
3 Building Envelope Requirements

This chapter describes the requirements that affect the design of the building envelope for residential buildings. The building's design and choices made for individual components can significantly impact the energy demand needed to meet heating and cooling loads to maintain the building's desired inside comfort temperature. Heating load calculations are used to determine the mechanical HVAC design needed for space heating and cooling. The principal components of heating loads are infiltration and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows and doors. Cooling loads, on the other hand, are dominated by solar gains through windows and skylights and from internal gains due to lighting and occupancy uses.

3.1 Organization

This chapter is organized by building system or building envelope component, and includes the following subject areas:

3.2 What's New for 2013

- Highlights of significant changes for 2013 affecting the building envelope Compliance Options
- Provisions allowing the Energy Commission to approve new products, methods, and procedures for compliance

3.3 Compliance Options

- A summary of the general requirements affecting compliance with the *2013 Building Energy Efficiency Standards*

3.4 Key Envelope Compliance Terms

- Terms used most often related to the building envelope for compliance purposes

3.5 Fenestration

- Detailed explanation of the mandatory requirements, and prescriptive and performance compliance approaches for fenestration

3.6 Envelope Features

- Detailed explanation of the mandatory requirements, and prescriptive and performance compliance approaches for the building envelope

3.7 Advanced Assembly Systems

- Discussion of design techniques that when used in more innovative ways can improve building energy efficiency and receive compliance energy credit

3.8 Compliance and Enforcement

- Discussion of issues to aid compliance and enforcement for elements of the building envelope

3.2 *What's New for 2013*

The 2013 Building Energy Efficiency Standards for residential buildings include increased efficiencies for several envelope measures, and there are improvements that have been made to better aid the designer, builder, and building official.

- An updated equation to calculate the aged solar reflectance for field-applied coatings (cool roof), §110.8(i)2.
- Minimum mandatory insulation requirement for insulation installed between a 2x6 inch and greater wall framing, §150.0(c).
- Introduced an alternative method to meet the prescriptive insulation requirement, TABLE 150.1-A.
- A prescriptive requirement for low- and steep-sloped roofing products (cool roof), §150.1(c)11.
- In alterations, an insulation tradeoff is allowed in the prescriptive requirements, §150.2(b)1H.
- More efficient fenestration (lower U-factor) and higher levels of shading (lower SGHC) are required in specific climate zones; and been introduced covering Dynamic Glazing, and Window Films used for alterations to existing buildings.

Prescriptive component packages C and E have been removed. There is now only one prescriptive component package, Package A (previously component package D).

3.3 *Compliance Options*

Public Resources Code, Section 25402.1 (b) requires the California Energy Commission to establish a formal process for certification of compliance options of new products, materials, designs or procedures that can improve building efficiency levels established by the *Building Energy Efficiency Standards*. §10-109 of the standards allows for the introduction of new calculation methods and measures which cannot be properly accounted for in the current approved compliance approaches. This process for approval of new products, materials, procedures and calculation methods is called compliance options and helps to improve building efficiency levels set by the standards.

The Energy Commission encourages the use of energy-saving techniques and designs for showing compliance with the standards. The compliance options process allows the Energy Commission to review and gather public input regarding the merits of new compliance techniques, products, materials, designs or procedures to demonstrate compliance for newly constructed buildings, additions, and alterations to existing buildings. Approved compliance options are generally carried for use with the newer energy code when revisions are made to the standards and information regarding their use and eligibility and/or installation criteria are incorporated in compliance and reference manuals.

When the Energy Commission approves a new compliance option it is listed in the Special Cases section of the Energy Commission's website based on the adoption year of the standards:

http://www.energy.ca.gov/title24/2008standards/special_case_appliance/.

Compliance Overview

Mandatory Feature and Devices

§150.0

When compliance is being demonstrated with either the prescriptive or performance compliance paths, there are mandatory measures that must be installed. The minimum mandatory levels are sometimes superseded by more stringent prescriptive or performance approach requirements. For example, the mandatory measures specify a weighted average U-factor of ceiling and rafter roof insulation to be U-0.031, but if compliance is being demonstrated with the prescriptive approach for a residential building, Table 150.1-A of the standards is used to establish the minimum roof/ceiling thermal compliance level. In this case, a U-0.025 or U-0.031 roof/ceiling assembly insulation (depending on climate zone) must be installed. Conversely, the mandatory measures may be of a higher efficiency than permitted under the performance approach. In these instances, the higher mandatory levels must be installed. For example, a building may comply using performance computer modeling software with only a U-factor of U-0.41 insulation in a wood-framed attic roof, but a U-factor of at least U-0.031 must be installed because that is the mandatory minimum.

Prescriptive Compliance Approach

Standards Table 150.1-A

The prescriptive requirements are the simplest way to comply with the building envelope requirements but offer little flexibility. If each and every prescriptive requirement is met, the building envelope complies with the standards.

The prescriptive compliance approach consists of meeting specific requirements for each envelope component, plus meeting all minimum mandatory requirements, such as mandatory levels of insulation. Prescriptive requirements apply to:

- roofs and ceilings,
- exterior roofing products
- exterior walls
- demising walls
- floors and soffits
- fenestration
- skylights

Fenestration must meet prescriptive minimum thermal performance values and have a maximum of 20% window-to-wall ratio. Thermal performance values are specified for the maximum U-factor, Solar Heat Gain Coefficient (SHGC) and maximum west facing area. The prescriptive envelope requirements are prescribed in §150.1 which include Table 150.1-A.

Performance Approach

§150.1

The prescribed mandatory measures and prescriptive requirements affect the design and operation of the building. Mandatory measures, prescriptive requirements and operational

schedules establish a minimum performance level which can be exceeded by other design measures and construction practices resulting in greater energy savings.

The performance approach is a more sophisticated compliance method and it offers greater design flexibility than the prescriptive approach. The performance approach may be used for any unique design element(s) that the user of compliance modeling software believes can contribute to the building's energy use.

The performance approach allows for more energy tradeoffs between building features, such as increasing HVAC equipment efficiency in order to allow more fenestration area. See Section 3.8 and Chapter 9 for a more complete discussion of the performance approach.

3.4 Key Envelope Compliance Terms

Elements of the building envelope significantly contribute to its energy efficiency. Several features are important to note when a method is chosen to demonstrate compliance. Components of the building shell include walls, floors, the roof and/or ceiling, and fenestration. Details for compliance of fenestration (windows) and doors are addressed in Section 3.2, Fenestration.

Walls and Space(s) Surrounding Occupancy Uses

Envelope and other building component definitions are listed in §100.1 of the *2013 Standards*, and the Reference Appendices.

- **Envelope** requirements vary by envelope component and are a function of their type of construction, their orientation and the space conditions on either side of the envelope surface.
- An **exterior partition** is an envelope component (roof, wall, floor, window etc.) that separates conditioned space from ambient (outdoor) conditions.
- A **demising partition** is an envelope component that separates conditioned space from an unconditioned space.
- A **conditioned space** is either directly conditioned or indirectly conditioned (see Section 100.1 for full definition). An indirectly conditioned space has less thermal resistance to a directly conditioned space than to the outside. An unconditioned space is enclosed space within a building that is not directly conditioned, or indirectly conditioned.
- A **plenum** is a space below an insulated roof and above an uninsulated ceiling. It is an indirectly conditioned space as there is less thermal resistance to the directly conditioned space below than to the ambient air outside. In comparison, an attic below an uninsulated roof and having insulation on the attic floor is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below. A plenum can also be the space between the underside of a raised floor and the crawl space ground, and is sometimes used as an air supply for the building when the exterior foundation is sealed to the outside.
- An **exterior wall** is considered separately from a **demising wall** or **demising partition** and has more stringent thermal requirements.

- **Sloping surfaces** are considered either a wall or a roof, depending on their slope (see Figure 3-1). If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including windows in walls and any skylights in roofs.
- Floors and roof/ceilings do not differentiate between demising and exterior. Thus an **exterior roof/ceiling** "is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below," ambient conditions or unconditioned space above "and that is not an exterior door or skylight."
- Similarly an "exterior floor/soffit is a **horizontal exterior partition**, or a horizontal demising partition, under conditioned space" and above an unconditioned space or above ambient (outdoor) conditions.

Vapor Retarders and Moisture Protection

- A **vapor retarder** or barrier is a special covering over framing and insulation or covering the ground of a crawl space that protects the assembly components from possible damage due to moisture condensation. During cold weather, the inside of the house is warm and moist (from breathing, showers, etc.) and the outside is cold and dry. Moisture moves from more to less and from warm to cold. When the moisture (in vapor form) reaches a point in the wall or roof assembly that has a temperature below the dew point, it will condense into liquid water. Water build up can cause structural damage, create mold that may contribute to indoor air quality problems and can cause the insulation to lose its effectiveness.
- **Fenestration or Windows** are considered part of the wall because the slope is typically over 60°. Where the slope of fenestration is less than 60°, the glazing indicated as a window is considered a skylight.

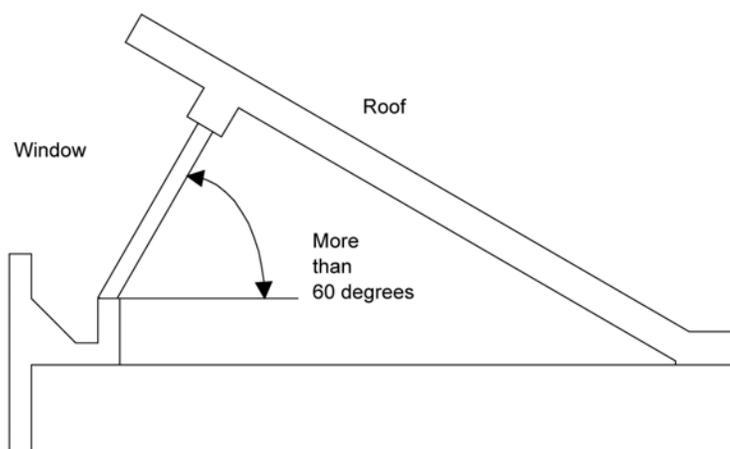


Figure 0-1 – Slope of a Wall or Window (Roof or Skylight slope is less than 60°)

- **Roofing Products (Cool Roof)**

Roofing products with a high solar reflectance and thermal emittance are referred to as “cool roofs.” These roofing types absorb less solar heat and give off more heat to their surroundings than traditional roofing material. These roofs are cooler and thus help reduce air conditioning loads by reflecting and emitting energy from the sun. Roof radiative properties are rated and listed by the Cool Roof Rating Council (CRRC) (<http://www.coolroofs.org/>).

Light-colored high reflectance surfaces reflect solar energy (visible light, invisible infrared and ultraviolet radiation) and stay cooler than darker surfaces that absorb the sun’s energy and become hot.

The standards specify radiative properties that represent minimum “cool roof performance” qualities of roofing products:

- Solar reflectance—the fraction of solar energy that is reflected by the roof surface
- Thermal emittance—the fraction of thermal energy that is emitted from the roof surface

Both solar reflectance and thermal emittance are measured from 0 to 1; the higher the value, the “cooler” the roof. There are numerous roofing materials in a wide range of colors that have relatively good cool roof properties. Excess heat can increase the building’s air conditioning load resulting in increased air conditioning energy needed for maintaining occupant comfort. High-emitting roof surfaces reject absorbed heat quickly (upward and out of the building) than darker roof surfaces with low-emitting properties.

The standards prescribe cool roof radiative properties for low-sloped and steep-sloped roofs (§141.0(b)2B). A low-sloped roof is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizon), while a steep-sloped roof is a surface with a pitch greater than 2:12 (9.5 degrees from the horizon). Because solar heat gain is based on the sun’s angle of incidence on a surface, low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is high in the sky.

-
-

Example 0-1

Question

I am a salesperson and represent some roofing products, and many of them are on the EPA’s Energy Star list for cool roofing materials. Is this sufficient to meet Standards?

Answer

No. Energy Star has different requirements for reflectance and NO requirements for emittance. The Cool Roof Rating Council (<http://www.coolroofs.org/>) is the only entity currently recognized by the Energy Commission to determine what qualifies as a cool roof under.

Example 0-2**Question**

How does a product get CRRC cool roof certification?

Answer

Any party wishing to have a product or products certified by CRRC should contact CRRC to get started call toll-free (866) 465-2523 from inside the US or (510) 485-7176, or email info@coolroofs.org. CRRC staff will walk interested parties through the procedures. In addition, CRRC publishes the procedures in "CRRC-1 Program Manual," available for free on <http://www.coolroofs.org> or by calling CRRC. However, working with CRRC staff is strongly recommended.

Example 0-2**Question**

I understand reflectance, but what is emittance?

Answer

Even a material that reflects the sun's energy will still absorb some of that energy as heat; there are no perfectly reflecting materials being used for roofing. That absorbed heat undergoes a physical change (an increase in wavelength, for readers who remember physics) and is given off – emitted – to the environment in varying amounts by various materials and surface types. This emittance is given a unitless value between 0 and 1, and this value represents a comparison (ratio) between what a given material or surface emits and what a perfect blackbody emitter (again, recall physics) would emit at the same temperature.

A higher emittance value means more energy is released from the material or surface; scientists refer to this emitted energy as thermal radiation (as compared to the energy from the sun, solar radiation, with shorter wavelength). Emittance is a measure of the relative efficiency with which a material, surface, or body can cool itself by radiation. Lower-emitting materials become relatively hotter for not being able to get rid of the energy, which is heat. Roof materials with low emittance therefore hold onto more solar energy as heat, get hotter than high-emittance roofs, and with help from the laws of physics, offer greater opportunity for that held heat to be given off downward into the building through conduction. More heat in the building increases the need for air conditioning for comfort. A cool roof system that reflects solar radiation (has high reflectance) and emits thermal radiation well (has high emittance) will result in a cooler roof and a cooler building with lower air-conditioning costs.

Air Leakage

Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It is a major component of heating and cooling loads. Air leakage can occur through holes and cracks in the building envelope and around doors and fenestration areas. Ventilation is the *intentional* replacement of conditioned air with unconditioned air through open windows or mechanical ventilation.

Reducing air leakage in the building envelope can result in significant energy savings, especially in climates with more severe winter and summer conditions. It also can result in improved building comfort, reduced moisture intrusion, and fewer air pollutants.

Advanced Assemblies

Common strategies for exceeding the minimum energy performance level set by the *2013 Standards* include the use of better components such as: higher insulation levels, more efficient fenestration, reducing the building's air leakage, using radiant barriers, "cool" roofing products, better framing techniques that accommodate more insulation (raised-heel truss) and reduce thermal bridging across framing members, greater use of non-framed assemblies or panelized systems (SIPs and ICFs), and more efficient heating, cooling and water heating equipment. The Energy Commission encourages the use of energy savings techniques for showing compliance with the standards. Innovative designs and practices are discussed in the "advanced Assembly System" section.

Advanced Building Design

The building's design, its floor plan and site design layout impacts energy use. A passive solar designed building uses elements of the building to help heat and cool itself as opposed to relying on mechanical systems to provide the building's thermal energy needs. Passive solar strategies encompass several advanced high performance envelope techniques, such as:

- carefully choosing the size, type and placement of fenestration and shading
- providing and controlling fresh air ventilation during the day or night
- having internal and external thermal mass components that help store useful heat and cooling energy
- having highly insulated envelope assemblies
- using radiative energy performing roofing materials (cool roofs) and radiant barriers
- having very low air leakage

Some measures included as part of an Advanced Assembly System may require specific installation procedures, or field verification and diagnostic testing to ensure their proper performance. Field verification and diagnostic testing is a way to ensure that the energy efficiency that is used in compliance calculations is actually realized as an energy benefit by the homeowner.

3.5 Fenestration

Windows, glazed doors, dynamic glazing, window films, and skylights have a significant impact on energy use in a home. Fenestration may account for up to 50 percent of residential space conditioning load. The size, orientation, and types of

fenestration products can dramatically affect the overall energy performance of a house. Glazing type, orientation, shading and shading devices not only play a major role in the building's energy use but can affect the operation of the HVAC system and the comfort of occupants.

3.5.1 Fenestration Types

There are five primary type of fenestration:

a. WINDOW

Window is fenestration that is not a skylight and that is an assembled unit consisting of a frame and sash component holding one or more pieces of glazing. There are so many window products to choose from it can be sometimes overwhelming. New advances in framing material such as, composites, fiberglass and vinyl help improve the fenestration product to be more efficient. New technology has advanced the glass industry to include reflective coatings such as silver, gold, bronze, and low-e or low-e² can be applied to clear and tinted glass. Other recent new technology is electrochromatic glass that darkens by demand or lightens up when more lighting is desired. Improved glass decreases the Solar Heat Gain Coefficient (SHGC) in the summer and reduces heat loss in the winter. A single, double, and triple layer of glass in combination with the frame improves the overall effect of the frame and window, also known as fenestration.

b. GLAZED DOOR

Glazed door is an exterior door having a glazed area of 50 percent or greater of the door. These doors are typically installed in exterior walls that separate exterior ambient from unconditioned space, similar to the exterior door that leads into the garage. Another example is when the glazed door separates unconditioned space and conditioned space mostly common in residential homes. When the door is less than 50 percent it will no longer be considered a glazed door but a door only. The glass area will still have to be counted towards the overall glass area of the conditioned space.

c. DYNAMIC GLAZING

Dynamic Glazing is a glazing system that has the ability to reversibly change their performance properties, including U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT) between well-defined end points. These may include, but are not limited to chromogenic glazing systems and integrated shading systems. Dynamic Glazing systems do not include internally mounted or externally mounted shading devices that attach to the window framing/glazing that may or may not be removable. For further details see Appendix B.

d. WINDOW FILMS

Window Films was developed in the early 1950's, window films are mostly made of polyester substrate that is durable, tough and highly flexible. It absorbs little moisture and has both high arid and low temperature resistances. Polyester film offers crystal clarity and can be pre-treated to accept different types of coatings for energy control and long term performance. Window films are made with a special scratch resistant coating on one side and with a mounting adhesive layer on the other side. The adhesive is normally applied to the interior surface (room side) of the glass, unless it is a film specifically designed to go on the exterior or outside window surface. For further details see Appendix B.

e. SKYLIGHTS

Skylights are an exceptional source of daylight, illuminating rooms in both residential and commercial buildings with direct and indirect sunlight. The availability of daylight is known to have a positive effect on visual performance, improving both psychological and physiological health and increasing human performance (productivity). In addition, when used appropriately, daylighting can increase the quality of room light and reduce dependence upon electrical lighting.

3.2.2 Relevant Sections in the Standards for Fenestration

§10-111 (Administrative Standards) establishes the rules for rating and labeling fenestration products and establishes the NFRC as the supervising authority.

