

CHAPTER 4 RESIDENTIAL ENERGY EFFICIENCY

This chapter has been revised in its entirety; there will be no marginal markings.

SECTION 401 GENERAL

401.1 Scope. This chapter applies to residential buildings.

401.2 Compliance. Projects shall comply with Sections 401, 402.4, 402.5, 402.6 and 403 (referred to as the mandatory provisions) and either:

1. Sections 402.1 through 402.3 (prescriptive); or
2. Section 404 (performance).

401.3 Certificate. A permanent certificate shall be posted on or in the electrical distribution panel. The certificate shall be completed by the builder or registered design professional. The certificate shall list the predominant *R*-values of insulation installed in or on ceiling/roof, walls, foundation (slab, basement wall, crawlspace wall and/or floor) and ducts outside conditioned spaces; *U*-factors for fenestration; and the solar heat gain coefficient (SHGC) of fenestration. Where there is more than one value for each component, the certificate shall list the value covering the largest area. The certificate shall list the type and efficiency of heating, cooling and service water heating equipment.

SECTION 402 BUILDING THERMAL ENVELOPE

402.1 General. (Prescriptive).

402.1.1 Insulation and fenestration criteria. The building thermal envelope shall meet the requirements of Table 402.1.1 based on the climate zone specified in Chapter 3.

402.1.2 *R*-value computation. Insulation material used in layers, such as framing cavity insulation and insulating sheathing, shall be summed to compute the component *R*-value. The manufacturer's settled *R*-value shall be used for blown insulation. Computed *R*-values shall not include an *R*-value for other building materials or air films.

402.1.3 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table 402.1.3 shall be permitted as an alternative to the *R*-value in Table 402.1.1.

Exception: For mass walls not meeting the criterion for insulation location in Section 402.2.3, the *U*-factor shall be permitted to be:

1. *U*-factor of 0.17 in Climate Zone 1.
2. *U*-factor of 0.14 in Climate Zone 2.
3. *U*-factor of 0.12 in Climate Zone 3.

**TABLE 402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT^a**

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT ^b U-FACTOR	GLAZED FENESTRATION SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE	FLOOR R-VALUE	BASEMENT ^c WALL R-VALUE	SLAB ^d R-VALUE & DEPTH	CRAWL SPACE ^e WALL R-VALUE
1	1.20	0.75	0.40	30	13	3	13	0	0	0
2	0.75	0.75	0.40	30	13	4	13	0	0	0
3	0.65	0.65	0.40 ^e	30	13	5	19	0	0	5 / 13
4 except Marine	0.40	0.60	NR	38	13	5	19	10 / 13	10, 2 ft	10 / 13
5 and Marine 4	0.35	0.60	NR	38	19 or 13+5 ^g	13	30 ^f	10 / 13	10, 2 ft	10 / 13
6	0.35	0.60	NR	49	19 or 13+5 ^g	15	30 ^f	10 / 13	10, 4 ft	10 / 13
7 and 8	0.35	0.60	NR	49	21	19	30 ^f	10 / 13	10, 4 ft	10 / 13

For SI: 1 foot = 304.8 mm.

a. *R*-values are minimums. *U*-factors and SHGC are maximums. *R*-19 shall be permitted to be compressed into a 2 × 6 cavity.

b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.

c. The first *R*-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.

d. *R*-5 shall be added to the required slab edge *R*-values for heated slabs.

e. There are no SHGC requirements in the Marine zone.

f. Or insulation sufficient to fill the framing cavity, *R*-19 minimum.

g. "13+5" means *R*-13 cavity insulation plus *R*-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, insulating sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least *R*-2.

TABLE 402.1.3
EQUIVALENT U-FACTORS^a

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT U-FACTOR	CEILING U-FACTOR	FRAME WALL U-FACTOR	MASS WALL U-FACTOR	FLOOR U-FACTOR	BASEMENT WALL U-FACTOR	CRAWL SPACE WALL U-FACTOR
1	1.2	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.75	0.75	0.035	0.082	0.165	0.064	0.360	0.477
3	0.65	0.65	0.035	0.082	0.141	0.047	0.360	0.136
4 except Marine	0.40	0.60	0.030	0.082	0.141	0.047	0.059	0.065
5 and Marine 4	0.35	0.60	0.030	0.060	0.082	0.033	0.059	0.065
6	0.35	0.60	0.026	0.060	0.06	0.033	0.059	0.065
7 and 8	0.35	0.60	0.026	0.057	0.057	0.033	0.059	0.065

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.

