof framing spaced at 24 inches on center and where the penetrations of the truss members through the cavity insulation do not exceed three penetrations of the truss members through the cavity insulation for each 4-foot length of the truss.
- b. As required by Section 502.2.4 and the tabular entry for “Ceiling R-value” shown in Tables 502.2.4(1) through 502.2.4(9).
- c. The cavity R-value requirement is listed first, followed by the continuous insulation R-value requirement.

**502.2.4.19 Steel-framed floor construction.** When C-shaped, cold-formed steel framing is used in floor construction, the steel floor assembly shall meet the equivalent wood framed  $U_f$ -factors in Table 502.2.4.19.

**502.2.5 Prescriptive path for additions and window replacements.** As an alternative to demonstrating compliance with Section 402 or 502.2, additions with a conditioned floor area less than 500 square feet (46.5 m<sup>2</sup>) to

existing single-family residential buildings and structures shall meet the prescriptive envelope component criteria in Table 502.2.5 for the designated heating degree days (HDD) applicable to the location. The  $U$ -factor of each individual fenestration product (windows, doors and skylights) shall be used to calculate an area-weighted average fenestration product  $U$ -factor for the addition, which shall not exceed the applicable listed values in Table 502.2.5. For additions, other than sunroom additions, the total area of fenestration products shall not exceed 40 percent of the gross wall and roof area of the addition. The  $R$ -values for opaque thermal envelope components shall be equal to or greater than the applicable listed values in Table 502.2.5. Replacement fenestration products (where some or all of an existing fenestration unit is replaced with an entire new replacement unit, including the frame, sash and glazing) shall meet the prescriptive fenestration  $U$ -factor criteria in Table 502.2.5 for the designated HDD applicable to the location.

Conditioned sunroom additions shall maintain thermal isolation; shall not be used as kitchens or sleeping rooms; and shall be served by a separate heating or cooling system, or be thermostatically controlled as a separate zone of the existing system.

Fenestration products used in additions and as replacement windows in accordance with this section shall also meet the requirements of Section 502.1.5.

**Exception:** Replacement skylights shall have a maximum  $U$ -factor of 0.60 when installed in any location above 1,999 HDD.

**TABLE 502.2.4.18(2)**  
**C-SHAPED COLD-FORMED STEEL ROOF/CEILING EQUIVALENT  $U_f$ -FACTORS<sup>a</sup>**

| FRAMING <sup>b</sup>    | SPACING        | R-13 <sup>c</sup> | R-19 <sup>c</sup> | R-26 <sup>c</sup> | R-30 <sup>c</sup> | R-38 <sup>c</sup> | R-49 <sup>c</sup> |
|-------------------------|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Steel / Wood Equivalent | 16 inches o.c. | 0.0773            | 0.0537            | 0.0405            | 0.0355            | 0.0285            | 0.0223            |
| 2 × 4                   |                | 0.1328            | 0.0530            | 0.0387            | 0.0336            | 0.0265            | 0.0206            |
| 2 × 6                   |                | 0.1328            | 0.0667            | 0.0456            | 0.0386            | 0.0295            | 0.0223            |
| 2 × 8                   |                | 0.1328            | 0.1208            | 0.0585            | 0.0475            | 0.0345            | 0.0251            |
| 2 × 10                  |                | 0.1328            | 0.1208            | 0.1094            | 0.1037            | 0.0398            | 0.0277            |
| 2 × 12                  |                | 0.1328            | 0.1208            | 0.1094            | 0.1037            | 0.0471            | 0.0311            |
| Steel / Wood Equivalent |                | 24 inches o.c.    | 0.0742            | 0.0519            | 0.0390            | 0.0342            | 0.0274            |
| 2 × 4                   | 0.1129         |                   | 0.0510            | 0.0376            | 0.0327            | 0.0260            | 0.0202            |
| 2 × 6                   | 0.1129         |                   | 0.0610            | 0.0428            | 0.0366            | 0.0284            | 0.0216            |
| 2 × 8                   | 0.1129         |                   | 0.0994            | 0.0517            | 0.0429            | 0.0320            | 0.0237            |
| 2 × 10                  | 0.1129         |                   | 0.0994            | 0.0873            | 0.0816            | 0.0357            | 0.0257            |
| 2 × 12                  | 0.1129         |                   | 0.0994            | 0.0873            | 0.0816            | 0.0403            | 0.0280            |

For SI: 1 inch = 25.4 mm.