§110.6(a)1 sets air leakage requirements for all manufactured windows whether they are used in residential or nonresidential buildings.

§110.6(a)2 through 4 require that the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT) for manufactured fenestration products be determined using NFRC procedures or use default values.

§110.6(a)5 requires that manufactured fenestration products have both a temporary and permanent label. The temporary label shall show the U-factor, SHGC and the VT and verify that the window complies with the air leakage requirements.

§110.6(b) field-fabricated fenestration and exterior doors that do not have an NFRC rating shall use the CEC default U-factors, SHGC and VT values.

§110.7 requires that openings around windows and doors be caulked, gasketed, weatherstripped or otherwise sealed to limit air leakage.

§150.0(q) requires a mandatory U-factor of 0.58 or a maximum weighted average U-factor of 0.58 for all fenestration and skylights separating conditioned space from unconditioned space or the outdoors. An exception allows the greater of 10 ft² or 0.5% of the conditioned floor area to exceed 0.58 U-factor.

§150.1(c)3 and 4 have the prescriptive requirements for fenestration and shading in low-rise residential buildings. These include requirements for maximum glazing area, maximum U-factor, and for some climate zones, a maximum SHGC requirement.

§150.1(c)3A Exception 1 allows each dwelling unit to have up to 3 ft² of glazing installed in doors and up to 3 ft² of tubular skylight with dual-pane diffusers to have an assumed U-factor and SHGC equivalent to the Package requirements.

§150.1(c)3A Exception 2 allows up to 16 ft² of the skylight to have up to 0.55 U-factor and up to 0.30 SHGC in each dwelling.

§150.1(c)3A Exception 3 allows automatically controlled chromogenic glazing (a type of dynamic glazing) to (1) assume the lowest U-factor and SHGC when connected to automatically controls to modulate the amount of heat flow into space in multiple steps in response to solar intensity, (2) chromogenic glazing shall be considered separately from other fenestration, and (3) requires that it must be not be weight averaged with other fenestration.

§150.1(c)3A Exception 4 specifies that if a residential dwelling unit contains only site-built fenestration, the U-factor and SHGC can be determined by either default values in Tables 110.6-A or B, or in accordance with Nonresidential Reference Appendix NA6.

§150.1(c)3B the maximum total fenestration area shall not exceed the percentage of conditioned floor area, CFA, as indicated in TABLE 150.1-A. Total fenestration includes skylights and west-facing glazing.

§150.1(c)3C states that when west-facing glazing is limited by Package A, west-facing includes skylights tilted in any direction when the pitch is less than 1:12.

§150.2(a) sets the fenestration area requirements for residential additions and requires that new windows meet the prescriptive requirements.

§150.2(b) establishes that replacement windows in existing residences must meet the prescriptive requirements. Performance compliance options (existing plus alteration) are also available.

3.2.4 Mandatory Measures, Feature and Devices

A. Air Leakage

<i>Applicable Sections</i> §110.6(a)1 §110.7
--

Manufactured fenestration products, including exterior doors, must be tested and certified to leak no more than 0.3 cubic feet per minute (cfm) per ft² of the window area. For a window that has an area of 10 ft², the maximum leakage would be 10 ft² times 0.3 cfm/ft² or a total leakage of 3 cfm. This is equal to about 86 in³ per second or about a quart and a half of air each second. This mandatory measure applies to all manufactured windows whether they are used in new residential or nonresidential buildings. To determine leakage, the test procedure that manufacturers use is either NFRC 400 or ASTM E283, which are essentially the same.

Site-built Products. There are no specific air leakage requirements for site-built fenestration products but the Standards require limiting air leakage through weatherstripping and caulking.

Field-fabricated Products. No air leakage testing is required for field-fabricated fenestration products; however, the Standards require limiting air leakage through weatherstripping and caulking.

Exterior Doors. Exterior doors must meet the following requirements:

- Manufactured exterior doors must be certified as meeting an air leakage rate of 0.3 cfm/ft² of door area of §110.6(a)1, which is the same as windows.
- Exterior doors must comply with the requirements of §110.7, as described in “Joints and Other Openings,” e.g., they must be caulked and weatherstripped if field-fabricated.
- Any door whose surface area that is more than one-half glass is a fenestration product and must comply with the Mandatory and Prescriptive requirements of §150.0, §150.1, and §150.2.

B. U-factor and SHGC Rating Mandatory Requirements

Applicable Sections
 §110.6(a)2 and §110.6(a)3
 TABLE 110.6-A and TABLE 110.6-B

For manufactured fenestration NFRC certified products, the mandatory requirements require that the U-factor and Solar Heat Gain Coefficient (SHGC) be rated by NFRC 100, NFRC 200 or be determined from NFRC's Certified Product Directory (CPD). The test procedure for U-factor is NFRC 100, and the test procedure for SHGC is NFRC 200 and NFRC-200 or ASTM E972, and NFRC-203 for tubular skylights and for certain type of skylights. Requiring that U-factor and SHGC be calculated using a common procedure ensures that the thermal performance data for fenestration products are accurate and the data provided by different manufacturers can be easily compared and verified. See Figure 3-2

At the time of field inspection, the actual fenestration U-factor and SHGC values are shown on attached NFRC labels or the default temporary default values. These values must result in equal or lower overall energy than the values indicated on the compliance documents.

Alternatively, when manufactures do not rate the thermal efficiencies by not using NFRC procedures, the Energy Commission default values must be used and documented using the suggested temporary default label. See Sample Default Label Figure 3-2

The Energy Commissions default U-factors are listed in TABLE 110.6-A, and the default SHGC values are listed in TABLE 110.6-B (also in Appendix B of this compliance manual).

Note: While there is no minimum VT value requirement for residential compliance, the value may be shown on the temporary label for information only. A listing of NFRC certified ratings is available at <http://www.NFRC.org>.

Energy Commission (CEC) default values in both Standards TABLE 110.6-A and TABLE 110.6-B are on the worst side of the performance range for windows. To get credit for high performance window features such as low-e (low-emissivity) coatings and thermal break frames, the window manufacturer must have the window tested, labeled, and certified according to NFRC procedures. Figure 3-2 shows an example of an NFRC-approved temporary fenestration label.

Requiring that U-factor, and SHGC be calculated using a common procedure ensures that the performance data for fenestration products are more accurate and that data provided by different manufacturers can be more easily compared and verified. The test procedure for U-factor is NFRC 100, and the test procedure for SHGC is NFRC 200 and NFRC-200, ASTM E972, or NFRC-203 for tubular skylights.

- A. Site-built Fenestration Products.** For low-rise residential construction, site-built products are treated the same as manufactured products: U-factor and SHGC values must come from NFRC ratings or from Standards TABLE 110.6-A and TABLE 110.6-B. As with manufactured fenestration, while there is no residential minimum VT value, the value is shown on the temporary label is based on NFRC testing and is basically informational.

Note In the case when unrated NFRC site-built fenestration is used in a residential application there is an alternative procedure to calculate the default thermal

efficiencies U-factor and SHGC values of such products. Though using this alternative may not result in meeting the prescriptive values as listed in Table 150.1-A. However, it may be used in the Performance Approach or prescriptively by area-weighting the resultant thermal efficiencies. The alternative calculation can be found in the Reference Nonresidential Appendices NA6.

- B. Field-fabricated Products §116(b).** Field-fabricated fenestration must always use the Energy Commission default U-factors from Standards TABLE 110.6-A and SHGC values from TABLE 110.6-B. There is no minimum requirement for VT.

For non-field-fabricated products, acceptable methods of determining U-factor are shown in **Error! Reference source not found.**. Acceptable methods of determining SHGC are shown in **Error! Reference source not found.**.

Table 0-1 – Allowable Methods for Determining U-factors

Fenestration Category				
U-factor Determination Method	Manufactured Windows	Site-Built Fenestration	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA) ¹	✓	✓	N/A	N/A
NFRC-100	✓	✓	N/A	N/A
Standards Table 110.6-A	✓	✓	✓	✓
NA6 ²		✓		N/A

Note:

1. This option may be available after January1, 2014.
2. New for 2013, NA6 allows residential site-built fenestration to comply with center-of-glass.

Table 0-2 – Methods for Determining Solar Heat Gain Coefficients

Fenestration Category				
SHGC Determination Method	Manufactured Windows	Site-Built Fenestration	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA) ¹	✓	✓	N/A	N/A
NFRC-200	✓	✓	N/A	N/A
Standards Table 110.6-B	✓	✓	✓	✓
NA6 ²		✓		N/A

Note:

1. This option may be available after January1, 2014.
2. New for 2013, NA6 allows residential site-built fenestration to comply with center-of-glass.

C. Labeling Mandatory Requirements

Applicable Sections
§10-111(a)

1. Default Temporary Label

The manufacturer can also choose to use Energy Commission (CEC) default values from TABLE 110.6-A for U-factors and TABLE 110.6-B for SHGC. If default values are used, the manufacturer must attach a temporary label meeting the following specific requirements (permanent etching labels are not required). Product shall meet the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, and SHGC criteria of §110.6(a)3 in the *Building Energy Efficiency Standards for Residential and Nonresidential Buildings*.

Figure 3-2 shows a sample default temporary label. Where possible, it is best to select a fenestration product that is NFRC-rated, and to do so before completing compliance documents. This enables the use of NFRC-certified data to be used for compliance purposes.

Although there is no exact format for the default temporary label, it must be clearly visible and large enough for the enforcement agency field inspectors to read easily and it must include all information required by the regulations.

The minimum suggested label size is 4 in. x 4 in. and the label must have the words at the bottom of the label as noted in Figure 3-2.

“Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2013 California Building Energy Efficiency Standards for Residential and Nonresidential Buildings.”

The U-factor and SHGC default values should be large enough to be visible from 4 ft. For skylights, the label must indicate the product was rated with a built-in curb or with-out. If the product claims the default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criteria, upon which the default value is based, are met. By placing a check in the check box or placing the term “Air space 7/16 in. or greater, Built-in Curb Meets Thermal-Break Default Criteria” on the temporary label will meet the default label requirements.

2013 California Energy Commission Default Label XYZ Manufacturing Co.		
Key Features:	<input type="checkbox"/> Doors	<input type="checkbox"/> Double-Pane
	<input type="checkbox"/> Skylight	<input type="checkbox"/> Glass Block
Frame Type	Product Type:	Product Glazing Type:
<input type="checkbox"/> Metal	<input type="checkbox"/> Operable	<input type="checkbox"/> Clear
<input type="checkbox"/> Non-Metal	<input type="checkbox"/> Fixed	<input type="checkbox"/> Tinted
<input type="checkbox"/> Metal, Thermal Break	<input type="checkbox"/> Greenhouse/Garden Window	<input type="checkbox"/> Single-Pane
<input type="checkbox"/> Air space 7/16 in. or greater <input type="checkbox"/> With built-in curb <input type="checkbox"/> Meets Thermal-Break Default Criteria	-----	To calculate VT see
California Energy Commission Default U-factor 0.61	California Energy Commission Default SHGC 0.53	California Energy Commission Calculated VT 0.51
Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.		

Figure 3-2 Sample of Temporary Label

2. Certified Temporary and Permanent Labels

<i>Applicable Sections</i> §10-111(a) §110.6(a)5
--

a. Certified Manufactured Fenestration Products:

The Standards require that manufactured windows have both temporary and permanent labels that show NFRC performance values. The temporary label shows the U-factor and SHGC, for each rated window. The label must also show that the window meets the air infiltration criteria. The temporary label must not be removed before inspection by the enforcement agency.

The **permanent label** must, at a minimum, identify the certifying organization and have a ID number or code to allow tracking back to the original information on file with the certifying organization, NFRC. The permanent label also can be inscribed on the spacer, etched on the glass, engraved on the frame, or otherwise located so as not to affect aesthetics.

Site-Built Fenestration. Labeling requirements apply to site-built fenestration products as well, except that a *label certificate* may be provided in place of an attached temporary label. The label certificate is a document that verifies the performance of the site-built fenestration product but that is not physically attached to the product. The label certificate is kept at the job site by the contractor for field inspector verification.

Field-Fabricated Fenestration. A label is not required for field-fabricated fenestration products, but must use the CEC default values in TABLE 110.6-A and TABLE 110.6-B from the Standards.

Example 0-4**Question**

My home will have a combination of window types, including fixed, operable, wood, metal, etc., some of which are field-fabricated. What are the options for showing compliance with the Standards?

Answer

For field-fabricated windows, you must select U-factors and SHGC values from the default tables (TABLE 110.6-A and TABLE 110.6-B from the Standards). Windows that are not field-fabricated must be labeled, either with an NFRC label or with a manufacturer's label that certifies the window to have a U-factor and SHGC from the default tables (again, TABLE 110.6-A and TABLE 110.6-B). The manufacturer must label the window in accordance with §110.6(a)5. If the U-factors or SHGC values do not comply with the prescriptive requirements, the performance method must be used (see Chapter 7). To simplify data entry into the compliance software, you may choose the U-factor from TABLE 110.6-A that is the highest of any of the windows and use this for all windows. However, you must use the appropriate SHGC from TABLE 110.6-B for each window type individually.

Example 0-5**Question**

When windows are labeled with a default value, are there any special requirements that apply to the label?

Answer

There are two criteria that apply to fenestration products labeled with default values. First, the Administrative Regulations (§10-111) require that the words "CEC Default U-factor" and "CEC Default SHGC" appear on the temporary label in front of or before the U-factor or SHGC (i.e., not in a footnote). Second, the U-factor and SHGC for the specific product must be listed. If multiple values are listed on the label, the manufacturer must identify, in a permanent manner, the appropriate value for the labeled product. Marking the correct value may be done in the following ways only:

1. Circle the correct U-factor and SHGC (permanent ink);
2. Black out all values except the correct U-factor and SHGC (permanent ink); or
3. Make a hole punch next to the appropriate values.

Example 0-6**Question**

What U-factor do I use for an operable metal framed, glass block? What solar heat gain coefficient do I use for clear glass block? Does it need a label?

Can I use the default clear glass SHGC values for tinted windows?

Answer

For glass block, use the U-factor and SHGC values from Standards TABLE 110.6-A and TABLE 110.6-B for the frame type in which the glass blocks are installed. The worst-case scenario would be metal-framed glass. The U-factor for metal framed glass block is from TABLE 110.6-A is 0.87. The SHGC depends on whether the glass block has a metal or non-metal frame, and is operable or fixed or clear or tinted. For this example, the glass block is operable and clear, therefore the SHGC is 0.70. Glass block is considered a field-fabricated product and therefore does not need a label.

No, the default tables for glass block do not include tinted glass.

Example 0-7

Question

Is there a default U-factor for the glass in sunrooms?

Answer

Yes. For the horizontal or sloped portions of the sunroom glazing, use the U-factor for skylights. For the vertical portions, use the U-factors for fixed windows, operable windows, or doors, as appropriate. As a simplifying alternative, the manufacturer may label the entire sunroom with the highest U-factor of any of the individual fenestration types within the assembly.

Example 0-8

Question

How are various door types treated in compliance documentation for U-factor and SHGC? How can I determine a U-factor and SHGC for doors when less than 50% of the door area is glass?

Answer

All doors with glass area greater than 50% of the door area, which includes French doors, are defined as fenestration products and are covered by the NFRC Rating and Certification Program. You may use either an NFRC-rated U-factor or a default glazed door U-factor from TABLE 110.6-A. The fenestration area for compliance documentation is the entire rough opening of the door (not just the glass area).

The SHGC for doors with glass area more than 50% may be determined in one of two ways:

1. Use the NFRC rated and labeled SHGC.
2. Refer to Standards TABLE 110.6-B. The SHGCs in this table have been pre-calculated based upon glazing type and framing type.

Doors with less than 50% glass areas are treated as a door with fenestration installed within the door. The glass area is calculated as the sum of the glass areas plus two inches on all sides (to account for framing). For prescriptive or performance approaches, use one of the following options for U-factor and SHGC:

- The NFRC label if one is available, or
- The default values from Standards TABLE 110.6-A and 110.6-B

The opaque part of the door is ignored in the prescriptive approach. If the performance approach is used for the glazing part of the door, an NFRC label or default values for U-factors and SHGC must be used, for the opaque portion of the door, a default value of 0.50 must be assumed. Alternatively, if available, NFRC values for U-factor and SHGC may be used for the entire door, including the opaque areas.

Example 0-9

Question

As a manufacturer of fenestration products, I place a temporary label with the air infiltration rates on my products. Can you clarify which products must be tested and certified?

Answer

Each product line must be tested and certified for air infiltration rates. Features such as weather seal, frame design, operator type, and direction of operation all affect air leakage. Every product must have a temporary label certifying that the air infiltration requirements are met. This temporary label may be combined with the temporary U-factor, SHGC and VT label.

Example 0-10

Question

Is a custom window “field-fabricated” for purposes of meeting air infiltration requirements?

Answer

No. Most custom windows are manufactured and delivered to the site either completely assembled or “knocked down,” which means they are a manufactured product. A window is considered field-fabricated when the windows are assembled at the building site from the various elements that are not sold together as a fenestration product (i.e., glazing, framing and weatherstripping). Field-fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits, and curtain walls).

Example 0-11

Question

What constitutes a “double-pane” window?

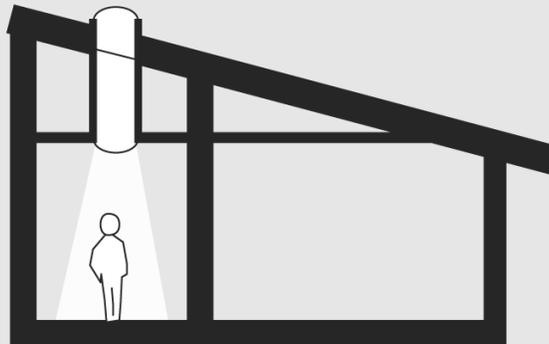
Answer

Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by space (generally 1/4" [6 mm] to 3/4" [18 mm]) filled with air or other gas. Two panes of glazing laminated together do not constitute double-pane glazing.

Example 0-12

Question

To get daylight into a room in my new house, I plan on installing a tubular skylight using the performance approach. The skylight has a clear plastic dome exterior to the roof, a single pane 1/4-inch (6 mm)-thick acrylic diffuser mounted at the ceiling, and a metal tube connecting the two. How do I determine the U-factor and SHGC that I will need to determine if I can comply with the Standards, if U_c is 1.20 and $SHGC_c$ is 0.85?

**Answer**

Tubular skylights are an effective means for bringing natural light into interior spaces.

There are three methods available for determining the U-factor for tubular skylights. The first is to use the default U-factor from Standards TABLE 110.6-A. This tubular skylight would be considered a metal frame, fixed, single-pane resulting in a U-factor of 1.19, which must appear on a label preceded by the words "CEC Default U-factor." (A tubular skylight would have to have two panes of glazing with an air space of less than 2 inches (50 mm) between them at the plane of the ceiling insulation for it to be considered double-pane.)