402.1.4 Total UA alternative. If the total building thermal envelope UA (sum of *U*-factor times assembly area) is less than or equal to the total UA resulting from using the *U*-factors in Table 402.1.3 (multiplied by the same assembly area as in the proposed building), the building shall be considered in compliance with Table 402.1.1. The UA calculation shall be done using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. The SHGC requirements shall be met in addition to UA compliance.

Exception: For walls that do not meet the criterion for insulation placement, the minimum added insulation *R*-value shall be permitted to be:

1. *R*-value of 4 in Climate Zone 1.
2. *R*-value of 6 in Climate Zone 2.
3. *R*-value of 8 in Climate Zone 3.

402.2 Specific insulation requirements. (Prescriptive).

402.2.1 Ceilings with attic spaces. When Section 402.1.1 would require R-38 in the ceiling, R-30 shall be deemed to satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Similarly R-38 shall be deemed to satisfy the requirement for R-49 wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves.

402.2.2 Ceilings without attic spaces. Where Section 402.1.1 would require insulation levels above R-30 and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation for such roof/ceiling assemblies shall be R-30. This reduction of insulation from the requirements of Section 402.1.1 shall be limited to 500 square feet (46 m²) of ceiling area.

402.2.3 Mass walls. Mass walls for the purposes of this Chapter shall be considered walls of concrete block, concrete, insulated concrete form (ICF), masonry cavity, brick (other than brick veneer), earth (adobe, compressed earth block, rammed earth) and solid timber/logs. The provisions of Section 402.1.1 for mass walls shall be applicable when at least 50 percent of the required insulation *R*-value is on the exterior of, or integral to, the wall. Walls that do not meet this criterion for insulation placement shall meet the wood frame wall insulation requirements of Section 402.1.1.

402.2.4 Steel-frame ceilings, walls and floors. Steel-frame ceilings, walls and floors shall meet the insulation requirements of Table 402.2.4 or shall meet the *U*-factor requirements in Table 402.1.3. The calculation of the *U*-factor for a steel-frame envelope assembly shall use a series-parallel path calculation method.

TABLE 402.2.4
STEEL-FRAME CEILING, WALL AND FLOOR INSULATION
(*R*-VALUE)

WOOD FRAME <i>R</i> -VALUE REQUIREMENT	COLD-FORMED STEEL EQUIVALENT <i>R</i> -VALUE ^a
Steel Truss Ceilings^b	
R-30	R - 38 or R - 30 + 3 or R - 26 + 5
R-38	R - 49 or R - 38 + 3
R-49	R-38+5
Steel Joist Ceilings^b	
R-30	R - 38 in 2×4 or 2×6 or 2×8 R - 49 in any framing
R-38	R - 49 in 2×4 or 2×6 or 2×8 or 2×10
Steel Framed Wall	
R-13	R - 13 + 5 or R - 15 + 4 or R - 21 + 3
R-19	R - 13 + 9 or R - 19 + 8 or R - 25 + 7
R-21	R - 13 + 10 or R - 19 + 9 or R - 25 + 8
Steel Joist Floor	
R-13	R - 19 in 2×6 R - 19 + 6 in 2×8 or 2×10
R-19	R - 19 + 6 in 2×6 R - 19 + 12 in 2×8 or 2×10

a. Cavity insulation *R*-value is listed first, followed by continuous insulation *R*-value.

b. Insulation exceeding the height of the framing shall cover the framing.

402.2.5 Floors. Floor insulation shall be installed to maintain permanent contact with the underside of the subfloor decking.