- a. Linear interpolation is permitted for determining  $U$ -factors which are between those given in the table.
- b. Applies to steel framing up to a maximum thickness of 0.064 inches (16 gage.)
- c. As required by Section 502.2.4 and the tabular entry for “Ceiling R-value” shown in Tables 502.2.4(1) through 502.2.4(9), as applicable.

**TABLE 502.2.4.19  
C-SHAPED COLD-FORMED STEEL FLOOR EQUIVALENT  $U_f$ -FACTORS<sup>a</sup>**

| FRAMING <sup>b</sup> |                 | SPACING           | R-11 <sup>c</sup> | R-13 <sup>c</sup> | R-15 <sup>c</sup> | R-19 <sup>c</sup> | R-21 <sup>c</sup> | R-25 <sup>c</sup> | R-30   |
|----------------------|-----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------|
| Steel                | Wood Equivalent | 16 inches<br>o.c. | 0.0725            | 0.0652            | 0.0595            | 0.0477            | 0.0452            | 0.0382            | 0.0327 |
|                      | 2 × 6           |                   | 0.1058            | 0.1031            | 0.1005            | 0.0583            | 0.0523            | NA                | NA     |
|                      | 2 × 8           |                   | 0.1058            | 0.1031            | 0.1005            | 0.0957            | 0.0935            | 0.0548            | NA     |
|                      | 2 × 10          |                   | 0.1058            | 0.1031            | 0.1005            | 0.0957            | 0.0935            | 0.0894            | 0.0838 |
|                      | 2 × 12          |                   | 0.1058            | 0.1031            | 0.1005            | 0.0957            | 0.0935            | 0.0894            | 0.0838 |
| Steel                | Wood Equivalent | 24 inches<br>o.c. | 0.0708            | 0.0633            | 0.0574            | 0.0464            | 0.0436            | 0.0370            | 0.0317 |
|                      | 2 × 6           |                   | 0.0941            | 0.0907            | 0.0875            | 0.0538            | 0.0486            | NA                | NA     |
|                      | 2 × 8           |                   | 0.0941            | 0.0907            | 0.0875            | 0.0818            | 0.0792            | 0.0488            | NA     |
|                      | 2 × 10          |                   | 0.0941            | 0.0907            | 0.0875            | 0.0818            | 0.0792            | 0.0745            | 0.0697 |
|                      | 2 × 12          |                   | 0.0941            | 0.0907            | 0.0875            | 0.0818            | 0.0792            | 0.0745            | 0.0697 |

For SI: 1 inch = 25.4 mm.

NA = Not applicable.

a. Linear interpolation is permitted for determining  $U$ -factors which are between those given in the table.

b. Applies to steel framing up to a maximum thickness of 0.064 inches (16 gage.)

c. As required by Section 502.2.4 and the tabular entry for “Floor  $R$ -value” shown in Tables 502.2.4(1) through 502.2.4(9), as applicable.

**TABLE 502.2.5  
PRESCRIPTIVE ENVELOPE COMPONENT CRITERIA ADDITIONS  
TO AND REPLACEMENT WINDOWS FOR EXISTING DETACHED ONE- AND TWO-FAMILY DWELLINGS**

| ZONE  | HEATING<br>DEGREE DAYS | MAXIMUM                                  |                                      | MINIMUM                         |                     |  |  |  |
|-------|------------------------|--|--------------------------------------|---------------------------------|---------------------|--|--|--|
|       |                        | Fenestration<br>$U$ -factor <sup>e</sup> | Ceiling<br>$R$ -value <sup>a,e</sup> | Wall<br>$R$ -value <sup>e</sup> | Floor<br>$R$ -value | Basement wall<br>$R$ -value <sup>b</sup> | Slab perimeter<br>$R$ -value and<br>depth <sup>c</sup> | Crawl space<br>wall<br>$R$ -value <sup>d</sup> |
| 1-4   | 0 - 1,999              | 0.75                                     | R-26                                 | R-13                            | R-11                | R-5                                      | R-0  | R-5  |
| 5-8   | 2,000 - 3,999          | 0.40                                     | R-30                                 | R-13                            | R-19                | R-8                                      | R-5, 2 ft.   | R-10   |
| 9-12  | 4,000 - 5,999          | 0.40                                     | R-38                                 | R-18                            | R-21                | R-10                                     | R-9, 2 ft.   | R-19   |
| 13-15 | 6,000 - 8,499          | 0.35                                     | R-49                                 | R-21                            | R-21                | R-11                                     | R-13, 4 ft.  | R-20   |
| 16-17 | 8,500 - 12,999         | 0.35                                     | R-49                                 | R-21                            | R-21                | R-19                                     | R-18, 4 ft.  | R-20   |