The second method is to determine the U-factor from the Reference Nonresidential Appendix NA6, Equation NA6-1. The U-factor for this tubular skylight is based on the metal with no curb (Table NA-1). The U-factor for this skylight using Equation NA6-1 is 1.25, where $U_t = (0.195 + (0.882 \times 1.20))$. This must appear on a label stated as "CEC Default U-factor 1.25."

The third and best method, applicable if the skylight has been tested and certified pursuant to NFRC procedures, requires a label that states, "Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures NFRC 100" followed by the U-factor.

There also are three methods available for determining SHGC. The first is to use the default table SHGC in Standards TABLE 110.6-B. This tubular skylight would be considered a metal frame, fixed, clear, single-pane product resulting in an SHGC of 0.83, which must appear on a label stated as "CEC Default SHGC 0.83."

The second method also determines the SHGC from the Reference Nonresidential Appendix NA6, Equation NA6-2. The SHGC for this skylight using Equation NA6-2 is 0.81, where $SHGC_t = (0.08 + (0.86 \times 0.85))$. This must appear on a label stated as "CEC Default SHGC 0.81."

The third method, applicable if the skylight has been tested and certified pursuant to NFRC procedures, requires a label that states, "Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures NFRC 200 followed by the skylight's SHGC.

Example 0-13

Question

How would the U-factor and the SHGC be determined if the skylight in the example above has a dual pane diffuser (instead of single pane) mounted at the ceiling?

Answer

The procedure would be exactly the same as the example above, except that double pane U-factor and SHGC values from Standards TABLE 110.6-A and TABLE 110.6-B would be used instead of single pane values. Note that up to 3 ft² of tubular skylight is assumed to have the U-factor required to meet prescriptive compliance or the Package A value for performance compliance (Exception 1 to §150.1(c)3A).

A. D.**Fenestration U-factor**

Applicable Section §150.1(q)

With the 2013 update, the mandatory maximum U-factor is set by §150.0(q) for fenestration including skylights to be at maximum U-factor of 0.58. While there is an allowance for weight-averaging, this will limit the use of single pane products. Up to 10 ft² or 0.5% of conditioned floor area (whichever is greater) is exempt from the maximum U-factor requirement.

3.2.5 Prescriptive Requirements

Applicable Section §150.1(c)3

Prescriptive requirements described in this chapter typically refer to Package A or Table 150.1-A of the Standards. The maximum U-factor required by prescriptive Package A for all climate zones is 0.32 and the maximum Solar Heat Gain Coefficient (SHGC) is 0.25 or lower for dwellings in climate zones 2, 4, and 6-16. Homes constructed in climate zones 1, 3, and 5 have no maximum SHGC requirements. The requirements apply to fenestration products without consideration of insect screens or interior shading devices. With some exceptions, the U-factor and SHGC of windows, doors and skylights can be area-weight averaged to meet the prescriptive requirement using Form WS-2R in Appendix A of this manual.

When using the prescriptive criteria, some windows may exceed the prescriptive requirement as long as the area-weighted average U-factor meets the requirement. Decorative or stained glass is an example that might not meet the prescriptive requirements unless weight-averaged with other higher efficiency fenestration. To calculate weight-averaged U-factors for prescriptive envelope compliance, see Form WS-2R in Appendix A of this manual.

A. Fenestration Prescriptive Exceptions

Applicable Section §150.1(c)3A through §150.1(c)3C

1. Doors and Tubular skylights

In each dwelling unit, up to 3 ft² of the glazing installed in doors and up to 3 ft² of tubular skylights with dual-pane diffusers at the ceiling are exempt from the prescriptive U-factor and SHGC requirements. Include this glazing area in determining compliance with the maximum 20% fenestration area, but exclude it from the area-weighted calculations to determine compliance with 0.32 U-factor. See Exception 1 of §150.1(c)3A.

2. Skylights

Each new dwelling unit may have up to 16 ft² of skylight with values that exceed prescriptive requirements if the skylight has a maximum 0.55 U-factor and a maximum SHGC of 0.30. The area of the skylight is included in determining compliance with the maximum 20% fenestration area, but the 16 ft² is excluded from the area-weighted calculations for U-factor and SHGC. See Exception 2 of §150.1(c)3A.

Aside from the Fenestration Prescriptive Exceptions, U-factors and SHGCs for skylights can be significantly higher than they are for windows. This means that unless the area-weighted average calculation meets the 0.55 U-factor or lower and meet the 0.30 SHGC or lower when large amounts of individual skylights may not comply with the prescriptive requirements, alternative the performance approach should be used for meeting energy compliance.

3. Dynamic Glazing

If a dwelling unit includes a type of dynamic glazing that is chromogenic or integrated shading device, and the glazing is automatically controlled, use the lowest U-factor and lowest SHGC to determine compliance with prescriptive or performance compliance requirements. Since this type of product has compliance that varies, it cannot be weight averaged with other non-chromogenic products as per Exception 3 of §150.1(c)3A.

4. Site-Built Fenestration

When residential dwelling unit contains only site-built fenestration, the U-factor and SHGC can be determined by either using CEC default values in Tables 110.6-A or B, or alternatively use the center-of-glass values in accordance with Nonresidential Reference Appendix NA6. See Exception 4 of §150.1(c)3A.

5. Window Maximum Area

In addition, the prescriptive requirements limit total glass area to a maximum of 20 percent of the conditioned floor area in all climate zones and west-facing glass to a maximum of 5 percent of the conditioned floor area in climate zones 2, 4, and 6-16. West-facing fenestration area includes skylights tilted to the west or tilted in any direction when the pitch is less than 1:12. See §150.1(c)3B

6. West-facing Orientation

In climate zones 2, 4, and 6 through 16, the window area facing west is limited to a maximum of 5 percent of the conditioned floor area. Any skylights with a pitch of less than 1:12 are considered to be west-facing. The west-facing area requirement is intended to reduce peak demand, since west-facing windows have more solar gain during the peak cooling period and contribute more to the peak cooling load. See §150.1(c)3C.

7. Shading

While a low emissivity (low-e) coating on the glass is one of the most common ways to reduce solar gain in combination with insulated window frame, there are other options to help reduce shading:

- Use of an exterior shade screen or louver on the outside of the window or for south facing windows(see Table 3-4 Exterior Shades and Solar Heat Gain Coefficients)
- Properly sized overhang (See Fixed Permanent Shading Devices)

B. Dynamic Glazing

1. Internal Shading System

Dynamic Glazing products are either internal shading systems or electrochromatic devices and are considered a fenestration product. Internal shading systems include blinds positioned between glass panes that can be opened and closed manually or using automatic controls. The labels for internal shading systems will reflect the endpoints of the product's performance for U-factor and SHGC ratings only. See Internal Shading Device Figure 3-3.

Its unique rating identifiers help consumers understand the “dynamics” of the product, and allow comparison with other similar fenestration products. The label references the following information:

- U-factor measures the rate of heat loss through a product. Therefore, the lower the U-factor, the lower the amount of heat loss. In cold climates where heating bills are a concern, choosing products with lower U-factors will reduce the amount of heat that escapes from inside the house.
- The Solar Heat Gain Coefficient (SHGC) measures the rate of heat gain from solar energy passing through a product. Therefore, the lower the SHGC, the less amount of solar heat gain. In hot climates where air conditioning bills are a concern, choosing products with a lower SHGC will reduce the amount of heat that comes in from the outside.
- Visible Transmittance (VT) measures the amount of light that comes through a product. The higher the VT rating, the more light is allowed through a window or door. VT is commonly used in commercial applications, but is mostly informational for residential application.
- The Variable Arrow – If the product can operate at intermediate states, a dual directional arrow, (\leftrightarrow), with the word “Variable” will appear on the label. Some dynamic glazings are able to adjust to intermediate states allowing for a performance level between the endpoints. The low value rating is displayed to the left (in Closed positioned) and the high value rating is displayed to the right (in the Open position). This lets the consumer know at a glance the best and worst case performance of the product and what the default or de-energized performance level will be.

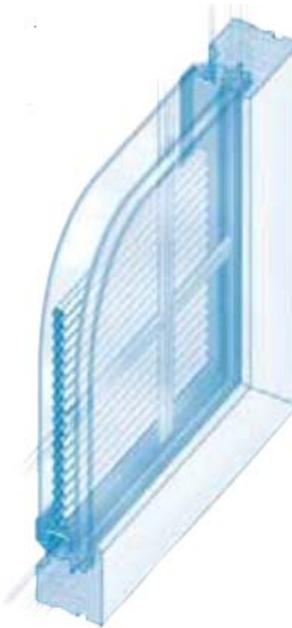


Figure 3-3 Example of a Dynamic Glazing Internal Shading Device

Source: NFRC Dynamic Glazing Products Fact Sheet

	World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Dynamic Glazing • Argon Fill • Low E Product Type: Vertical Slider	
	ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P) 0.30 ↔ 0.40 <small>Off/Closed On/Open</small>	Solar Heat Gain Coefficient 0.10 ↔ 0.50 <small>Off/Closed On/Open</small>	
ADDITIONAL PERFORMANCE RATINGS		
—		Air Leakage (U.S./I-P) 0.2
<small>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org</small>		

Figure 3-4 Dynamic Glazing Internal Shading Device NFRC Label

C. Fenestration with Internal Shading Device

To use Internal Shading Device high performance values the following must be met:

- Automatic controls must be used to receive best rated label value
- With an NFRC Certified Label, but no automatic controls are use then Table 150.1-A prescriptive U-factor of 0.32 and SHGC 0.25 values will be used;
- When no NFRC Internal Shading Device label is available then default to Table 110.6-A and 110-B values.

1. Chromatic Glazing

Another type of fenestration is a Chromatic type fenestration that has the ability to change its performance properties, allowing the occupant to control manually or automatically their environment by tinting or darkening a window with the flip of a switch. Some windows and doors can change their thermal performance automatically in response to a Photosensor control. These high-performance windows sometimes referred to as “smart windows,” provide a variety of benefits, including reduced energy costs due to controlled daylighting and unwanted heat gain or heat loss. While still a relatively new technology, they are expected to grow substantially in the coming years.

Chromatic type fenestration have the ability to change its performance properties, allowing the occupant to control manually or automatically their environment by tinting or darkening a window with the flip of a switch or by raising and lowering a shade positioned between panes of glass. Some windows and doors can change their performance automatically in response to a control or environmental signal. These high-performance windows sometimes referred to as “smart windows,” provide a variety of benefits, including reduced energy costs due to controlled daylighting and unwanted heat gain or heat loss. While still a relatively new technology, they are expected to grow substantially in the coming years.

Look for the NFRC Dynamic Glazing Label to compare products. NFRC-certified Dynamic Glazing label helps consumers understand the contrast in energy performance for these new products. See Chromatic type Figure below.



Figure 3-5

Source: Chabot College, Hayward, California by Sage Electrochromics

 National Fenestration Rating Council® CERTIFIED	World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Dynamic Glazing • Argon Fill • Low E Product Type: Vertical Slider	
	ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P) 0.30 ↔ 0.40 <small>Off/Closed</small> <small>On/Open</small>	Solar Heat Gain Coefficient 0.10 ↔ 0.50 <small>Off/Closed</small> <small>On/Open</small>	
ADDITIONAL PERFORMANCE RATINGS		
Visible Transmittance 0.03 ↔ 0.65 <small>Off/Closed</small> <small>On/Open</small>	Air Leakage (U.S./I-P) 0.2	
Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org		

Figure 3-6 Dynamic Glazing Chromatic Type NFRC Label

Its unique rating identifiers help consumers understand the “dynamics” of the product, and allow comparison with other similar fenestration products. The label references the following information:

- U-factor measures the rate of heat loss through a product. Therefore, the lower the U-factor, the lower the amount of heat loss. In cold climates where heating bills are a concern, choosing products with lower U-factors will reduce the amount of heat that escapes from inside the house.
- The Solar Heat Gain Coefficient (SHGC) measures the rate of heat gain from solar energy passing through a product. Therefore, the lower the SHGC, the less amount of solar heat gain. In hot climates where air conditioning bills are a concern, choosing products with a lower SHGC will reduce the amount of heat that comes in from the outside.
- Visible Transmittance (VT) measures the amount of light that comes through a product. The higher the VT rating, the more light is allowed through a window or door. VT is commonly used in commercial applications, but is mostly informational for residential application.
- The Variable Arrow – If the product can operate at intermediate states, a dual directional arrow, (\leftrightarrow), with the word “Variable” will appear on the label. Some dynamic glazings are able to adjust to intermediate states allowing for a performance level between the endpoints. The low value rating is displayed to the left (in Closed positioned) and the high value rating is displayed to the right (in the Open position). This lets the consumer know at a glance the best and worst case performance of the product and what the default or de-energized performance level will be.

2. Chromatic Glazing Compliance

To use Chromatic Glazing high performance values the following must be met:

- Automatic controls must be used to receive best rated label value
- With an NFRC Certified Label, but no automatic controls are use then Table 150.1-A prescriptive U-factor of 0.32 and SHGC 0.25 values will be used;
- When no NFRC Chromatic Glazing label is available then default to Table 110.6-A and 110-B values.

3. Window Films

Window films is a Polyester film offers crystal clarity and can be pre-treated to accept different types of coatings. Polyester film can also be metalized and easily laminated to other layers of polyester film. It can be tinted or dyed, or metalized through vacuum coating, sputtering, or reactive deposition to produce an array of colored and spectrally selective films, either clear or in color, many times with the color coming from the metallic coating rather than from tinting or dyeing. There are three basic categories:

1. Clear (Non-Reflective);
2. Tinted or Dyed (Non-Reflective); and
3. Metalized (Reflective), which can be metalized through vacuum coating, sputtering, or reactive deposition or reactive deposition and may be clear or colored.

- Clear films are used as safety or security films and to reduce ultraviolet (UV) light which contributes greatly to fading; however, they are not normally used for solar control or energy savings.
- Tinted or dyed films reduce both heat and light transmission, mostly through increased absorptance and can be used in applications where the primary benefit desired is glare control with energy savings secondary.
- Metalized (reflective) films are the preferred film in most energy savings applications, since they reduce transmission primarily through reflectance, and are manufactured to selectively reflect heat more than visible light through various combinations of metals.

Look for the NFRC certified- Attachment Ratings Energy- Performance Label which helps consumers understand the contrast in energy performance of Window Films. See Window Films Figure 3-7 below.

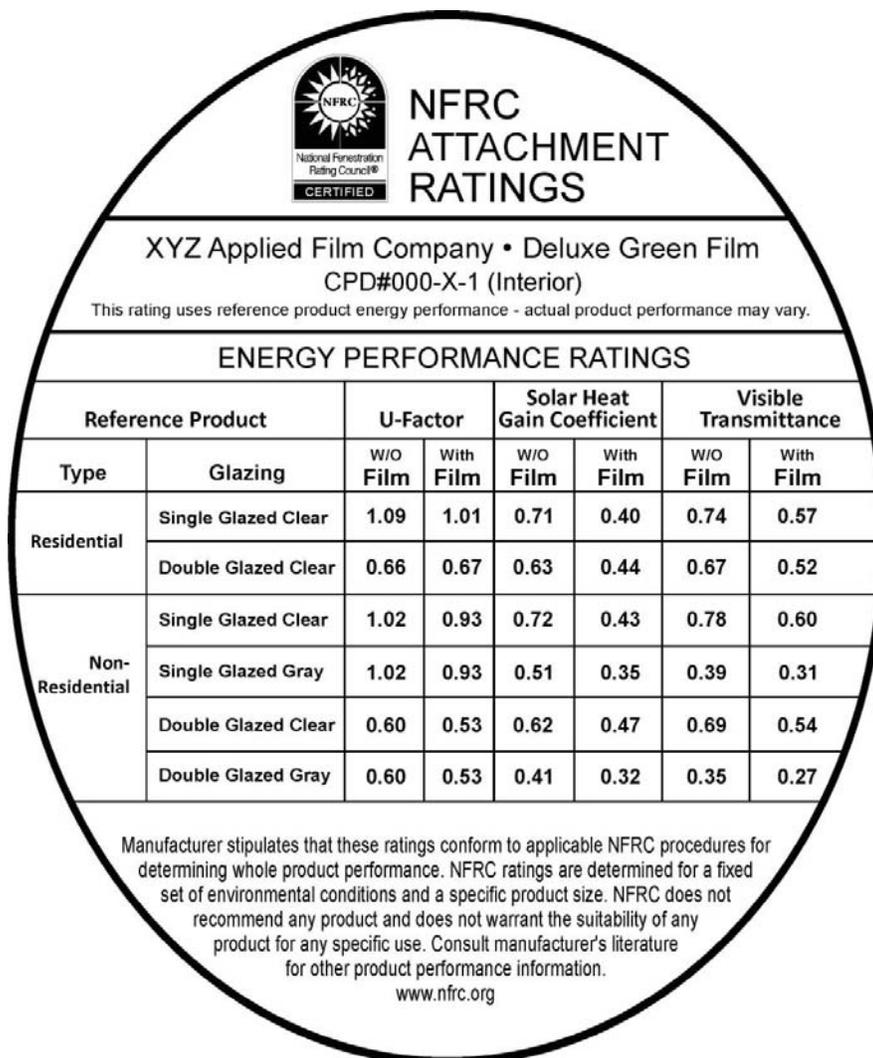


Figure 3-7 Window Film Energy Performance Label

a. Window Film Compliance

To receive window film credit the following must be met:

- The Performance Approach (See Performance Compliance Section (Chapter 8) must be used;
- Only to be use when the Alteration to Existing building compliance method;
- NFRC Window Film Energy Performance Label is required for each different film; otherwise, use the Default Table 110.6-A and 110.6-B values will be used.
- Window Films to be used shall have a 10 year warranty or better

Table 0-3 – Maximum U-factors, SHGC and Fenestration Area by Climate Zone in Packages A

Climate Zone	1, 3, 5	2,4,6-16
Maximum U-factor	0.32	0.32
Maximum SHGC	NR	0.25
Maximum Fenestration Area	20%	20%
Maximum West-Facing Fenestration	NR	5%



Figure 0-8 – Package A SHGC Criteria by Climate Zone

Applicable Sections
 §100.1(b)
 §150.1(c)3C
 §150.1(e)

4. Glazed Doors

§110.6

The following rules apply to doors that have glass areas included in them.

Any door that is more than one-half glass is considered a glazed door and must comply with the mandatory and prescriptive measures and other Standards requirements that apply.