402.2.6 Basement walls. Walls associated with conditioned basements shall be insulated from the top of the basement wall down to 10 feet (3048 mm) below grade or to the basement floor, whichever is less. Walls associated with unconditioned basements shall meet this requirement unless the floor overhead is insulated in accordance with Sections 402.1.1 and 402.2.5.

402.2.7 Slab-on-grade floors. Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table 402.1.1. The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall. Insulation located below grade shall be extended the distance provided in Table 402.1.1 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building. Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil. 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 (0.79 rad) angle away from the exterior wall. Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation.

402.2.8 Crawl space walls. As an alternative to insulating floors over crawl spaces, crawl space walls shall be permitted to be insulated when the crawl space is not vented to the outside. Crawl space wall insulation shall be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches (610 mm). Exposed earth in unvented crawl space foundations shall be covered with a continuous vapor retarder. All joints of the vapor retarder shall overlap by 6 inches (153 mm) and be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (153 mm) up the stem wall and shall be attached to the stem wall.

402.2.9 Masonry veneer. Insulation shall not be required on the horizontal portion of the foundation that supports a masonry veneer.

402.2.10 Thermally isolated sunroom insulation. The minimum ceiling insulation *R*-values shall be *R*-19 in zones 1 through 4 and *R*-24 in zones 5 through 8. The minimum wall *R*-value shall be *R*-13 in all zones. New wall(s) separating a sunroom from conditioned space shall meet the building thermal envelope requirements.

402.3 Fenestration. (Prescriptive).

402.3.1 *U*-factor. An area-weighted average of fenestration products shall be permitted to satisfy the *U*-factor requirements.

402.3.2 Glazed fenestration SHGC. An area-weighted average of fenestration products more than 50 percent glazed shall be permitted to satisfy the SHGC requirements.

402.3.3 Glazed fenestration exemption. Up to 15 square feet (1.4 m²) of glazed fenestration per dwelling unit shall be permitted to be exempt from *U*-factor and SHGC requirements in Section 402.1.1.

402.3.4 Opaque door exemption. One opaque door assembly is exempted from the *U*-factor requirement in Section 402.1.1.

402.3.5 Thermally isolated sunroom *U*-factor. For Zones 4 through 8, the maximum fenestration *U*-factor shall be 0.50 and the maximum skylight *U*-factor shall be 0.75. New windows and doors separating the sunroom from conditioned space shall meet the building thermal envelope requirements.

402.3.6 Replacement fenestration. Where some or all of an existing fenestration unit is replaced with a new fenestration product, including sash and glazing, the replacement fenestration unit shall meet the applicable requirements for *U*-factor and SHGC in Table 402.1.1.

402.4 Air leakage. (Mandatory).

402.4.1 Building thermal envelope. The building thermal envelope shall be durably sealed to limit infiltration. The sealing methods between dissimilar materials shall allow for differential expansion and contraction. The following shall be caulked, gasketed, weatherstripped or otherwise sealed with an air barrier material, suitable film or solid material:

1. All joints, seams and penetrations.
2. Site-built windows, doors and skylights.
3. Openings between window and door assemblies and their respective jambs and framing.
4. Utility penetrations.
5. Dropped ceilings or chases adjacent to the thermal envelope.
6. Knee walls.
7. Walls and ceilings separating a garage from conditioned spaces.
8. Behind tubs and showers on exterior walls.
9. Common walls between dwelling units.
10. Other sources of infiltration.

402.4.2 Fenestration air leakage. Windows, skylights and sliding glass doors shall have an air infiltration rate of no more than 0.3 cfm per square foot (1.5 L/s/m²), and swinging doors no more than 0.5 cfm per square foot (2.6 L/s/m²), when tested according to NFRC 400 or AAMA/WDMA/CSA 101/I.S.2/A440 by an accredited, independent laboratory and listed and labeled by the manufacturer.

Exceptions: Site-built windows, skylights and doors.