For SI: 1 foot = 304.8 mm.

a. “Ceiling  $R$ -value” shall be required for flat or inclined (cathedral) ceilings. Floors over outside air shall meet “Ceiling  $R$ -value” requirements.

b. Basement wall insulation shall be installed in accordance with Section 502.2.1.6.

c. Slab perimeter insulation shall be installed in accordance with Section 502.2.1.4. An additional R-2 shall be added to “Slab perimeter  $R$ -value” in the table if the slab is heated.

d. “Crawl space wall  $R$ -value” shall apply to unventilated crawl spaces only. Crawl space insulation shall be installed in accordance with Section 502.2.1.5.

e. Sunroom additions shall be required to have a maximum fenestration  $U$ -factor of 0.50 in locations with 2,000 - 12,999 HDD. In locations with 0-5,999 HDD, the minimum ceiling  $R$ -value shall be R-19 and the minimum wall  $R$ -value shall be R-13. In locations with 6,000 - 12,999 HDD, the minimum ceiling  $R$ -value shall be R-24 and the minimum wall  $R$ -value shall be R-13.

### SECTION 503 BUILDING MECHANICAL SYSTEMS AND EQUIPMENT

**503.1 General.** This section covers mechanical systems and equipment used to provide heating, ventilating and air-conditioning functions. This section assumes that residential buildings and dwelling units therein will be designed with individual HVAC systems. Where equipment not shown in Table 503.2 is specified, it shall meet the provisions of Sections 803.2.2 and 803.3.2.

**503.2 Mechanical equipment efficiency.** Equipment shown in Table 503.2 shall meet the specified minimum performance. Data furnished by the equipment supplier, or certified under a nationally recognized certification procedure, shall be used to satisfy these requirements. All such equipment shall be installed in accordance with the manufacturer’s instructions.

**503.3 HVAC systems.** HVAC systems shall meet the criteria set forth in Sections 503.3.1 through 503.3.3.

**[M] 503.3.1 Load calculations.** Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with the procedures described in the ASHRAE *Fundamentals Handbook*. Heating and cooling loads shall be adjusted to account for load reductions that are achieved when energy recovery systems are utilized in the HVAC system in accordance with the ASHRAE *HVAC Systems and Equipment Handbook*. Alternatively, design loads shall be determined by an approved equivalent computation procedure, using the design parameters specified in Chapter 3.

**TABLE 503.2  
MINIMUM EQUIPMENT PERFORMANCE**

| EQUIPMENT CATEGORY  | SUBCATEGORY <sup>e</sup> | REFERENCED STANDARD                        | MINIMUM PERFORMANCE  |
|---|--------------------------|--|--|
| Air-cooled heat pumps, Heating mode < 65,000 Btu/h cooling capacity                     | Split systems            | ARI 210/240                                | 6.8 HSPF <sup>a,b</sup>  |
|   | Single package           |  | 6.6 HSPF <sup>a,b</sup>  |
| Gas-fired or oil-fired furnace < 225,000 Btu/h  | —                        | DOE 10 CFR Part 430, Subpart B, Appendix N | AFUE 78% <sup>b</sup><br><i>E<sub>t</sub></i> 80% <sup>c</sup> |
| Gas-fired or oil-fired steam and hot-water boilers < 300,000 Btu/h                      | —                        | DOE 10 CFR Part 430, Subpart B, Appendix N | AFUE 80% <sup>b,d</sup>  |
| Air-cooled air conditioners and heat pumps, Cooling mode <65,000 Btu/h cooling capacity | Split systems            | ARI 210/240                                | 10.0 SEER <sup>b</sup>   |
|   | Single package           |  | 9.7 SEER <sup>b</sup>  |

For SI: 1 British thermal unit per hour = 0.2931 W.