In the prescriptive and performance approach, doors with less than 50 percent glass area, up to 3 ft² is exempt from the U-factor and SHGC. Glass area greater than 3 ft² shall be based on either the NFRC values for the entire door including glass area, or use default values in Table 110.6-A for the U-factor or Table 110.6-B for the SGHC and use either operable or fix. The opaque part of the door is ignored in the prescriptive approach, but in the performance method it is assumed a default U-factor of 0.50. The glass area of the door is calculated as the sum of all glass surfaces plus 2 inches on all sides of the glass to account for a frame.

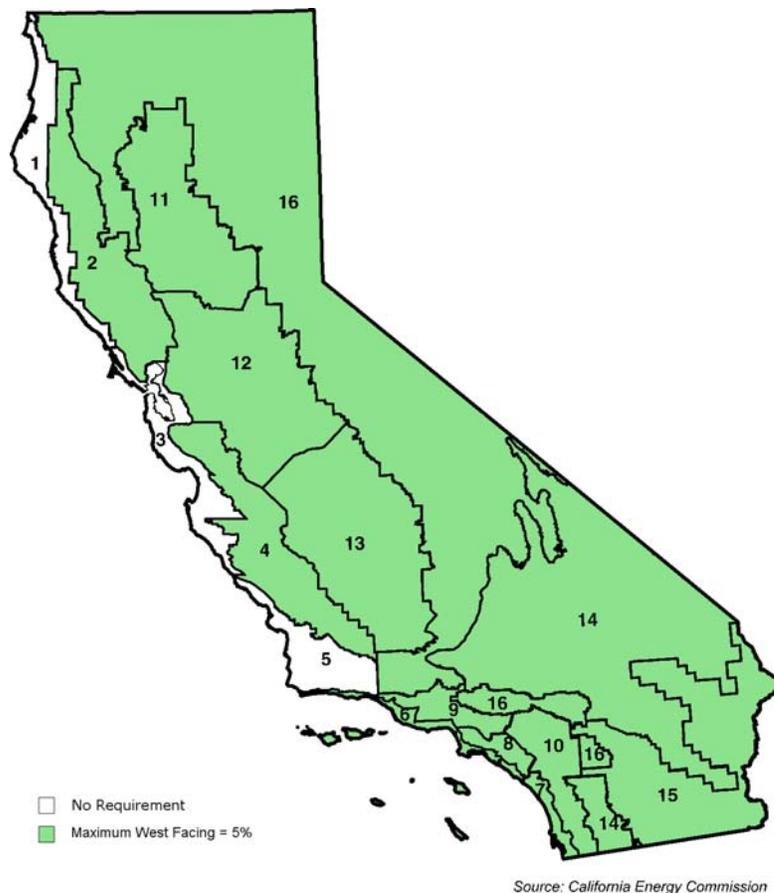


Figure 0-9 – Package A, Prescriptive West-Facing Window Area Limits by Climate Zone

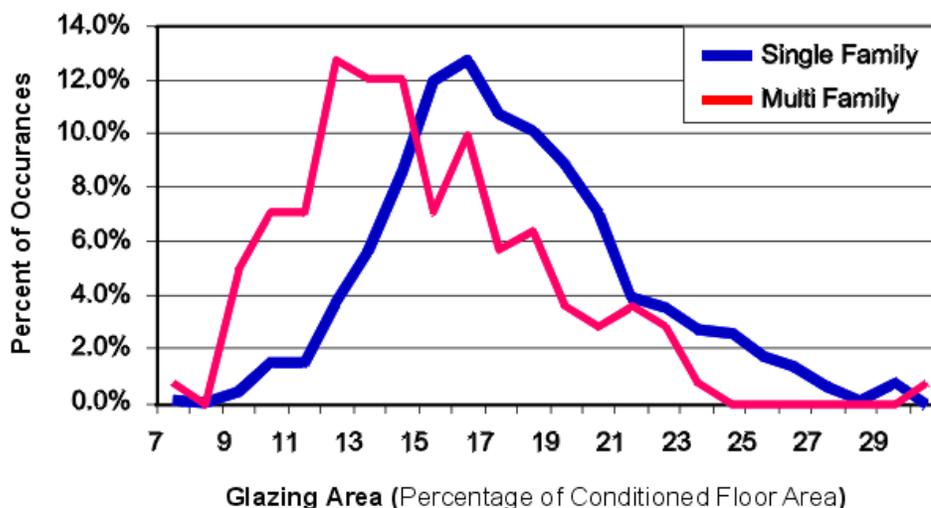
3.2.6 Compliance Alternatives

While the prescriptive requirements and mandatory measures establish a minimum level of performance, the opportunities to exceed the requirements of the standards are considerable. Some of these compliance options are discussed in this section while others are included in the Performance Compliance section (Chapter 8). Options that are recognized for credit through the performance method are called compliance options. Most require using the performance approach, but a few exterior shading devices and south facing overhangs may be used to comply with the prescriptive requirements.

A. Fenestration Area

Beginning with the 2005 update to the Standards, no credit is offered through the performance approach for reducing fenestration area below the maximum allowed 20 percent of the conditioned floor area (CFA).

Data show that the average window area in single family homes is about 17.3 percent of the CFA. In multifamily buildings, the average window area is about 14.5 percent of the conditioned floor area. While these are averages, the variations are considerable as shown in **Error! Reference source not found.**. The variation in fenestration areas has little to do with energy efficiency.



(Source: Residential New Construction Database)

Figure 0-10 – Glass Area in Single Family and Multifamily Residence

Based on data shown in **Error! Reference source not found.**, and as a matter of policy, the Energy Commission made fenestration area less than or equal to 20 percent a neutral variable in the performance approach with the 2005 update and there is no change in this regard in the 2013 update. The Commission recognizes that area and orientation can have a big impact on energy use, but because these are so variable in buildings, the Commission does not want the energy efficiency of other building components to be eroded in buildings that have small window areas. While there is no credit for window area less than 20 percent of CFA, there is a penalty for buildings that have a window area that exceeds 20 percent of CFA. Such buildings

are permitted only with the performance approach, where the standard design has a window area equal to the proposed design, up to 20 percent of the conditioned floor area, and the glass area in the standard design is uniformly distributed among cardinal orientations. The proposed design has the exact proposed glass area and orientation.

B. Orientation

Window and skylight orientation has a huge impact on both energy use and peak electric demand. Orientation is a compliance option that is recognized in the performance approach, since the standard design has windows uniformly distributed on the north, south, east, and west sides of the building.

With the 2005 update and continuing under the 2013 update, the method used to compare whole building performance is TDV energy. With TDV energy, savings during peak periods are worth more than savings at non-peak times. Window and skylight orientation was always an important feature and one for which the Standards offer a credit. The change to TDV makes window orientation even more important in the context of compliance.

C. Improved Window Performance

With the 2013 update, the U-factor has been reduced to 0.32 in all climate zones as indicated in Package A. This means there is less credit available for installing high performance windows that could be traded off or be used to avoid other measures, such as duct sealing and verification. However, choosing high performance windows that perform better than the prescriptive requirements can still earn significant credit through the performance method. In air conditioning climates, choosing a window with an SHGC lower than 0.25 will reduce the cooling loads compared to the standard design.

The magnitude of the impact will vary by climate zone; in mild coastal climates the benefit from reducing window U-factor will be smaller than in cold mountain climates. Computer compliance programs can be a useful tool to compare the impact of different windows and can help the designer determine when an investment in better windows is worthwhile.

Several factors affect window performance. For windows with NFRC ratings, these performance features are accounted for in the U-factor and SHGC ratings:

Frame materials, design, and configuration (including cross-sectional characteristics). Fenestration is usually framed in wood, aluminum, vinyl, or composites of these. Frame materials such as wood and vinyl are better insulators than metal. Some aluminum-framed units have thermal breaks that reduce the conductive heat transfer through the framing element as compared with similar units that have no such conductive thermal barriers.

Number of panes of glazing, coatings, and fill gases. Double-glazing, dynamic glazing offers opportunities for improving performance beyond the dimension of the air space between panes. For example, special materials that reduce emissivity of the surfaces facing the air space, including low-e or other coatings and chromogenic glazing, improve the thermal performance of fenestration products. Fill gases other than dry air such as, carbon dioxide, argon, or krypton and chromogenic glazing – also improve thermal performance.

- Gap Width (i.e., the distance between panes)
- Window type (i.e., casement versus double hung)

- Spacer material (i.e., the type of material separating multiple panes of glass)
- Electro-chromatic glazing with controls

D. Fixed permanent Shading Devices

Shading of windows is also an important compliance option. Overhangs or sidefins that are attached to the building or shading from the building itself are compliance options for which credit is offered through the performance approach. However, no credit is offered for shading from trees, adjacent buildings, or terrain.

Shading devices for which there is credit are those that are a part of the building design. For these, the designer and the builder have control over the measure and can assure that it will be constructed correctly and will perform properly. Non-credit devices are those that the designer has little or no control over, such as the height of a neighboring house or tree.

Windows that face south can be effectively shaded by overhangs positioned above the window. The ideal overhang is one that provides shade during the months when the building is likely to be in an air conditioning mode and allows direct solar gains in the heating months. This can be achieved because during the summer the sun is high as it passes over the south side, while in the winter it is low enabling solar radiation to pass beneath the overhang. Due to the potential effectiveness of south-facing overhangs, a prescriptive compliance option is offered. See the following section for details.

Shading is much more difficult on the east and west sides of the house (see Figure 3-11 **Error! Reference source not found.**). When the sun strikes these façades it is fairly low in the sky, making overhangs ineffective. Vertical fins can be effective, but they degrade the quality of the view from the window and limit the natural light that can enter. In cooling climates, the best approach is to minimize windows that face east and west. Landscaping features can be considered to increase comfort but cannot be used for compliance credit.

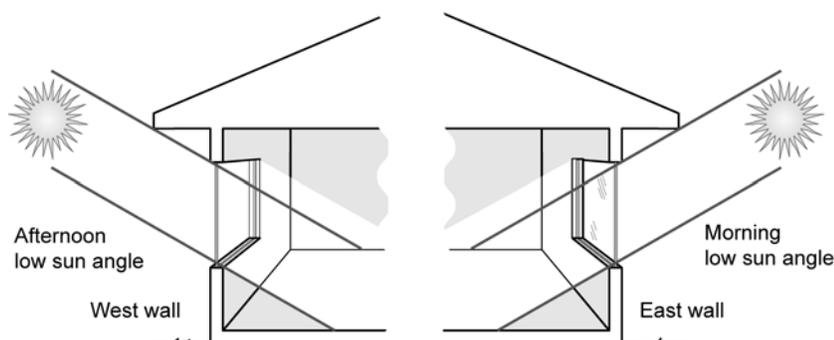


Figure 0-11 – Difficulty of Shading East- and West-Facing Windows

E. Prescriptive Compliance Using South-Facing Overhangs

A south-facing overhang may be used to meet the prescriptive SHGC criteria in the cooling climates. To qualify, the south overhang must be sized to completely shade the window at solar noon on August 21 and to allow the window to be substantially exposed to solar gains at solar noon on December 21. The minimum and maximum overhang depths that meet these criteria are illustrated in Figure 0-12. It is important to note that windows that do not face directly south will require larger overhangs for complete shading.

Credit is also offered for south facing overhangs with the performance method, but in this case the specific dimensions of the overhang are entered into a qualifying computer program and the benefit of the overhang is calculated for each hour of the day or sun angle. With the performance method, credit is not limited to south facing overhangs, although they are still most effective on this orientation.

When a south facing overhang is used for compliance, it must be shown on the plans.

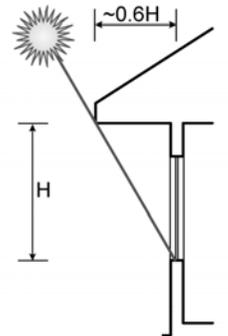
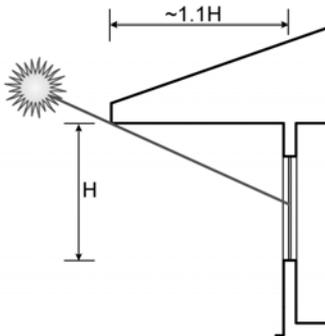
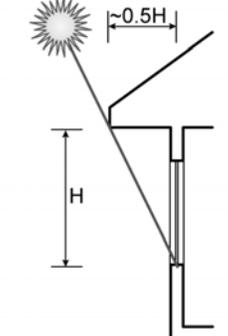
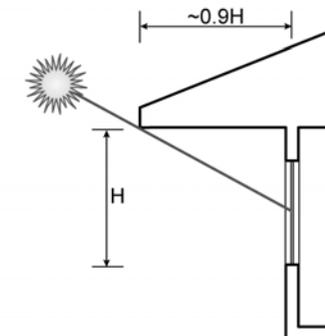
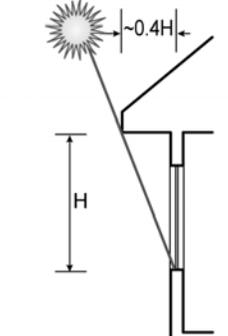
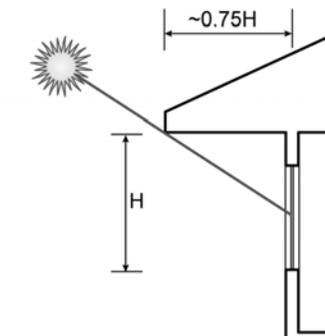
Location/Latitude	Minimum Depth (Noon August 21st)	Maximum Depth (Noon December 21st)
Redding Lat. ~ 41°		
Fresno Lat. ~ 37°		
San Diego Lat. ~ 33°		

Figure 0-12 – South-Facing Overhang Dimensions for Prescriptive Compliance

F. Exterior Shading Devices

The prescriptive Standards require fenestration products with an SHGC of 0.25 or lower in climate zones 2, 4 and 6 through 16. However, a fenestration product with a SHGC greater than 0.25 may be used with the prescriptive requirements if a qualifying exterior shading device is used. Exterior shading devices and their SHGC values are shown in Table 3-4 **Error! Reference source not found.** These include woven sunscreens as well as perforated metal sunscreens. As shown in the table,

these devices transmit between 13 percent and 30 percent of the sun that strikes them.

When exterior shading devices are used, the SHGC requirements of prescriptive Package A may be met for all climate zones without calculations.

For compliance credit, exterior shading devices must be permanently attached as opposed to clips, hooks, latches, snaps, or ties. Exterior shading devices on windows or skylights that are prohibited by life-safety codes from being permanently attached for emergency egress reasons are exempt from this requirement.

The SHGC of the window in combination with an exterior device is given by the following:

$$\text{Equation 1: } \text{SHGC}_{\text{combined}} = (0.2875 \times \text{SHGC}_{\text{max}} + 0.75) \times \text{SHGC}_{\text{min}}$$

All windows are assumed to have an insect screen and this is the default condition against which other window/exterior shading device combinations are compared. The standard case is a window with an SHGC of 0.24 and an insect screen with an SHGC of 0.76. For this default case, the SHGC of the window is the SHGC_{min} , and the SHGC of the exterior sunscreen is SHGC_{max} . Working through the math on WS-3R, $\text{SHGC}_{\text{combined}}$ is 0.24. This means that any combination of window SHGC and exterior SHGC that results in a $\text{SHGC}_{\text{combined}}$ of 0.24 or less complies with the prescriptive requirements.

Most of the shading devices (other than the default) have an SHGC of 0.30 or lower. Combining this with the SHGC of any window may result in an $\text{SHGC}_{\text{combined}}$ which is equal or lower than the prescriptive criterion of 0.25. This method of combining the SHGC of the window with the SHGC of the exterior shading device is also used with the whole building performance approach.

Compliance WS-3R is used to calculate the combined SHGC of windows and exterior shading devices. When exterior shades are required for compliance, they must be listed on the CF-1R form and be documented on the plans.

Table 0-4 –Exterior Shades and Solar Heat Gain Coefficients

Exterior Shading Device	SHGC*
Standard Bug (insect) Screen (default for windows)	0.76
Exterior Sunscreens with Weave 53 x 16/inch	0.30
Louvered Sunscreens w/Louvers as wide as Window Openings	0.27
Low Sun Angle Louvered Sunscreen	0.13
Vertical Roller Shades or retractable/Drop Arm/ Combination/Marquisolette and Operable Awnings	0.13
Roll Down Blinds or Slats	0.13
None (for skylights only)	1.00
* Reference glass values assume single pane clear glass and metal framing 1/8 th inch double strength (DSS) glass. Use WS-3R Worksheet for calculation.	

¹ The equation can be found in the 2013 Residential Compliance Manual and it is included in WS-3R in Appendix A.

G. Interior Shading

There is no credit for interior shading devices, although they can be effective in reducing solar gains and should be considered by homeowners. The Energy Commission considers interior shades in the category of home furnishings and not a feature of the house that is provided by the builder. Draperies, blinds, shades, and other interior devices are therefore not offered credit toward compliance. While there is no compliance credit, a default standard shade is still considered in performance calculations so that estimates of energy use are more realistic, and tradeoffs against other measures are more equitable. A default interior shade is not modeled, however, with skylights.

H. Bay Windows

Bay windows are a special compliance case. Bay windows may either have a unit NFRC rating (i.e., the rating covers both the window and all opaque areas of the bay window), an NFRC rating for the window only, or no NFRC rating. Non-rated bay windows may or may not have factory-installed insulation.

For bay windows that come with an NFRC rating for the entire unit, compliance is determined based on the rough opening area of the entire unit, applying the NFRC U-factor and SHGC. If the unit U-factor and SHGC do not meet the package requirements, the project must show compliance using the performance approach.

Bay windows with no rating for the entire unit (where there are multiple windows that make up the bay) and with factory-installed or field-installed insulation must comply accounting for the performance characteristics of each component separately. Opaque portions of bay windows including roofs and floors, must be insulated to meet the wall insulation requirements of Package A. For prescriptive compliance, the opaque portion must either meet the minimum insulation requirements of Package A for the applicable climate zone or be included in a weighted average U-factor calculation of an overall opaque assembly that does meet the Package A requirements. For the windows, the U-factor and SHGC values may be determined either from an NFRC rating or by using default values in §110.6-A and §110.6-B. If the window U-factor and SHGC meet the package requirements, the bay window complies prescriptively (if overall building fenestration area meets prescriptive compliance requirements). If the bay window does not meet package requirements, the project must show compliance under the performance approach.

I. Natural Ventilation through Fenestration

Operable windows can be a source of ventilation air useful for improving indoor air quality by dilution of indoor air contaminants and moisture and “free” cooling. During periods when the outdoor temperature is lower than the desired indoor temperature and the indoor temperature is uncomfortably warm from solar gains through windows or from heat generated inside the house, windows may be opened for some or all of the cooling. Natural ventilation can reduce the need to run the air conditioner. Not only does natural ventilation save energy, but it can also provide better air quality inside the home.