402.4.3 Recessed lighting. Recessed luminaires installed in the building thermal envelope shall be sealed to limit air leakage between conditioned and unconditioned spaces by being:

1. IC-rated and labeled with enclosures that are sealed or gasketed to prevent air leakage to the ceiling cavity or unconditioned space; or

2. IC-rated and labeled as meeting ASTM E 283 when tested at 1.57 psi (75 Pa) pressure differential with no more than 2.0 cfm (0.944 L/s) of air movement from the conditioned space to the ceiling cavity; or
3. Located inside an airtight sealed box with clearances of at least 0.5 inch (12.7 mm) from combustible material and 3 inches (76 mm) from insulation.

402.5 Moisture control. (Mandatory). The building design shall not create conditions of accelerated deterioration from moisture condensation. Above-grade frame walls, floors and ceilings not ventilated to allow moisture to escape shall be provided with 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. Frame walls, floors and ceilings in jurisdictions in Zones 1 through 4. (Crawl space floor vapor retarders are not exempted.)
3. Where other approved means to avoid condensation are provided.

402.6 Maximum fenestration U-factor and SHGC. (Mandatory). The area weighted average maximum fenestration U-factor permitted using trade offs from Section 402.1.4 or Section 404 shall be 0.48 in zones 4 and 5 and 0.40 in zones 6 through 8 for vertical fenestration, and 0.75 in zones 4 through 8 for skylights. The area weighted average maximum fenestration SHGC permitted using trade-offs from Section 404 in Zones 1 through 3 shall be 0.50.

SECTION 403 SYSTEMS (Mandatory)

403.1 Controls. At least one thermostat shall be provided for each separate heating and cooling system.

403.1.1 Heat pump supplementary heat. Heat pumps having supplementary electric-resistance heat shall have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.

403.2 Ducts.

403.2.1 Insulation. Supply and return ducts shall be insulated to a minimum of R-8. Ducts in floor trusses shall be insulated to a minimum of R-6.

Exception: Ducts or portions thereof located completely inside the building thermal envelope.

403.2.2 Sealing. All ducts, air handlers, filter boxes, and building cavities used as ducts shall be sealed. Joints and seams shall comply with Section M1601.3.1 of the *International Residential Code*.

403.2.3 Building cavities. Building framing cavities shall not be used as supply ducts.

403.3 Mechanical system piping insulation. Mechanical system piping capable of carrying fluids above 105°F (41°C) or below 55°F (13°C) shall be insulated to a minimum of R-2.

403.4 Circulating hot water systems. All circulating service hot water piping shall be insulated to at least R-2. Circulating hot water systems shall include an automatic or readily accessible manual switch that can turn off the hot water circulating pump when the system is not in use.

403.5 Mechanical ventilation. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

403.6 Equipment sizing. Heating and cooling equipment shall be sized in accordance with Section M1401.3 of the *International Residential Code*.

SECTION 404 SIMULATED PERFORMANCE ALTERNATIVE (Performance)

404.1 Scope. This section establishes criteria for compliance using simulated energy performance analysis. Such analysis shall include heating, cooling, and service water heating energy only.

404.2 Mandatory requirements. Compliance with this Section requires that the criteria of Sections 401, 402.4, 402.5, 402.6 and 403 be met.

404.3 Performance-based compliance. Compliance based on simulated energy performance requires that a proposed residence (proposed design) be shown to have an annual energy cost that is less than or equal to the annual energy cost of the standard reference design. Energy prices shall be taken from a source approved by the code official, such as the Department of Energy, Energy Information Administration's *State Energy Price and Expenditure Report*. Code officials shall be permitted to require time-of-use pricing in energy cost calculations.

Exception: Jurisdictions that require site energy (1kWh = 3,413 Btu) rather than energy cost as the metric of comparison.

404.4 Documentation.

404.4.1 Compliance software tools. Documentation verifying that the methods and accuracy of the compliance software tools conform to the provisions of this section shall be provided to the code official.

404.4.2 Compliance report. Compliance software tools shall generate a report that documents that the proposed design has annual energy costs less than or equal to the annual energy costs of the standard reference design. The compliance documentation shall include the following information:

1. Address of the residence;
2. An inspection checklist documenting the building component characteristics of the proposed design as listed in Table 404.5.2(1). The inspection checklist shall show the estimated annual energy cost for both