- a. For multicapacity equipment, the minimum performance shall apply to each capacity step provided. Multicapacity refers to manufacturer-published ratings for more than one capacity mode allowed by the product's controls.
- b. This is used to be consistent with the National Appliance Energy Conservation Act (NAECA) of 1987 (Public Law 100-12).
- c. These requirements apply to combination units not covered by NAECA (three-phase power or cooling capacity 65,000 Btu/h).
- d. Except for gas-fired steam boilers for which the minimum AFUE shall be 75 percent.
- e. Seasonal rating.

**503.3.2 Temperature and humidity controls.** Temperature and humidity controls shall be provided in accordance with Sections 503.3.2.1 through 503.3.2.4.

**503.3.2.1 System controls.** Each dwelling unit shall be considered a zone and be provided with thermostatic controls responding to temperature within the dwelling unit. Each heating and cooling system shall include at least one temperature control device.

**503.3.2.2 Thermostatic control capabilities.** Where used to control comfort heating, thermostatic controls shall be capable of being set locally or remotely by adjustment or selection of sensors down to 55°F (13°C) or lower.

Where used to control comfort cooling, thermostatic controls shall be capable of being set locally or remotely by adjustment or selection of sensors up to 85°F (29°C) or higher.

Where used to control both comfort heating and cooling, thermostatic controls shall be capable of providing a temperature range or deadband of at least 5°F (Δ3°C) within which the supply of heating and cooling energy is shut off or reduced to a minimum.

**Exceptions:**

1. Special occupancy or special usage conditions approved by the code official.
2. Thermostats that require manual changeover between heating and cooling modes.

**503.3.2.3 Heat pump auxiliary heat.** Heat pumps having supplementary electric resistance heaters shall have controls that prevent heater operation when the heating load is capable of being met by the heat pump. Supplemental heater operation is not allowed except during outdoor coil defrost cycles not exceeding 15 minutes.

**503.3.2.4 Humidistat.** Humidistats used for comfort purposes shall be capable of being set to prevent the use of fossil fuel or electricity to reduce relative humidity below 60 percent or increase relative humidity above 30 percent.

**503.3.3 Distribution system, construction and insulation.** Distribution systems shall be constructed and insulated in accordance with Sections 503.3.3.1 through 503.3.3.7.

**503.3.3.1 Piping insulation.** All HVAC system piping shall be thermally insulated in accordance with Table 503.3.3.1.

**Exceptions:**

1. Factory-installed piping within HVAC equipment tested and rated in accordance with Section 503.2.
2. Piping that conveys fluids which have a design operating temperature range between 55°F and 105°F (13°C and 41°C).
3. Piping that conveys fluids which have not been heated or cooled through the use of fossil fuels or electricity.

**TABLE 503.3.3.1  
MINIMUM PIPE INSULATION  
(thickness in inches)**

| PIPING SYSTEM TYPES                  | FLUID TEMPERATURE RANGE, °F | PIPE SIZES                    |             |             |            |          |               |
|--------------------------------------|-----------------------------|-------------------------------|-------------|-------------|------------|----------|---------------|
|                                      |                             | Runouts up to 2' <sup>a</sup> | 1" and less | 1.25" to 2" | 2.5" to 4" | 5" to 6" | 8" and larger |
| <b>HEATING SYSTEMS</b>               |                             |                               |             |             |            |          |               |
| Steam and hot water                  |                             |                               |             |             |            |          |               |
| High pressure/temperature            | 306-450                     | 1½                            | 2½          | 2½          | 3          | 3½       | 3½            |
| Medium pressure/temperature          | 251-305                     | 1½                            | 2           | 2½          | 2½         | 3        | 3             |
| Low pressure/temperature             | 201-250                     | 1                             | 1½          | 1½          | 2          | 2        | 2             |
| Low temperature                      | 106-200                     | ½                             | 1           | 1           | 1½         | 1½       | 1½            |
| Steam condensate (for feed water)    | Any                         | 1                             | 1           | 1½          | 2          | 2        | 2             |
| <b>COOLING SYSTEMS</b>               |                             |                               |             |             |            |          |               |
| Chilled water, refrigerant and brine | 40-55                       | ½                             | ½           | ¾           | 1          | 1        | 1             |
|                                      | Below 40                    | 1                             | 1           | 1½          | 1½         | 1½       | 1½            |

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, °C = [(°F)-32]/1.8.

a. Deleted.

b. Runouts not exceeding 12 feet in length to individual terminal units.