When building envelopes are sealed to reduce infiltration, air exchange with the outside air is reduced which increases the need for a mechanical means of bringing in outside air.

Energy Commission sponsored research in California homes has shown that a significant number of home occupants do not regularly open their windows for

ventilation. Starting with the 2008 update, it is mandatory to meet the requirements of ASHRAE Standard 62.2 which include mechanical ventilation and minimum openable window area requirements. This mandatory measure is discussed in greater detail in Section 3.5 **Error! Reference source not found.**. Also see Section 4.6 for mechanical ventilation requirements.

Construction Practice/Compliance and Enforcement

The compliance and enforcement process, should ensure that the fenestration efficiency values, areas, orientation, etc. be indicated on the CF-1R form and are also specified on the building plans. In addition, the same efficiency values of the actual installed fenestration products meet or exceed the efficiency values on the CF-1R form. For more information, see Compliance and Enforcement on fenestration in chapter 2 of this manual.

3.6 Envelope Features

This section of the building envelope chapter addresses the requirements for the building shell, excluding fenestration. Components of the building shell include walls, floors, and roofs and/or ceilings. Fenestration, and windows and doors are addressed in Section 3.2, Fenestration.

3.3.1 Mandatory Measures, Features and Devices

Mandatory measures apply to the manufacture, construction and installation of components used in the building envelope.

A. Joints and Other Openings

§110.7

Air leakage through joints, penetrations, cracks, holes and openings around windows, doors, walls, roofs and floors can result in higher energy use for home heating and cooling than necessary. The following openings in the building envelope shall be caulked, gasketed, weatherstripped or otherwise sealed:

1. Exterior joints around window and door frames, including doors between the house and garage, between interior HVAC closets and conditioned space, between attic access and conditioned space, and between wall sole plates, floors, exterior panels and all siding materials;
2. Openings for plumbing, electricity, and gas lines in exterior walls, ceilings and floors;
3. Openings in the attic floor (such as where ceiling panels meet interior and exterior walls and masonry fireplaces);
4. Openings around exhaust ducts such as those for clothes dryers;
5. Weatherstripping is required for all field-fabricated operable windows and doors (other windows and doors must meet infiltration requirements and be laboratory tested). This includes doors between the garage and the house, between interior HVAC closets and conditioned space, and between the attic access and conditioned space (§110.6(b)); and
6. All other such openings in the building envelope

Note also that range hoods must have dampers.

Alternative techniques may be used to meet the mandatory caulking and sealing requirements for exterior walls. These include, but are not limited to:

- Continuous stucco
- Caulking and taping all joints between wall components (e.g., between slats in wood slat walls)
- Building wraps
- Rigid wall insulation installed continuously on the exterior of the building

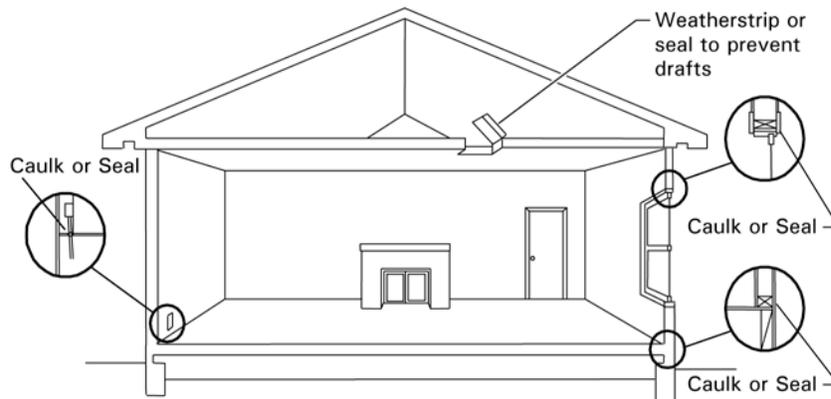


Figure 0-13 – Caulking and Weatherstripping

Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that all potential sources of infiltration and exfiltration in the building envelope, joints and openings are caulked, gasketed, or otherwise sealed. For more information on Compliance and Enforcement on joints and openings, see Chapter 2.

B. Certification of Insulation Materials

§110.8(a)

The California Quality Standards for Insulating Materials ensure that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.

Manufacturers must certify that insulating materials comply with *California Quality Standards for Insulating Materials* (CCR, Title 24, Part 12, Chapters 12-13), which ensure that insulation sold or installed in the state performs according to stated R-values and meets minimum quality, health, and safety standards. Builders may not install insulating materials, unless the product has been certified by the Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Material* to verify the certification of the insulating material. The Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Joint Appendix JA4; only U-factors may be used to demonstrate compliance. The stated R-values for insulation are nominal values and cannot be used for compliance purposes; the U-factors represent the actual thermal conductance of the assembly, including air film

coefficients, framing factors and all layers used to construct the assembly. If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation Program, at (916) 999-2041 or by E-mail: HomeProducts@dca.ca.gov.

C. Urea Formaldehyde Foam Insulation

§110.8(b)

The mandatory measures restrict the use of urea formaldehyde foam insulation. The restrictions are intended to limit human exposure to formaldehyde, which is a volatile organic chemical known to be harmful to humans.

If foam insulation is used that has urea formaldehyde, it must be installed on the exterior side of the wall (not in the cavity of framed walls), and a continuous barrier must be placed in the wall construction to isolate the insulation from the interior of the space. The barrier must be 4-mil (0.1 mm) thick polyethylene or equivalent.

D. Flame Spread Rating of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* also require that all exposed installations of faced mineral fiber and mineral aggregate insulations use fire retardant facings that have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications.

Flame spread ratings and smoke density ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

E. Insulation Placement on Roof/Ceilings

§110.8(e)

Insulation installed on the top of suspended (T-bar) ceilings with removable ceiling panels may not be used to comply with the Standards unless the installation meets the criteria described in the *Exception* to §110.8(e)3 below. Insulation may be installed in this location for other purposes such as for sound control, but it will have no value in terms of meeting roof/ceiling insulation requirements of the Standards.

Acceptable insulation installations include placing the insulation in direct contact with a continuous roof or ceiling that is sealed to limit infiltration and exfiltration as specified in §110.7; including but not limited to placing insulation either above or below the roof deck or on top of a drywall ceiling. See the *2013 Standards* for further requirements. These issues are also addressed in the Nonresidential Compliance Manual.

F. Insulation for Demising Walls

§110.8(f)

Demising walls separating conditioned space from enclosed unconditioned space must be insulated with a minimum of R-13 insulation if the wall is a wood or metal framed assembly. This requirement applies to buildings meeting compliance under the prescriptive or performance approach. This requirement assures at least some insulation in a wall where an adjoining space

may remain unconditioned indefinitely. Demising walls that are constructed of brick, concrete masonry units, or solid concrete are not required to be insulated.

G. Insulation Requirements for Heated Slab Floors

§110.8(g)

Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A of the standards. The top of the insulation must be protected with a rigid plate to prevent intrusion of insects into the building foundation.

A common location for the slab insulation is on the perimeter of the foundation. Insulation that extends downward to the top of the footing is acceptable. Otherwise, the insulation must extend downward from the level of the top of the slab, down 16 inches (40 cm) or to the frost line, whichever is greater.

For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.

Another option is to install the insulation between the heated slab and foundation wall. In this case insulation must extend downwards to the top of the footing and then extend horizontally inwards a distance of 4 ft towards the center of the slab. R-5 vertical insulation is required in all climates except climate zone 16, which requires R-10 of vertical insulation and R-7 horizontal insulation.

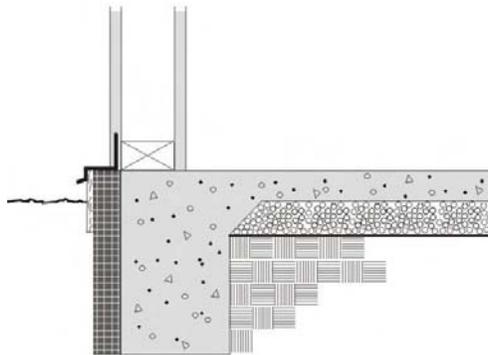


Figure 0-14 – Perimeter slab insulation

Table 3-5 -- Slab Insulation Requirements for Heated Slab Floors

Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Value
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop at the top of the footing where this is less than the required depth. For below grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.	1 – 15	5
			16	10

Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plan view.	1 – 15	5
			16	10 vertical and 7 horizontal

H. Wet Insulation Systems

§110.8(h)

Wet insulation systems are roofing systems where the insulation is installed above the roof's waterproof membrane. Water can penetrate this insulation material and have an effect on the energy performance of the roofing assembly in wet and cool climates. In climate zones 1 and 16, the insulating R-value of continuous insulation materials installed above the roof's waterproof membrane must be multiplied by 0.8 before choosing the table column in Reference Joint Appendix JA4 for determining assembly U-factor. See the footnotes for Tables 4.2.1 through 4.2.7 in the Reference Joint Appendix JA4.

I. Roofing Products Solar Reflectance and thermal Emittance

§110.8(i)

Roofing products be tested and labeled by the Cool Roof Rating Council (CRRC) and that liquid-applied products meet minimum standards for performance and durability per §110.8(i)4 of the Standards. Note that installing cool roofs is *not* a mandatory measure. However, to receive compliance credit, a roofing product's reflectance and thermal emittance must be tested and certified according to CRRC procedures. If a CRRC rating is not obtained for roofing products, default values for reflectance and emittance must be used.

J. Rating and Labeling

§10-113

When a cool roof is installed to meet the prescriptive requirement or are used for compliance credit, the products must be tested and labeled by the Cool Roof Rating Council (CRRC) as specified in §10-113 of the Standards. The CRRC is the supervisory entity responsible for certifying cool roof products. The CRRC test procedure is documented in CRRC-1, the CRRC Product Rating Program Manual. This test procedure includes tests for both solar reflectance and thermal emittance.

	Initial	Weathered	
	Solar Reflectance	0.00	Pending
	Thermal Emittance	0.00	Pending
	Rated Product ID Number	-----	
Licensed Seller ID Number	-----		
Classification	Production Line		
<p>Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary.</p> <p>Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.</p>			

Figure 0-15 – Sample CRRC Product label and information

K. Solar Reflectance, Thermal Emittance, and Solar Reflectance Index (SRI)

§110.8(i)1,2, and 3

To demonstrate compliance with the Standards, all cool roofing products must be certified and labeled according to CRRC procedures. The CRRC certification includes solar reflectance and thermal emittance. There are two kinds of solar reflectance:

- Initial solar reflectance
- 3-year aged solar reflectance

All requirements of the Standards are based on the 3-year aged reflectance. However, if the aged value for the reflectance is not available in the CRRC’s Rated Product Directory, then the aged value shall be derived from the CRRC initial value. The equation below can be used to calculate the aged rated solar reflectance until the appropriate aged rated value for the reflectance is posted in the directory.

Equation 2:

$$\text{Aged Reflectance}_{\text{calculated}} = (0.2 + \beta[\rho_{\text{initial}} - 0.2])$$

Where,

ρ_{initial} = Initial Reflectance listed in the CRRC Rated Product Directory

β = soiling resistance which is listed in Table 3-6

Table 3-6 – Values Of Soiling Resistance β By Product Type

PRODUCT TYPE	β
Field-applied coating	0.65
Other	0.70

The Standards do not distinguish between initial and aged thermal emittance, meaning that either value can be used to demonstrate compliance with the Standards. If a manufacturer fails to obtain CRRC certificate for their roofing products,

the following default aged solar reflectance and thermal emittance values must be used for compliance:

- For asphalt shingles, 0.08/0.75
- For all other roofing products, 0.10/0.75

Solar Reflectance Index (SRI): the temperature of a surface depends on the solar radiation incident, surface's reflectance, and emittance. The SRI measures the relative steady-state surface temperature of a surface with respect to standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient condition. A calculator has been produced by the staff at Lawrence Berkeley National Laboratory, which calculates the SRI by designating the Solar Reflectance and Thermal emittance of the desired roofing material. The calculator can be found at <http://www.energy.ca.gov/title24/2013standards>. SRI calculations must be based on moderate wind velocity of 2-6 meters per second. To calculate the SRI, the 3-year aged value of the roofing product must be used. By using the SRI calculator a cool roof may comply with an emittance lower than 0.85, as long as the aged reflectance is higher and vice versa.

L. Field Applied Liquid Coatings

§110.8(i)4, Table 110.8-C

Liquid roof coatings applied to low-sloped roofs in the field as the top surface of a roof covering shall comply with the following mandatory requirements and descriptions. There are a number of liquid products, including elastomeric coatings and white acrylic coatings that qualify for Field Applied Liquid Coatings. The Standards specify minimum performance and durability requirements for field-applied liquid coatings. Please note that these requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail below.

Aluminum-Pigmented Asphalt Roof Coatings

Aluminum-pigmented coatings are silver-colored coatings that are commonly applied to modified bitumen and other roofing products. The coating has aluminum pigments that float to the top surface of the coating while it is setting, providing a shiny and reflective surface. Because of the shiny surface and the physical properties of aluminum, these coatings have a thermal emittance below 0.75, which is the minimum rating for prescriptive compliance. The overall envelope TDV energy approach is typically used to achieve compliance with these coatings.

This class of field-applied liquid coatings shall be applied across the entire surface of the roof and meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied to. Also, the aluminum-pigmented asphalt roof coatings shall be manufactured in accordance with ASTM

D2824². Standard Specification is also required for Aluminum-Pigmented Asphalt Roof Coatings, Nonfibered, Asbestos Fibered, and Fibered without Asbestos that are suitable for application to roofing or masonry surfaces by brush or spray. Use ASTM D6848, Standard Specification for Aluminum Pigmented Emulsified Asphalt used as a Protective Coating for Roofing; installed in accordance with ASTM D3805³, Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

Cement-Based Roof Coatings

This class of coatings consists of a layer of cement and has been used for a number of years in the central valley of California and in other regions. These coatings may be applied to almost any type of roofing product.

Cement-based coatings shall be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the manufacturer. Also, cement-based coatings shall be manufactured to contain no less than 20% Portland Cement and meet the requirements of ASTM D822⁴, ASTM C1583 and ASTM D5870.

Other Field-Applied Liquid Coatings

Other field-applied liquid coatings include elastomeric and acrylic-based coatings. These coatings must be applied across the entire surface of the roof surface to meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the sub strate on which the coating will be applied. The field-applied liquid coatings must be tested to meet a number of performance and durability requirements as specified in Table

² A. This specification covers asphalt-based, aluminum roof coatings suitable for application to roofing or masonry surfaces by brush or spray.

B. The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

C. The following precautionary caveat pertains only to the test method portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

³ A. This guide covers the application methods for Specification D 2824 Aluminum-Pigmented Asphalt Roof Coatings, Non-Fibered (Type I), Asbestos Fibered (Type II), and Fibered without Asbestos (Type III), for application on asphalt built-up roof membranes, modified bitumen roof membranes, bituminous base flashings, concrete surfaces, metal surfaces, emulsion coatings, and solvent-based coatings. This guide does not apply to the selection of a specific aluminum-pigmented asphalt roof coating type for use on specific projects.

B. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

C. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given in Section 4.

⁴ A. This guide is intended for the evaluation of clear and pigmented coatings designed for use on rigid or semi rigid plastic substrates. Coated film and sheeting are not covered by this guide.

B. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

110.8-C of the Standards or the minimum performance requirements of ASTM C836, D3468, D6083, or D6694, whichever are appropriate to the coating material.

M. Radiant Barriers

§110.8(j)

The radiant barrier is a reflective material that reduces radiant heat transfer caused by solar heat gain in the roof. Radiant barriers reduce the radiant gain to air distribution ducts and insulation located below the radiant barrier. In the performance approach, radiant barriers are modeled as separate adjustments to the heating U-factor and the cooling U-factor. The duct efficiency is also affected by the presence of a radiant barrier, with the performance approach.

Radiant Barrier Construction Practice

To qualify, a radiant barrier must have an emittance of 0.05 or less. The product must be tested according to ASTM C-1371-98 or ASTM E408-71(2002) and must be certified by the California Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation² and listed in their Consumer Guide and Directory of Certified Insulation material, at <http://www.bhfti.ca.gov/industry/tinsulation.shtml>. Radiant barriers must also meet installation criteria as specified in Residential Appendices RA4.2.2 (Section RA4.2.1 is also reproduced in Appendix D of this document).

The most common way of meeting the radiant barrier requirement is to use roof sheathing that has a radiant barrier bonded to it by the manufacturer. Some oriented strand board (OSB) products have a factory-applied radiant barrier. The sheathing is installed with the radiant barrier (shiny side) facing down toward the attic space. Alternatively, a radiant barrier material that meets the same ASTM test and moisture perforation requirements that apply to factory-laminated foil can be field-laminated. Field lamination must use a secure mechanical means of holding the foil type material to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material. Roofs with gable ends must have a radiant barrier installed on them to meet the radiant barrier requirement.

Other acceptable methods are to drape a foil type radiant barrier over the top of the top chords before the sheathing is installed, stapling the radiant barrier between the top chords after the sheathing is installed, and stapling the radiant barrier to the underside of the truss/rafters (top chord). For these installation methods, the foil must be installed with spacing requirements as described in Residential Reference Appendices RA4.2.1. Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces, particularly when roof sheathing is installed that does not include a laminated foil type radiant barrier. Radiant barrier foil material may be field-laminated after the sheathing has been installed by "laminating" the foil as described above to the roof sheathing between framing members. This construction type is described in the Residential Reference Appendices RA 4.2.2. See below for drawings of radiant barrier installation methods.

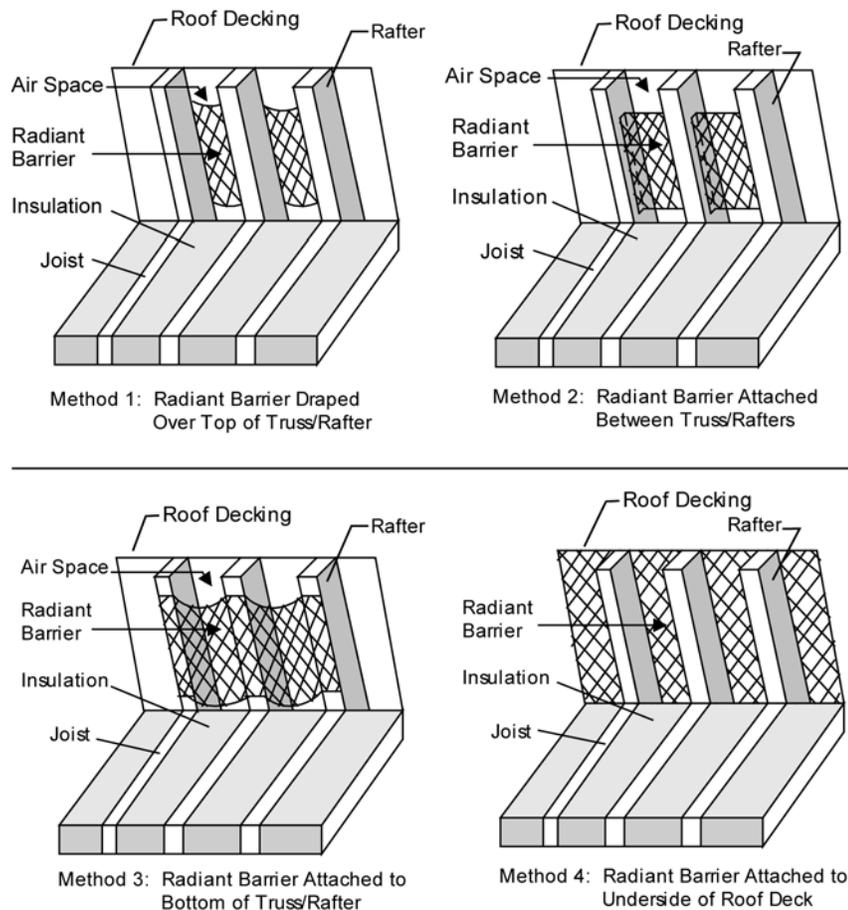


Figure 0-16 – Methods of Installation for Radiant Barriers

N. Ceiling and Rafter Roof Insulation

§110.8(d), §110.8(e), §150.0(a), §150.0(b) These sections are also shown in Appendix B of this document.

- Wood framed roof/ceiling construction assemblies must have at least R-30 insulation or a maximum U-factor of 0.031 based on 24 inch on center wood framed rafter roofs, as determined from the Reference Joint Appendix JA4. Some areas of the roof/ceiling can be less than the mandatory minimum U-factor as long as other areas exceed the requirement and the weighted average U-factor for the overall ceiling/roof is 0.031 or less.
- Metal-framed and roof/ceiling constructions other than wood framed must have a U factor of 0.031 or less in order to comply with the mandatory measures. If the insulation is not penetrated by framing, such as rigid insulation laid over a structural deck, then the rigid insulation can actually have a rated R-value of less than R-30 so long as the total roof/ceiling assembly U-factor is not greater than U-0.031.

O. Loose Fill Insulation

§150.0(b) Loose Fill Insulation

Loose fill insulation must be blown in evenly, and insulation levels must be documented on the Certificate of Installation (CF-2R). The insulation level can be verified by checking that the depth of insulation conforms to the manufacturer's coverage chart for achieving the required R-value. The insulation must also meet the manufacturer's specified minimum weight per ft² for the corresponding R-value. When installing loose fill insulation, the following guidelines should be followed:

For wood trusses that provide a flat ceiling and a sloped roof, the slope of the roof should be at about 4:12 or greater in order to provide adequate access for installing the insulation. Insulation thickness near the edge of the attic will be reduced with all standard trusses, but this is acceptable as long as the average thickness is adequate to meet the minimum insulation requirement.

If the ceiling is sloped (for instance, with scissor trusses), loose fill insulation can be used as long as the slope of the ceiling is no more than 4:12. If the ceiling slope is greater than 4:12, loose fill should be used only if the insulation manufacturer will certify the installation for the slope of the ceiling.

At the apex of the truss, a clearance of at least 30 inch should be provided to facilitate installation and inspection.

P. Wall Insulation

§150.0(c) Wall Insulation

The mandatory measures have two requirements depending on frame size:

1. 2x4 inch wood-framed walls above grade shall have at least R-13 insulation installed in the cavities between framing members, or a U-factor that cannot exceed U-0.102. Insulation may be of greater insulating value in certain areas of the wall and of lesser insulating value in other areas of the wall provided that the area-weighted U- factor does not exceed 0.102 to show equivalence to an R-13 wall.
2. 2x6 inch or greater wood-framed walls above grade shall have at least R-19 insulation installed in the cavities between framing members or a U-factor not exceeding 0.074. Insulation may be of greater insulating value in certain areas of the wall and of lesser insulating value in other areas of the wall provided that the area-weighted U-factor does not exceed 0.074 to show equivalence to an R-19 wall.

There are several cases where the mandatory measures for wall insulation do not apply or apply in a special way. These include the following:

1. The mandatory measures apply to framed foundation walls of heated basements or heated crawl spaces that are located above grade, but not to the portion that is located below grade.

2. For additions to existing buildings, existing wood-framed walls that are already insulated with R-11 insulation need not comply with the mandatory R-13 wall insulation. See the Exception §150.2(a)2B.
3. Rim joists between floors of a multi-story building are deemed to comply with these mandatory measures if they have R-13 insulation installed on the inside of the rim joist and are properly installed between joist members.

Q. Raised-floor Insulation

§150.0(d)

Wood-framed floors must have at least R-19 insulation installed between framing members, or the construction must have a U-factor of 0.049 or less. The equivalent U-factor is based on R-19 insulation in a wood-framed floor. The R-19 insulation value and U-factor of U-0.049 are for the floor assembly alone and do not assume the effects of a crawlspace or buffer zone beneath the floor. The corresponding floor construction from Reference Joint Appendix JA4 is Table 4.4.2, cell entry A4. If comparing to a crawlspace assembly, the equivalent U-factor is 0.037, which includes the effect of the crawlspace. The corresponding floor construction from Reference Joint Appendix JA4 is Table 4.4.1, cell entry A4.

Other types of raised floors, except for concrete raised floors, must also meet the maximum U-factor. In all cases, some areas of the floor can have a U-factor less than the requirement as long as other areas have a U-factor that exceeds the requirement and the area-weighted average U-factor is less than described above.

Raised slab floors with radiant heat (heated slab floors) must meet special insulation requirements that are described in Chapter 4 of this manual.

Table 4.4.1 from Reference Joint Appendix JA4 contains U-factors for floors located over a crawlspace, and JA4 Table 4.4.2 has U-factors for floors located over ambient conditions. Difference in U-factors is accounted by approximately R-6 thermal effect is added to approximate temperature buffering due to the surface areas of the crawlspace and ground soil. The additional R-6 is automatically accounted for when modeling floors over crawlspaces with the performance compliance approach.

There is an exception to the mandatory measures for controlled ventilation crawlspaces. If all eligibility and installation criteria for a controlled ventilated crawlspace are met, raised floors above the controlled ventilation crawlspace need not meet the minimum insulation requirement. See the discussion below in the Advance Assembly System section.

R. Fireplaces, Decorative Gas Appliances and Gas Logs

§150.0(e)

The Standards have mandatory requirements to limit infiltration associated with fireplaces, decorative gas appliances, and gas logs. Fireplace efficiency can be greatly improved through proper air control, and reduced infiltration is also a benefit when the fireplace is not operating (the majority of the time for most houses).

Installation of factory-built or masonry fireplaces (see Figure 3-17) must include the following:

1. Closable metal or glass doors covering the entire opening of the firebox;

2. Doors covering the entire opening of the firebox that can be closed when the fire is burning. A combustion air intake that is at least 6 inch² to draw air from outdoors equipped with a readily accessible, operable and tight-fitting damper or combustion air control device;
3. A combustion air intake that is at least 6 inch² to draw air from outdoors equipped with a readily accessible, operable and tight-fitting damper or combustion air control device (*Exception: An outside combustion air intake is not required if the fireplace is installed over concrete slab flooring and the fireplace is not located on an exterior wall*); and
4. A flue damper with a readily accessible control. (*Exception: When a gas log, log lighter or decorative gas appliance is installed in a fireplace, the flue damper shall be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code*).

Continuous burning pilot lights are prohibited for fireplaces as well as for decorative gas appliances and gas logs. In addition, indoor air may not be used for cooling a firebox jacket when that indoor air is vented to the outside of the building.

When a gas log, log lighter or decorative gas appliance is installed in a fireplace, the flue damper must be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.

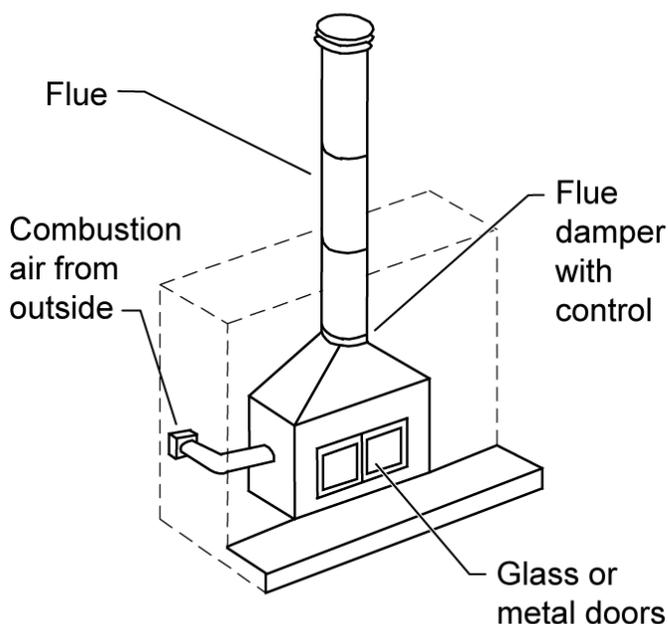


Figure 0-1 – Fireplace Installation

S. Recessed Luminaires in Ceilings

§150.0(k)8

Luminaires recessed in insulated ceilings can create thermal bridging through the insulation. Not only does this degrade the performance of the ceiling assembly, but it can also permit condensation on a cold surface of the luminaire if exposed to moist air, as in a bathroom.

For these reasons, luminaires recessed in insulated ceilings must meet three requirements:

They must be listed as defined in the Article 100 of the California Eclectic Code for zero clearance insulation cover (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials. This enables insulation to be packed in direct contact with the luminaire. (See).

The luminaire must have a label certified as per §150.0(k)8B for air tight (AT) construction. Air tight construction means that leakage through the luminaire will not exceed 2.0 cfm when exposed to a 75 Pa pressure difference, when tested in accordance with ASTM E283.

The luminaire must be sealed with a gasket or caulk between the housing and ceiling.

Refer to the Lighting chapter (Chapter 6) of this compliance manual for more information regarding the applicable requirements for recessed luminaires.

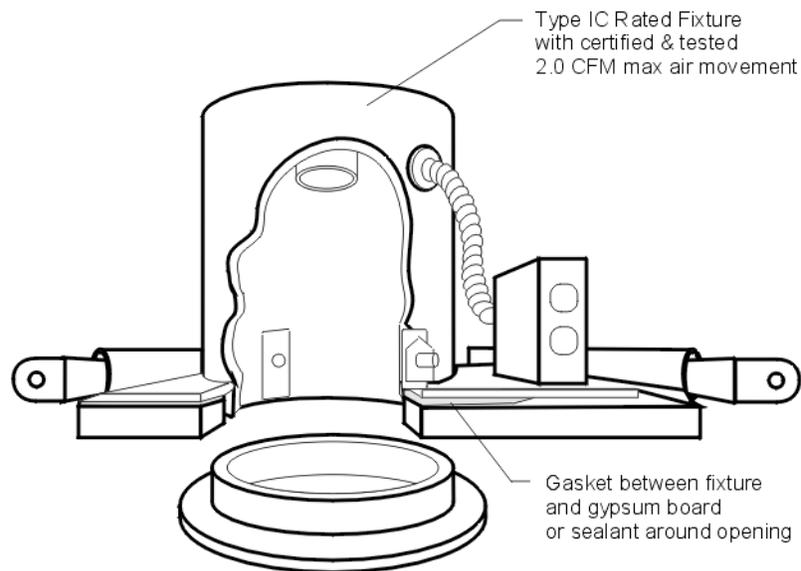


Figure 0-2 – IC-Rated Luminaire (Light Fixture)

T. Slab Insulation

§150.0(l) and §118(g)

The mandatory measures do not require slab insulation, but when the prescriptive requirements call for it, the mandatory measures require that the insulation material must be suitable for the application, with a water absorption rate no greater than 0.3 percent when tested in accordance with ASTM C272 Test Method A, 24-Hour-Immersion, and a vapor permeance no greater than 2.0 perm/inch when tested in accordance with ASTM E96. An example of an insulating material that meets these specifications is smooth-skin extruded polystyrene.

The insulation must also be protected from physical and UV degradation by either installing a water-resistant protection board, extending sheet metal flashing below grade, choosing an insulation product that has a hard durable surface on one side, or by other suitable means.

Slab edge insulation is mandatory with heated slabs, as required by §110.8(g) of the Standards. See Chapter 6 of this manual for details

U. Ventilation for Indoor Air Quality

§150.0(o)

All buildings shall meet the requirements of ASHRAE Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Low-Residential Buildings.

Ventilation Openings

ASHRAE Standard 62.2 requires ventilation openings in habitable spaces, toilets and utility rooms. Ventilation openings usually will mean operable windows, although a dedicated non-window opening for ventilation is acceptable. Spaces that meet the local exhaust requirements are exempted from this requirement so a complying exhaust system can be substituted for a ventilation opening (see Section 4.6.6).

Habitable Spaces

Habitable spaces are required to have ventilation openings with an operable area equal to at least 4 percent of the space floor area (but not less than 5 ft²). Rooms people occupy are considered habitable space. Additional items to be aware of are:

1. Dining rooms, living rooms, family rooms, bedrooms and kitchens are considered habitable space. Closets, crawl spaces, garages and utility rooms are generally not. If the washer and dryer are located in an open basement that is also the family room, it would be considered habitable space.
2. The openings do not have to be provided by windows. They can also be provided by operable, insulated, weather-stripped panels.
3. Ventilation openings, which include windows, skylights, through-the-wall inlets, window air inlets, or similar devices, shall be readily accessible to the occupant. This means that the occupant must be able to operate the opening without having to climb or step up on anything. An operable skylight must have some means of

being operated while standing on the floor; a push rod, a long crank handle, or an electric motor.

4. If a ventilation opening is covered with louvers or otherwise obstructed, the operable area is the unobstructed free area through the opening.

Continuous Operation of Forced Air System

Whole-building ventilation airflow shall be provided to meet the requirements of ASHRAE 62.2. Use of a continuously operating central fan integrated with a forced-air system air handler cannot be used to meet the whole-building ventilation airflow requirement.

- A. Field verification and diagnostic testing is required to confirm proper ventilation airflow following the procedures specified in the Residential Reference Appendices, Appendix RA3.7.

Example 0-14 – Ventilation Openings

Question

I am building a house with a 14 ft. by 12 ft. bedroom. What size window do I need to install?

Answer

It depends on the type of window. The standard requires that the operable area of the window, not the window unit, be 4% of the floor area, or $14\text{ft} \times 12\text{ft} \times 0.04 = 6.7\text{ ft}^2$. The fully opened area of the window or windows must be greater than 6.7 ft^2 . The requirement for this example can be met using two double hung windows each with a fully opened area of 3.35 ft^2 . Any combination of windows whose opened areas add up to at least 6.7 ft^2 will meet the requirement.

There are different minimum requirements for existing (“egress”) in habitable rooms. These are Health and Safety Code requirements and typically require enough operable window area to exit the building through the window. Consult other code requirements because your energy compliance will need to include your total fenestration area.

Example 0-15 – Ventilation Opening Louvers

Question

There are fixed wooden louvers over a window in a bedroom. The louvers have slats that are $1/8$ inch thick, and they are spaced 1 inch apart. What is the reduction in operable area?

Answer

Assuming that the 1 inch spacing was measured perpendicular to the slats (the correct way), then the reduction is the slat thickness divided by the spacing, or $1/8$ inch. So the credited opening area is the original opening area $\times (1\text{ inch} - 1/8\text{ inch})/1\text{ inch} = 7/8$ inch of the original opening area.

Example 0-16

Question

Are closable glass or metal doors required for decorative gas appliances?

Answer

No. The only requirements that apply to decorative gas appliances are the prohibition on continuously burning pilot lights and the prohibition on using indoor air to cool the firebox if the air is then vented to outdoors. If there is a question about whether a device is a fireplace, which requires glass doors, the distinction is that a fireplace has a hearth, chamber or other place in which a solid fuel fire or a decorative gas log set may be burned, while a decorative gas appliance is for visual effect only and merely simulates a fire in a fireplace.

Example 0-17

Question

If I want to have a gas log or some other device in the fireplace of my home, can I block open the damper? Can it have a standing pilot light?

Answer

§150.0(e)1 (which contains the requirements for fireplaces, decorative gas appliances, and gas logs), allows the flue damper to be blocked open if required by either the manufacturer's installation instructions or the California Mechanical Code. Continuously burning pilot lights in these appliances are prohibited by §150(e)2.

Example 0-18

Question

§150.0(e)2 states that no fireplace, decorative gas appliance or gas log can be installed if it has a continuously burning pilot light. The California Mechanical Code requires all gas appliances installed in California to have a manually operated shut-off valve, accessible to the inhabited space. Does this shut-off valve meet the intent of this section?

Answer

Not if the pilot light must be manually extinguished when the appliance is off. A unit that meets the intent of this section will have a pilot light that cannot stay on when the unit is off.

Example 0-19

Question

A building plan specifies a freestanding gas heater that is decorative; however, the equipment is vented and is rated as a room heater. Is it acceptable that this appliance have a pilot light?

Answer

Yes. Since this equipment is rated as a room heater, it can have a continuous burning pilot light.

Example 0-20

Question

Do decorative gas appliances need glass or metal doors?

Answer

Decorative gas appliances do not need doors. The door requirement applies to masonry or factory-built fireplaces only. If a decorative gas appliance is installed inside a fireplace, the fireplace needs doors. Consult with the manufacturer of the decorative gas appliance regarding combustion air requirements.

V. Vapor Retarder

§150.0(g) and Reference Residential Appendix RA4.5.2

In climate zones 14 and 16, a continuous Class II vapor retarder, lapped or joint sealed, must be installed on the conditioned space side of all insulation in all exterior walls, on the floors of vented attics, and in unvented attics with air-permeable insulation.

Buildings with unvented crawl spaces in Climate zones 1-16 must have a Class I or Class II vapor retarder covering the earth floor to protect against moisture condensation.

If a building has a controlled ventilation crawl space (see Section XX), a Class I or Class II vapor retarder must be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with Reference Residential Appendix RA4.5.2.

Vapor retarder class is a measure of the ability of a material or assembly to limit the amount of moisture that passes through the material or assembly. Vapor retarder classes are defined in Section 202 of the CBC. Testing for vapor retarder class is defined using the desiccant method of ASTM E96.