**503.3.3.2 Other insulation thicknesses.** Insulation thicknesses in Table 503.3.3.1 are based on insulation having thermal resistivity in the range of 4.0 to 4.6 h · ft<sup>2</sup> · °F/Btu/inch (0.704 to 0.810 m<sup>2</sup> · K/W per 25 mm) of thickness on a flat surface at a mean temperature of 75°F (24°C).

Minimum insulation thickness shall be increased for materials having values less than 4.0, or shall be permitted to be reduced for materials having thermal resistivity values greater than 4.6 in accordance with Equation 5-15.

$$\frac{4.6 \times \text{Table 503.3.3.1 Thickness}}{\text{Actual Resistivity}} = \frac{\text{New Thickness}}{\text{Minimum Thickness}} \quad \text{(Equation 5-15)}$$

For materials with thermal resistivity values less than 4.0, the minimum insulation thickness shall be permitted to be increased in accordance with Equation 5-16.

$$\frac{4.0 \times \text{Table 503.3.3.1 Thickness}}{\text{Actual Resistivity}} = \frac{\text{New Thickness}}{\text{Minimum Thickness}} \quad \text{(Equation 5-16)}$$

**503.3.3.3 Duct and plenum insulation.** All supply and return-air ducts and plenums installed as part of an HVAC air-distribution system shall be thermally insulated in accordance with Table 503.3.3.3, or where such ducts or plenums operate at static pressures greater than 2 inches w.g. (500 Pa), in accordance with Section 503.3.3.4.1.

**Exceptions:**

1. Factory-installed plenums, casings or ductwork furnished as a part of the HVAC equipment tested and rated in accordance with Section 503.2.

2. Ducts within the conditioned space that they serve.

**[M] 503.3.3.4 Duct construction.** Ductwork shall be constructed and erected in accordance with the *International Mechanical Code*.

**503.3.3.4.1 High-and medium-pressure duct systems.** All ducts and plenums operating at static pressures greater than 2 inches w.g. (500 Pa) shall be insulated and sealed in accordance with Section 803.2.8. Ducts operating at static pressures in excess of 3 inches w.g. (750 Pa) shall be leak tested in accordance with Section 803.3.6. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

**503.3.3.4.2 Low-pressure duct systems.** All longitudinal and transverse joints, seams and connections of supply and return ducts operating at static pressures less than or equal to 2 inches w.g. (500 Pa) shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems or tapes installed in accordance with the manufacturer’s installation instructions. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

**Exception:** Ducts exposed within the conditioned space they serve shall not be required to be sealed.

**503.3.3.4.3 Sealing required.** All joints, longitudinal and transverse seams, and connections in ductwork, shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems or tapes. Tapes and mastics used to seal ductwork shall be listed and labeled in accor-

**TABLE 503.3.3.3  
MINIMUM DUCT INSULATION<sup>a</sup>**

| ZONE  | ANNUAL HEATING DEGREE DAYS | INSULATION R-VALUE (h · ft <sup>2</sup> · °F.)/Btu <sup>d</sup> |        |  |                     |
|-------|----------------------------|---|--------|--|---------------------|
|       |                            | Ducts in unconditioned attics or outside building               |        | Ducts in unconditioned basements, crawl spaces, garages, and other unconditioned spaces <sup>c</sup> |                     |
|       |                            | Supply  | Return | Supply   | Return <sup>b</sup> |
| 1-3   | < 1,500                    | 8   | 4      | 4  | 0                   |
| 4-7   | 1,500 to 3,500             | 8   | 4      | 6  | 2                   |
| 8-14  | 3,501 to 7,500             | 8   | 4      | 8  | 2                   |
| 15-17 | > 7,500                    | 11  | 6      | 11   | 2                   |

For SI: °C= [(°F)-32]/1.8, 1 (h·ft<sup>2</sup>·°F)/Btu= 0.176 (m<sup>2</sup>·K)/W, 1 foot= 304.5 mm.