- Class I: 0.1 perm or less
- Class II: $0.1 < \text{perm} \leq 1.0$ perm
- Class III: $1.0 < \text{perm} \leq 10$ perm

A perm is a measure of resistance to the transmission of water vapor and is equal to one grain of water vapor transmitted per ft² per hour per inch of mercury pressure difference.

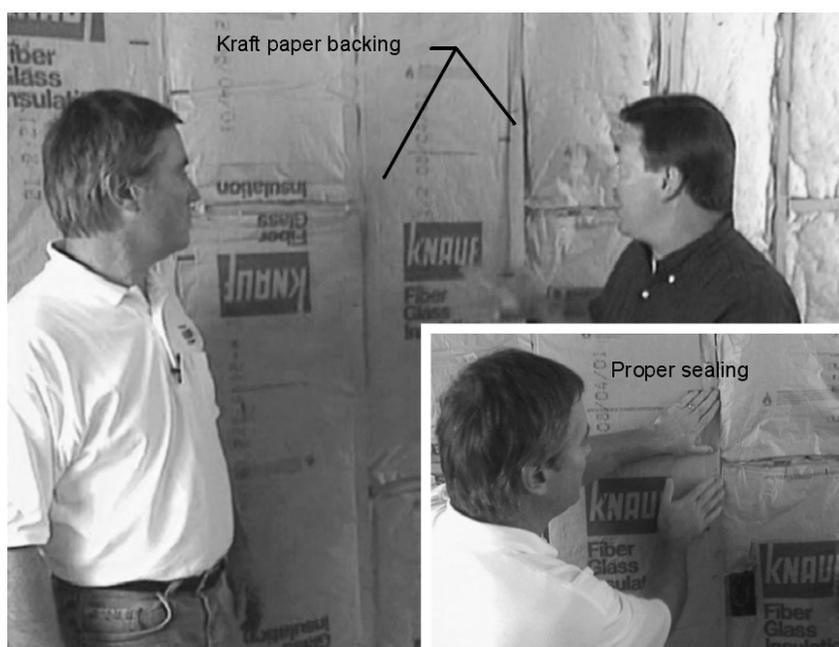
There are many product types having tested vapor retarder performance. Some common examples are:

- Foil and other facings on gypsum board can provide moisture resistance and product literature should always be checked to ensure conformance to ASTM E96.
- The kraft paper used as facing on thermal batt insulation material is typically a Class II vapor retarder. Faced-batts may or may not have flanges for fastening to assembly framing. Fastening flanges may be face or inset stapled, or not stapled at all as the flanges provide no moisture control. Face stapling of flanged thermal batts helps ensure the insulation material is installed fully and properly within the framed cavity. Flangeless batts are also common and require no fastening as these materials maintain their installation integrity through friction-fitting within the cavity of framed assemblies. In all cases, the insulation must be installed properly.

For proper installation of batt insulation with kraft paper backing (see Section XXX). A discussion of best practices for installing flanged thermal batts is provided under Wall Insulation in Reference Residential Appendix RA3.5 and RA3.5.4.

- Many interior painted surfaces may also qualify for meeting the vapor retarder requirement if the paint product has been tested to show its compliance as a vapor retarder. The effectiveness of vapor retarder paint is dependent on the installed thickness, in mils. These products often require more than one layer to achieve their tested perm rating and care must be shown by the installer of the paint and for inspection by the building official.

For all types of vapor barriers, care should be taken to seal penetrations such as electric outlets on exterior walls.



Source: California Energy Commission

Figure 0-3 – Typical Kraft Faced Vapor Retarder Facing

3.3.2 Prescriptive Requirements

A. Roof/Ceiling

The prescriptive package, Component Package A, compliance method requires R-38 insulation or a U-factor of 0.025 in climate zones 1, and 11 through 16. R-30 insulation or U-factor of 0.031 is required in all other climate zones. In addition, a radiant barrier is required in climate zones 2 through 15; the climate zones where air conditioning is more common.

There are three ways to meet the prescriptive insulation requirement. The first way is to install R-30 or R-38 attic insulation in wood-framed construction. Wood-framed

constructions include those in Tables 4.2.1 and 4.2.2 in Reference Joint Appendix JA4.

The second way is to use a different roof assembly from Reference Joint Appendix JA4, including structural insulated panel systems (SIPS) or metal-framed roofs, as long as they have a U-factor less than that of a wood-framed attic (the choices from Table 4.2.1 in Reference Joint Appendix JA4). The U-factor criteria are 0.025 (Table 4.2.1, cell entry A21) in climate zones 1 and 11 through 16 (where R-38 is required) and 0.031 (Table 4.2.1, cell entry A20) in the other climate zones (where R-30 is required).

The third way is to use the Energy Commission's EZ-Frame assembly calculator to calculate the U-factor of the assembly components intended for the building design than those listed for Reference Joint Appendix JA4. The EZ-Frame assembly calculator can be used to calculate the total overall R-value and assembly's U-factor. EZ-Frame is based on procedures of ASHRAE Handbook of Fundamentals.

Note that R-30 or R-38 installed in a wood rafter construction (the choices from JA4 Table 4.2.2) are acceptable for complying with Component Package A, since they have the minimum required insulation, even though these have a U-factor higher than the U-factor criteria stated above.

Construction Practice/Compliance and Enforcement

Insulation coverage should extend far enough to the outside walls to cover the bottom chord of the truss. However, insulation should not block eave vents in attics because the flow of air through the attic space helps remove moisture that can build up in the attic and condense on the underside of the roof. This can cause structural damage and reduce the insulation's effectiveness.

Insulation may be tapered near the eave, but it must be applied at a rate to cover the entire ceiling at the specified level. An elevated truss is not required but may be desirable. See the Advanced Assembly section.

B. RADIANT BARRIERS

§150.1(c)2

The prescriptive requirements call for a radiant barrier in climate zones 2 through 15. The radiant barrier is a reflective material that reduces radiant heat transfer caused by solar heat gain in the roof. Radiant barriers reduce the radiant gain to air distribution ducts and insulation located below the radiant barrier, typically within the attic space. In the performance approach, radiant barriers are modeled as separate adjustments to the heating U-factor and the cooling U-factor. The duct efficiency is also affected by the presence of a radiant barrier when using the performance approach.

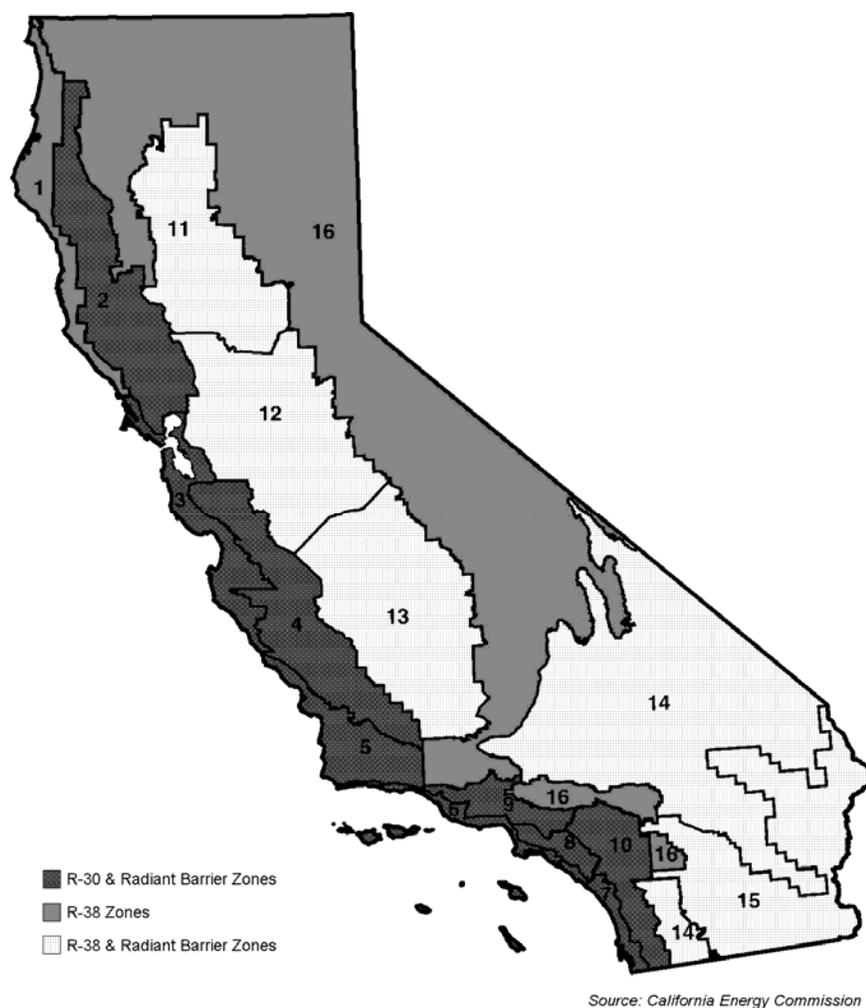


Figure 0-20 – Package A Prescriptive Ceiling/Roof Insulation Requirements

C. Roofing Products (Cool Roof)

§150.1(c)11

The prescriptive requirements call for a cool roof in both low-sloped and steep-sloped applications for residential buildings. A low-slope roof is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizontal or less) while a steep-slope roof is a surface with a pitch greater than 2:12 (more than 9.5 degrees from the horizontal). The prescriptive requirements for cool roofs under the 2013 *Standards* are climate zone dependent and the aged reflectance and emittance criteria do not depend on the type of roofing material being used.

The residential roofing product requirement in the prescriptive package is as follows. For steep-sloped applications in climate zones 10-15, the three year aged solar reflectance requirement of 0.20 and a (three year aged or initial) thermal emittance requirement of 0.75, or a minimum solar reflectance index (SRI) of 16.

For low-sloped roofing applications, in climate zones 13 and 15, there is a minimum aged solar reflectance of 0.55 and thermal emittance of 0.75, or a minimum SRI of 64.

There are two exceptions to meeting the roofing products requirements in the prescriptive package:

- The roof area with building integrated photovoltaic panels and building integrated solar thermal panels are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI Exception 1 to §150.1(c)11B.
- If roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft² are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI under Exception 2 to §150.1(c)11B.

Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that the cool roof efficiency values (solar reflectance and thermal emittance values) modeled on the CF-1R form are specified on the building plans, and that those same values of the actual installed cool roof product meet or exceed the efficiency values on the CF-1R form. For more information on Compliance and Enforcement on cool roof, see chapter 2 of this manual.

Example 0-21

Question

A computer method analysis shows that a new house requires R-38 ceiling insulation to comply using the performance approach, but the minimum mandatory insulation level for ceiling insulation is only R-30. Which insulation level should be used?

Answer

R-38 the higher insulation level must be installed for the building to comply. In some cases such as this, minimum mandatory measures are superseded by stricter compliance measures when using the performance approach.

Example 0-22

Question

A small addition to an existing house appears to comply using only R-15 ceiling insulation with the performance approach. Does this insulation level comply with the Standards?

Answer

No. R-15 would not be sufficient because the required minimum ceiling insulation level established by the mandatory measures is R-30. However, R-15 could be used in limited areas, as follows:

1. 16-inches on center framing with attic with the weighted average U-factor for the entire ceiling/roof less than 0.032.
2. 24-inches on center framing with attic with the weighted average U-factor for the entire ceiling/roof less than 0.031
3. 16-inches on center rafter without attic with the weighted average U-factor for the entire ceiling/roof less than 0.051.
4. 24-inches on center rafter without attic with the weighted average U-factor for the entire ceiling/roof less than 0.049.

D. Wall Insulation

1. Framed Walls

§150.1(c)1B

The Package A prescriptive requirements (Standards Table 150.1-A call for either R-15 cavity wall insulation with R-4 continuous insulation or R-13 cavity wall insulation with R-5 continuous insulation in all climate zones.

Wood-framed walls may comply by specifying and installing the minimum R-value indicated. For metal-framed walls, or as an alternative to meeting the installed R-value in wood-framed walls, the designer may choose any wall construction from Reference Joint Appendix JA4 that has a U-factor equal to or less than 0.065 (Reference Joint Appendix JA4 Table 4.3.1, cell entry C3).

Metal-framed assemblies will require rigid insulation in order to meet the maximum U-factor criteria. U-factors for metal-framed walls are given in Reference Joint Appendix JA4 Table 4.3.4.

2. Mass Walls

§150.1(c)

These sections are also shown in Appendix B of this document.

The prescriptive requirements have separate criteria for interior mass and exterior mass for both above grade walls and below grade walls. The mass wall interior denotes that insulation is installed on the interior surface of the wall and mass wall exterior denotes insulation is installed on the exterior surface of the wall. While the Standards recognize both mass wall systems, separate criteria are presented only for mass wall interior and mass wall exterior in Package A. Package A The R-value listed in Standards Table 150.1-A (also in Appendix B of this document) for mass walls is the minimum R-value or the maximum U-factor for the entire wall assembly, including insulation and both interior and exterior air films. Placement of insulation exterior or interior on mass walls does affect the thermal mass properties of a building. The affect of thermal mass helps temper the fluctuation of heating and cooling loads throughout the year in the building.

3. Concrete Mass and Furred Walls

To determine the total R-value of a mass wall, the U-factor from Reference Joint Appendix JA4 Table 4.3.5, 4.3.6 or other masonry tables is added to an insulation layer selected from Reference Joint Appendix JA4 Table 4.3.14. When the prescriptive requirements are used, the insulation must be installed integral with or on the exterior or interior of the mass wall. To accurately calculate the effective overall efficiency of the concrete wall and furring the Prescriptive CF-1R form can calculate the U-factor by using the Insulation Values for Opaque Surface table.



Figure 0-21 – Brick wall with furring details

The walls addressed in the Properties of Solid Unit Masonry and Solid Concrete Walls tables in the Reference Joint Appendix JA4 tables are rarely used in residential construction, but are common in some types of nonresidential construction. For residential construction, the Prescriptive CF-1R, CF-1R-ADD and CF-1R-ALT can calculate complex wall systems to include furred strip walls.

A four step process is required to calculate the effective U-factor of a furred wall;

Select one of the concrete or masonry walls tables and select a U-factor; and

Select the appropriate Effective R-value for Interior or Exterior Insulation Layers in Table 4.3.14; and

Fill out the CF-1R Insulation Values for Opaque Surface table columns. To achieve the Proposed Assembly U-factor or R-value column, first the *Furring Strips Construction Table for Mass Walls Only* table needs to be filled out; and

Calculate the Final Assembly R-value and carry the value to back to the Insulation Values for Opaque Surface Details table. Compare the R-value, it must be equal to or greater than the mass standard R-value from Energy Standards Prescriptive TABLE 150.1-A.

Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that the insulation R-value for walls (cavity and/or continuous) modeled on the CF-1R form is specified on the building plans and that the same value for the actual installed wall insulation meets or exceeds the R-value on the CF-1R form. For more information on Compliance and Enforcement on *wall insulation*, see Chapter 2 of this manual.

Because it is difficult to inspect wall insulation behind tub/shower enclosures after the enclosures are installed, insulation of these wall sections should be inspected during the framing inspection.

Batt and loose fill insulation should fill the wall cavity evenly. If Kraft or foil-faced insulation is used, it should be installed per manufacturer recommendations to minimize air leakage and avoid sagging of the insulation.

Wall insulation should extend into the perimeter floor joist (rim joist) cavities along the same plane as the wall.

If a vapor retarder is required, it must be installed on the conditioned space side of the framing.

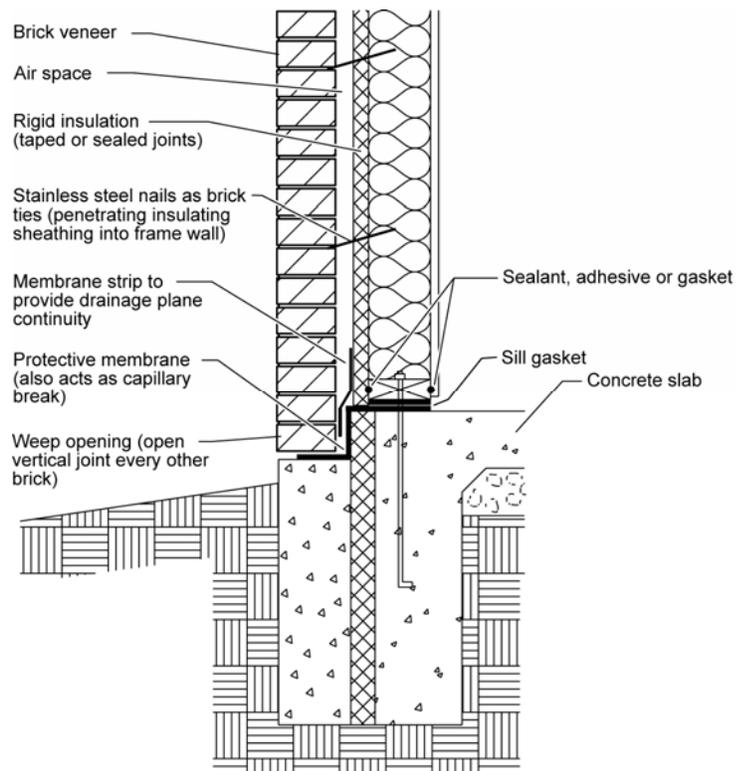


Figure 0-22 – Brick Wall Construction Details

Wood-Framed Wall with Brick Veneer, Mandatory Minimum R-13 Insulation

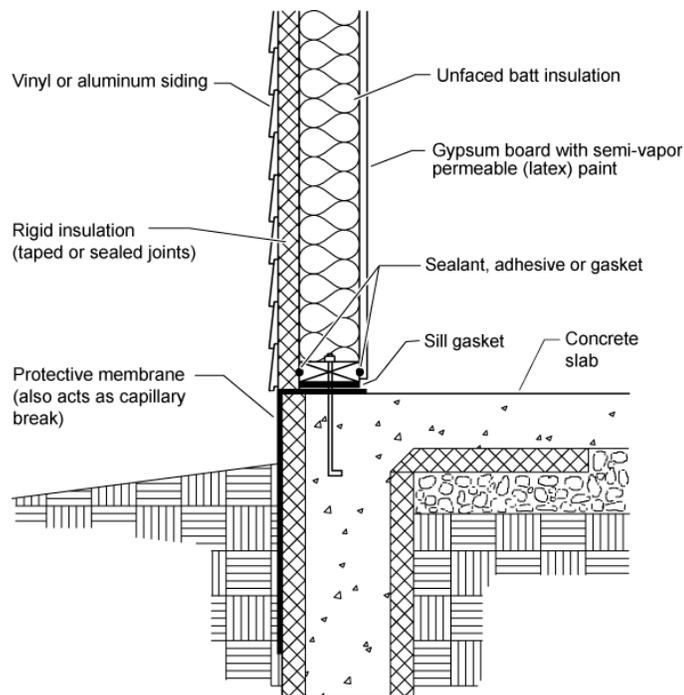


Figure 0-4 – Wall Construction Detail

Wood-Framed Wall with Vinyl or Aluminum Siding, Mandatory Minimum R-13 Insulation

Example 0-23

Question

Do new residential buildings or additions consisting of block walls (for example, converting a garage into living space) have to comply with the R-13 minimum wall insulation requirement? If not, what insulation R-value do they need?