- a. Insulation R-values shown are for the insulation as installed and do not include film resistance. The required minimum R-values do not consider water vapor transmission and condensation. Where control of condensation is required, additional insulation, vapor retarders or both shall be provided to limit vapor transmission and condensation. For ducts that are designed to convey both heated and cooled air, duct insulation shall be as required by the most restrictive condition. Where exterior walls are used as plenums, wall insulation shall be as required by the most restrictive condition of this section.
- b. Insulation on return ducts in basements is not required.
- c. Unconditioned spaces include ventilated crawl spaces and framed cavities in those floors, wall and ceiling assemblies which separate conditioned space from unconditioned space or outside air, and are uninsulated on the side facing away from the condition space.
- d. Insulation resistance measured on a horizontal plane in accordance with ASTM C 518, at a mean temperature of 75°F.

dance with UL 181A or UL 181B. Duct connections to flanges of air distribution system equipment shall be sealed and mechanically fastened. Unlisted duct tape is not permitted as a sealant on any metal ducts.

**Exception:** Ducts exposed within the conditioned space they serve shall not be required to be sealed.

**503.3.3.5 Mechanical ventilation.** Each mechanical ventilation system (supply or exhaust, or both) shall be equipped with a readily accessible switch or other means for shutoff, or volume reduction and shutoff, when ventilation is not required. Automatic or gravity dampers that close when the system is not operating shall be provided for outdoor air intakes and exhausts.

**503.3.3.6 Transport energy.** The air transport factor for each all-air system shall be not less than 5.5 when calculated in accordance with Equation 5-17. Energy for transfer of air through heat-recovery devices shall not be included in determining the air transport factor.

$$\text{Air Transport Factor} = \frac{\text{Space Sensible Heat Removal}^a}{\text{Supply} + \text{Return Fans(s) Power Input}^a}$$

(Equation 5-17)

- a. Expressed in consistent units, either Btu/h or Watts.

For purposes of these calculations, space sensible heat removal is equivalent to the maximum coincident design sensible cooling load of all spaces served for which the system provides cooling. Fan power input is the rate of energy delivered to the fan prime mover.

Air and water, all-water and unitary systems employing chilled, hot, dual-temperature or condenser water-transport systems to space terminals shall not require greater transport energy (including central and terminal fan power and pump power) than an equivalent all-air system providing the same space sensible heat removal and having an air transport factor of not less than 5.5.

**503.3.3.7 Balancing.** The HVAC system design shall provide means for balancing air and water systems. Balancing mechanisms shall include, but not be limited to, dampers, temperature and pressure test connections, and balancing valves.

## SECTION 504 SERVICE WATER HEATING

**504.1 Scope.** The purpose of this section is to provide criteria for design and equipment selection that will produce energy savings when applied to service water heating. Water supplies to ice-making machines and refrigerators shall be taken from a cold-water line of the water distribution system.

**504.2 Water heaters, storage tanks and boilers.** Water heaters, storage tanks and boilers shall meet the performance criteria set forth in Sections 504.2.1 and 504.2.2.

**504.2.1 Performance efficiency.** Water heaters and hot water storage tanks shall meet the minimum performance of water-heating equipment specified in Table 504.2.1. Where multiple criteria are listed, all criteria shall be met.

**Exception:** Storage water heaters and hot water storage tanks having more than 140 gallons (530 L) of storage capacity need not meet the standby loss (SL) or heat loss (HL) requirements of Table 504.2.1 if the tank surface area is thermally insulated to R-12.5 and if a standing pilot light is not used.

**504.2.2 Combination service water-heating/space-heating boilers.** Service water-heating equipment shall not be dependent on year-round operation of space-heating boilers; that is, boilers that have as another function winter space heating.

**Exceptions:**

1. Systems with service/space-heating boilers having a standby loss (Btu/h) (W) less than that calculated in equation 5-18:

$$SL \leq \frac{(13.3 \cdot pmd) + 400}{n}$$

(Equation 5-18)

as determined by the fixture count method where:

*pmd* = Probable maximum demand in gallons/hour as determined in accordance with the ASHRAE *HVAC Applications Handbook*.

*n* = Fraction of year when outdoor daily mean temperature exceeds 64.9°F (18°C).

The standby loss is to be determined for a test period of 24-hour duration while maintaining a boiler water temperature of 90°F (32°C) above an

ambient of 60 to 90°F (16 to 32°C) and a 5-foot (1524 mm) stack on appliance.

- For systems where the use of a single heating unit will lead to energy savings, such unit shall be utilized.

**504.3 Swimming pools.** Swimming pools shall be provided with energy-conserving measures in accordance with Sections 504.3.1 through 504.3.3.

**504.3.1 On-off switch.** All pool heaters shall be equipped with an ON-OFF switch mounted for easy access to allow shutting off the operation of the heater without adjusting the thermostat setting and to allow restarting without relighting the pilot light.

TABLE 504.2.1  
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

| CATEGORY   | TYPE                      | FUEL     | INPUT RATING                 | $V_T^a$<br>(gallons) | INPUT TO $V_T$<br>RATIO<br>(Btuh/gal) | TEST METHOD | ENERGY FACTOR <sup>b</sup> | THERMAL EFFICIENCY $E_t$<br>(percent) | STANDBY LOSS<br>(percent/hour) <sup>a</sup> |
|--|---------------------------|----------|------------------------------|----------------------|---------------------------------------|-------------|----------------------------|---------------------------------------|---|
| NAECA-covered water-heating equipment <sup>c</sup> | All                       | Electric | ≤ 12kW                       | All <sup>e</sup>     | —                                     | Note f      | ≥ 0.93-0.00132V*           | —                                     | —   |
|  | Storage                   | Gas      | ≤ 75,000 Btu/h               | All <sup>e</sup>     | —                                     | Note f      | ≥ 0.62-0.0019V*            | —                                     | —   |
|  | Instantaneous             | Gas      | ≤ 200,000 Btu/h <sup>e</sup> | All                  | —                                     | Note f      | ≥ 0.62-0.0019V*            | —                                     | —   |
|  | Storage                   | Oil      | ≤ 105,000 Btu/h              | All                  | —                                     | Note f      | ≥ 0.59-0.0019V*            | —                                     | —   |
|  | Instantaneous             | Oil      | ≤ 210,000 Btu/h              | All                  | —                                     | Note f      | ≥ 0.59-0.0019V*            | —                                     | —   |
|  | Pool heater               | Gas/oil  | All                          | All                  | —                                     | Note g      | —                          | ≥ 78%                                 | —   |
| Other water-heating equipment <sup>d</sup>         | Storage                   | Electric | All                          | all                  | —                                     | Note h      | —                          | —                                     | ≤ 0.30+27/ $V_T^*$                          |
|  | Storage/<br>instantaneous | Gas/oil  | ≤ 155,000 Btu/h              | All                  | < 4,000                               | Note h      | —                          | ≥ 78%                                 | ≤ 1.3+114/ $V_T^*$                          |
|  |                           |          | > 155,000 Btu/h              | All                  | < 4,000                               | Note h      | —                          | ≥ 78%                                 | ≤ 1.3+95/ $V_T^*$                           |
|  |                           |          | < 10<br>≥ 10                 | ≥ 4,000<br>≥ 4,000   | Note h                                | —           | ≥ 80%<br>≥ 77%             | —<br>≤ 2.3+67/ $V_T^*$                |   |
| Unfired storage tanks                              | —                         | —        | —                            | All                  | —                                     | —           | —                          | ≤ 6.5 Btuh/ft <sup>2</sup> i*         |   |

For SI: 1 British thermal unit per square foot = 3.155 W/m<sup>2</sup>, 1 British thermal unit per hour = 0.2931 W, 1 gallon = 3.785 L, °C = [(°F)-32]/1.8.

- $V_T$  is the storage volume in gallons as measured during the standby loss test. For the purpose of estimating the standby loss requirement using the rated volume shown on the rating plate,  $V_T$  should be no less than 0.95V for gas and oil water heaters and no less than 0.90V for electric water heaters.
- V is rated storage volume in gallons as specified by the manufacturer.
- Consistent with National Appliance Energy Conservation Act (NAECA) of 1987.
- All except those water heaters covered by NAECA.
- DOE CFR 10; Part 430, Subpart B, Appendix E applies to electric and gas storage water heaters with rated volumes 20 gallons and gas instantaneous water heaters with input ratings of 50,000 to 200,000 Btu/h.
- DOE CFR 10; Part 430, Subpart B, Appendix E.
- ANSI Z21.56.
- ANSI Z21.10.3. When testing an electric storage water heater for standby loss using the test procedure of Section 2.9 of ANSI Z21.10.3, the electrical supply voltage shall be maintained within ± 1 percent of the center of the voltage range specified on the water heater nameplate. Also, when needed for calculations, the thermal efficiency ( $E_t$ ) shall be 98 percent. When testing an oil water heater using the test procedures of Sections 2.8 and 2.9 of ANSI Z21.10.3, the following modifications will be made: A vertical length of the flue pipe shall be connected to the flue gas outlet of sufficient height to establish the minimum draft specified in the manufacturer's installation instructions. All measurements of oil consumption will be taken by instruments with an accuracy of ± 1 percent or better. The burner shall be adjusted to achieve an hourly Btu input rate within ± 2 percent of the manufacturer's specified input rate with the CO<sub>2</sub> reading as specified by the manufacturer with smoke no greater than 1 and the fuel pump pressure within ± 1 percent of the manufacturer's specification.
- Heat loss of tank surface area (Btu/h · ft<sup>2</sup>) based on 80°F water-air temperature difference.

\*Minimum efficiencies marked with an asterisk are established by preemptive federal law and are printed for the convenience of the user.

**504.3.2 Pool covers.** Heated swimming pools shall be equipped with a pool cover.

**Exception:** Outdoor pools deriving more than 20 percent of the energy for heating from renewable sources (computed over an operating season) are exempt from this requirement.

**504.3.3 Time clocks.** 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.

**504.4 Hot water system controls.** Automatic-circulating hot water system pumps or heat trace shall be arranged to be conveniently turned off, automatically or manually, when the hot water system is not in operation.

**504.5 Pipe insulation.** For automatic-circulating hot water systems, piping heat loss shall be limited to a maximum of 17.5 Btu/h per linear foot (16.8 W/m) of pipe in accordance with Table 504.5, which is based on design external temperature no lower than 65°F (18°C). For external design temperatures lower than 65°F (18°C) insulation thickness must be calculated in accordance with Section 503.3.3.2.

**Exception:** Piping insulation is not required when the heat loss of the piping, without insulation, does not increase the annual energy requirements of the building.

**TABLE 504.5  
MINIMUM PIPE INSULATION  
(thickness in inches)**

| SERVICE WATER-HEATING TEMPERATURES (°F) | PIPE SIZES <sup>a</sup> |                               |             |            |
|---|-------------------------|-------------------------------|-------------|------------|
|   | Noncirculating runouts  | Circulating mains and runouts |             |            |
|   |                         | Up to 1"                      | Up to 1.25" | 1.5" to 2" |
| 170 -180                                | 1/2                     | 1                             | 1 1/2       | 2          |
| 140 -169                                | 1/2                     | 1/2                           | 1           | 1 1/2      |
| 100 -139                                | 1/2                     | 1/2                           | 1/2         | 1          |

For SI: 1 inch = 25.4 mm, °C = [(°F)-32]/1.8, 1 Btu/h/inch · ft<sup>2</sup> · °F = 0.144 W/(m · K).

a. Nominal iron pipe size and insulation thickness. Conductivity, *k* = 0.27.

**504.6 Conservation of hot water.** Hot water shall be conserved in accordance with Section 504.6.1.

**504.6.1 Showers.** Shower heads shall have a maximum flow rate of 2.5 gallons per minute (gpm) (0.158 L/s) at a pressure of 80 pounds per square inch (psi) (551 kPa) when tested in accordance with ASME A112.18.1.

**504.7 Heat traps.** Water heaters with vertical pipe risers shall have a heat trap on both the inlet and outlet of the water heater unless the water heater has an integral heat trap or is part of a circulating system.

**SECTION 505  
ELECTRICAL POWER AND LIGHTING**

**505.1 Electrical energy consumption.** In residential buildings having individual dwelling units, provisions shall be made

to determine the electrical energy consumed by each tenant by separately metering individual dwelling units.

**505.2 Lighting power budget.** The lighting system shall meet the applicable provisions of Section 805.

**Exception:** Detached one- and two- family dwellings and townhouses and the dwelling portion of Group R-2 and R-4 residential buildings.