Answer

Yes, the mandatory wall insulation requirement is a R-13 which applies to frame walls, but for non framed wall assembly the U-factor that associates with a R-13 framed wall must be met. . The amount of insulation needed, if any, will vary depending on the compliance approach selected. Performance compliance may not require any additional insulation if compliance can be achieved without insulation in that space. Prescriptive compliance may require some level of insulation, depending on the climate zone, package selected, and whether the walls are light (block) or heavy mass. Use Reference Joint Appendix JA4 or EZ-Frame to determine the R-value of the mass wall alone. If additional insulation is required, it must be integral with the wall or installed on the outside of the mass wall.

Example 3-24

Question

If 2-inches of medium density foam is used in combination with R-13 batt insulation in the cavity of a 2x6 wood framed wall, without continuous insulation added, what is the total u-factor for the wall assembly? Does this assembly meet prescriptive compliance Package A requirements?

Answer

No. Medium density foam is given a default value of R-5.8 per inch. When added with R-11 batt insulation, the total cavity insulation is R-22. The Reference Joint Appendix JA4 Table 4.3.1 shows the wall u-factor for this assembly as 0.072 (cell entry A7). The assembly does meet the minimum mandatory wall insulation u-factor requirement of 0.110, but does not meet the prescriptive compliance Package A U-factor requirement of 0.065. To meet the Package A requirement, Advanced Wall System (AWS) techniques may be used to reduce the framing factor, or continuous insulation may be added.

E. Floor Insulation

1. Raised-floor

§150.1(c)1C

Package A prescriptive requirements call for R-19 or maximum U-factor of 0.037 insulation in raised floors in all climates..

The requirement may be satisfied by installing the specified amount of insulation in a wood-framed floor or by meeting an equivalent U-factor. Those U-factors are listed in along with the corresponding constructions from Reference Joint Appendix JA4. Package A this type of construction is typical for the floor that separates the first habitable floor of multifamily buildings from a parking garage. For this class of construction, R-4 insulation is required for climate zones 12 and 15, and R-8 is required for climate zones 1, 2, 11, 13, 14, and 16. No insulation is required in other climate zones

Table 0-7 – Raised Floor Constructions Used as Basis for Equivalent U-factor Compliance

Insulation R-value	Crawlspace?	Reference Joint Appendix JA4 Construction and Table Cell Entry	Equivalent U-factor
R-19	No	4.4.2 A4	0.049
R-19	Yes	4.4.1 A4	0.037

Construction Practice/Compliance and Enforcement

Floor insulation should be installed in direct contact with the subfloor so that there is no air space between the insulation and the floor. Support is needed to prevent the insulation from falling, sagging, or deteriorating.

Options for support include netting stapled to the underside of floor joists, insulation hangers running perpendicular to the joists, or other suitable means. Insulation hangers should be spaced at 18 inch or less prior to rolling out the insulation. Insulation hangers are heavy wires up to 48 inch long with pointed ends, which provide positive wood penetration. Netting or mesh should be nailed or stapled to the underside of the joists. Floor insulation should not cover foundation vents.

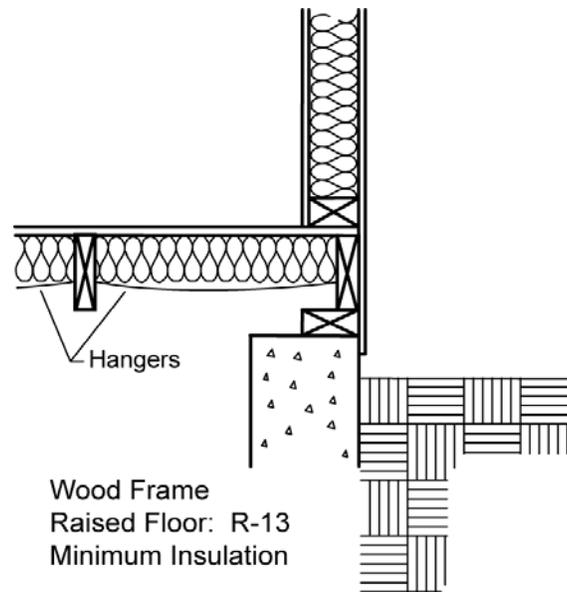


Figure 0-5 – Raised Floor Insulation

2. Slab Insulation

§150.1(c)1D

Prescriptive Table 150.1-A, Package A, requires slab insulation only in climate zone 16. In this case, a minimum of R-7 must be installed. The insulation must be installed to a minimum depth of 16 in. or to the bottom of the footing, whichever is less. The depth is measured from the top of the insulation, as near the top-of-slab as practical, to the bottom edge of the insulation (see).

Perimeter insulation is not required along the slab edge between conditioned space and the concrete slab of an attached unconditioned enclosed space such as a garage, covered porch, or covered patio. Neither would it be practical or necessary to insulate concrete steps attached to the outside slab edge.

In situations where the slab is below grade and slab edge insulation is being applied to a basement or retaining wall, the top of the slab edge insulation should be placed as near to ground level as possible and extended down at least 16 inches. In situations where the slab is above grade and slab edge insulation is being applied, the top of the slab edge insulation should be placed at the top of the slab.

Construction Practice/Compliance and Enforcement

Slab-edge insulation should be protected from physical damage and ultraviolet light exposure because deterioration from moisture, pest infestation, ultraviolet light and other factors can significantly reduce the effectiveness of the insulation.

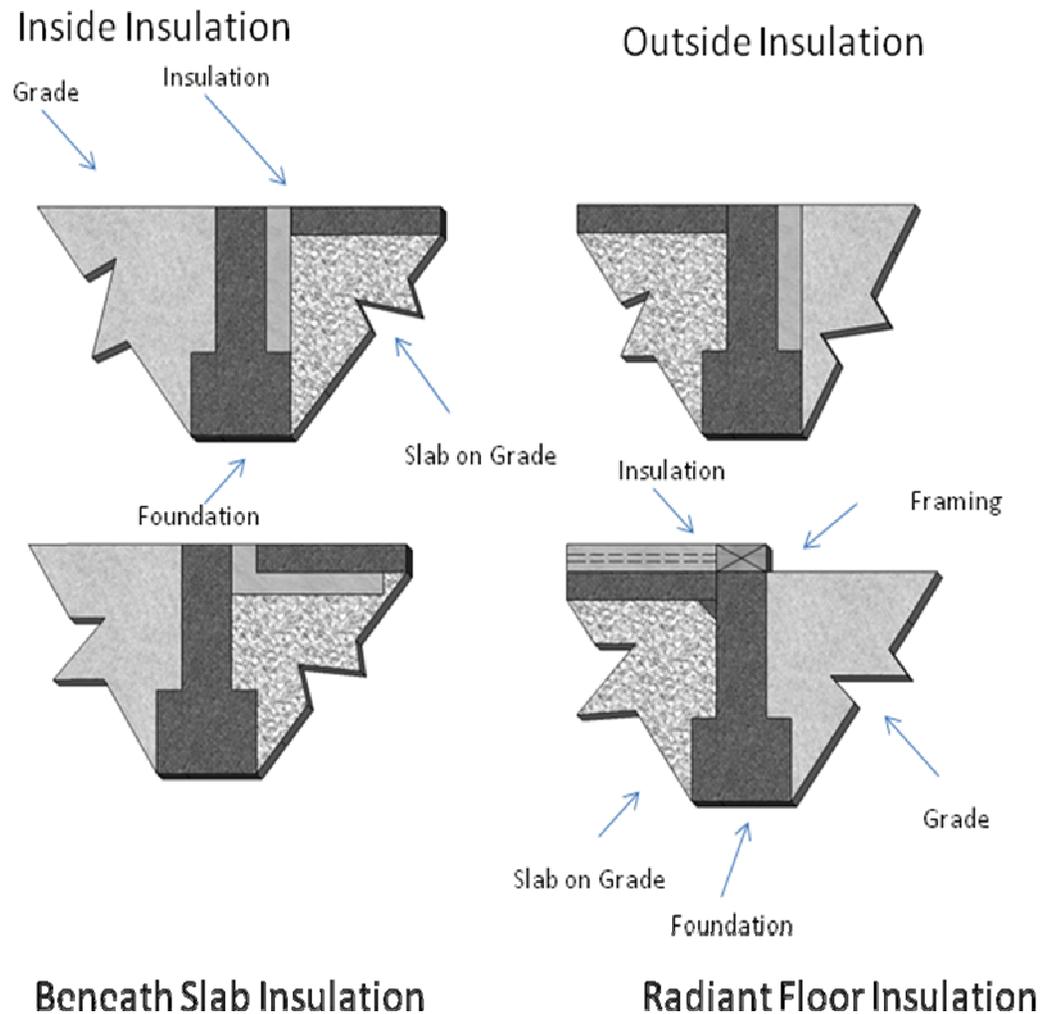


Figure 0-6 – Allowed Slab Edge Insulation Placement

When slab-edge insulation is required by the prescriptive or performance requirements, then minimum depth is 16 inch or to the top of the footing, whichever is less.

Example 0-25

Question

What are the slab edge insulation requirements for a hydronic-heating system with the hot water pipes in the slab?

Answer

The requirements for insulation of heated slabs can be found in §110.8(g) of the Standards and are described in Chapter 4 of this manual. The material and installation specifications are as follows:

- Insulation values as shown in Table 110.8-A of the Standards

- Protection from physical damage and ultra-violet light deterioration
- Water absorption rate no greater than 0.3% (ASTM-C-272)
- Water vapor permeance no greater than 2.0 perm/inch (ASTM-E-96)

3.3.3 Performance Approach

3.7 Advanced Assembly Systems

The Energy Commission encourages the use of energy saving techniques and designs for showing compliance with the standards. Many standard products with traditional construction practices can be used in ways that improve building efficiency beyond requirements set by the standards. In addition, innovative construction techniques and building products are being used more often by designers and builders who recognize the value of energy efficient high performance buildings. When the performance compliance method is used an energy credit can be taken for design strategies that reduce building energy use below the standard design energy budget (compliance credit). Some strategies may require third-party verification by a HERS rater, others do not.

A. Quality Insulation Installation (QII)

Energy Commission videos
Reference Residential Appendix RA3.5

Many residential insulation installations have flaws that degrade thermal performance. Four problems are generally responsible for this degradation:

1. There is an inadequate air barrier in the building envelope, or holes and gaps within the air barrier system inhibit its ability to limit air leakage.
2. Insulation is not in contact with the air barrier creating air spaces that short-circuits the insulation's thermal control when the air barrier is not limiting air leakage properly.
3. The insulation has voids or gaps resulting in portions of the construction assembly that are not insulated and, therefore, has less thermal resistance than other portions of the assembly.
4. The insulation is compressed, creating a gap near the air barrier and/or reducing the thickness of the insulation.

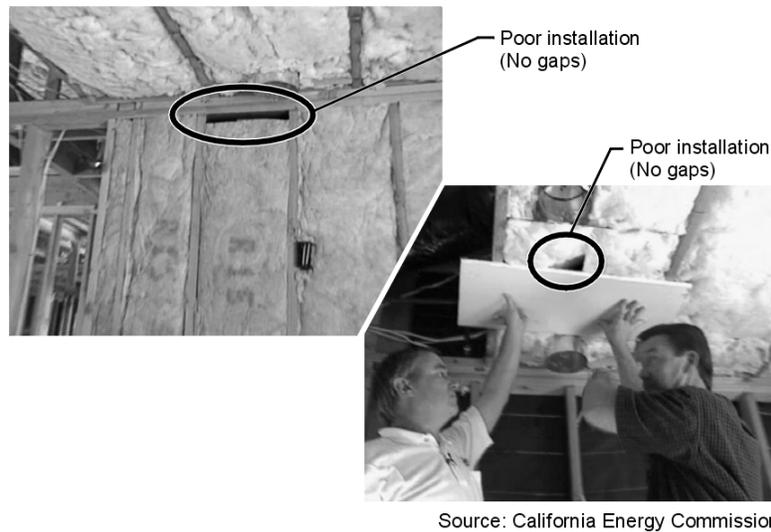


Figure 0-7 – Examples of Poor Quality Insulation Installation

An energy credit for correctly installing an air barrier and insulation to eliminate or reduce common problems associated with poor installation are provided in the Reference Appendices, Residential Appendix RA3.5. This compliance credit applies to framed and nonframed assemblies. Residential construction may incorporate multiple frame types; for example, using a combination of nonframed walls with a framed roof/ceiling. Likewise, multiple insulation materials are often used. Framed assemblies include wood and steel construction insulated with batts of mineral fiber, mineral and natural wool, and cellulose; loose fill insulation of mineral fiber, mineral and natural wool, and cellulose, and light and medium density spray polyurethane foam; and for rigid board insulation used on the exterior or interior of framed and nonframed assemblies. Nonframed assemblies include structural insulated panels, insulated concrete forms, and mass walls of masonry, concrete and concrete sandwich panels, log walls, and straw bale.

This compliance credit can only be taken for the whole building—roof/ceilings, walls and floors, and requires field verification by a third-party HERS rater. Further explanation is provided below:

- Compliance credit is not allowed for walls alone; or for roofs/ceilings but not walls also.
- Compliance credit is allowed for a building built on a slab floor, where the slab has no requirement for insulation. However, if insulation is installed (i.e., slab edge insulation for radiant floor heating) then the integrity of the slab edge insulation must also be field verified in addition to the air barrier and insulation system for walls and the roof/ceiling.
- Combinations of insulation types (hybrid systems) are allowed.
- An air barrier shall be installed for the entire envelope.
- Compliance credit is allowed for additions to existing buildings where energy compliance has been demonstrated for the “addition alone” (§150.2(a)2A).
- Compliance credit is not allowed for additions to existing buildings where the “existing plus alteration plus addition” approach is used (§150.2(a)2B).

Approved computer compliance modeling software automatically reduces the effectiveness of insulation for compliance purposes. This reduction is accounted for in developing the Standards and prescribing the required prescriptive measures for each climate zone the forms the basis of the standard design energy budget in performance compliance calculations. The effect of a poorly installed air barrier system and envelope insulation results in approximately 13.3 percent higher wall heat loss and heat gain than standard R-value and U-factor calculations would indicate. Similar increases in heat loss and heat gain are experienced for roof/ceilings where construction and installation flaws are present.

Structural Bracing, Tie-Downs, Steel Structural Framing

Reference Residential Appendix RA3.5.5.2.8

When metal bracing, tie-downs or steel structural framing is used to connect to wood framing for structural or seismic purposes the QII energy credit still can be taken if:

1. Metal bracing, tie-downs or steel structural framing is identified on the structural plans, and
2. Insulation is installed in a manner that restricts the thermal bridging through the structural framing assembly, and
3. Insulation fills the entire cavity and/or adheres to all sides and ends of structural assembly that separates conditioned from unconditioned space.

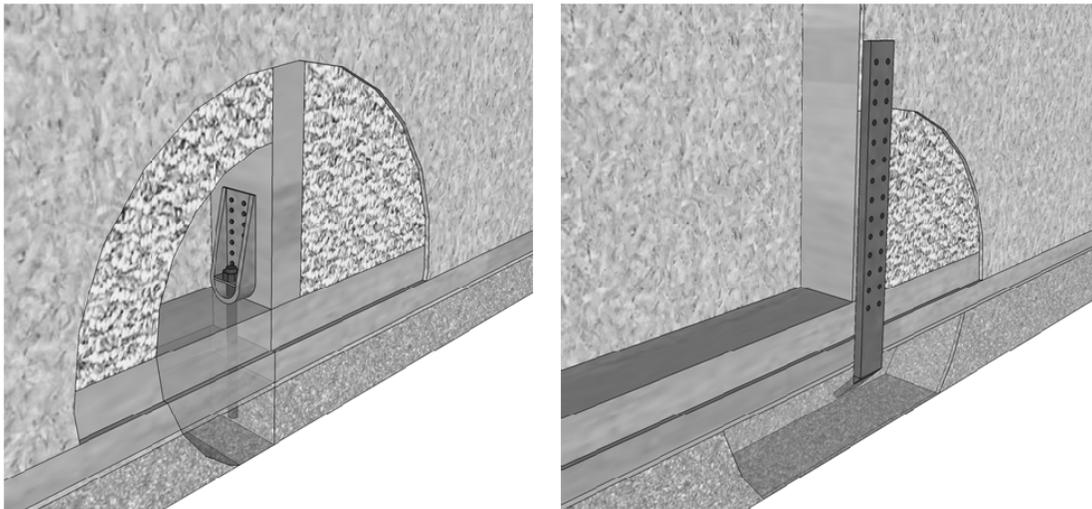


Figure 0-27 – STRUCTURAL BRACING, TIE-DOWNS

To take advantage of the QII energy credit two primary installation criteria must be adhered to and they both will be field verified by a HERS rater:

1. Air Barrier

Reference Residential Appendix RA3.5.2

An air barrier shall be installed enclosing the entire building and when this credit is shown to be taken on compliance documentation a third-party HERS rater is required to verify the integrity of the air barrier system. The air barrier must be installed in a

continuous manner across all components of framed and non-framed envelope assemblies. The installer shall provide evidence with compliance documentation that the air barrier system meets one or more of the air barrier specifications shown in Table 3-8 below. More detailed explanation is provided in Reference Appendices, Residential Appendix RA3.5. Documentation for the air barrier includes product data sheets and manufacturer specifications and installation guidelines. The third-party HERS rater shall verify that the air barrier has been installed properly and is integral with the insulation being used throughout the building.

Table 3-8: Continuous Air Barrier

Continuous Air Barrier	<p>A combination of interconnected materials and assemblies joined and sealed together to provide a continuous barrier to air leakage through the building envelope separating conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses. An air barrier is required in all thermal envelope assemblies to limit air movement between unconditioned/outside spaces and conditioned/inside spaces and must meet one of the following:</p> <ol style="list-style-type: none"> 1. Using individual materials that have an air permeance not exceeding 0.004cfm/ft² under a pressure differential of 0.3in. w.g. (1.57psf) (0.02 L/s.m² at 75 pa) when tested in accordance with ASTM E2178; or 2. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft² under a pressure differential of 0.3 in. w.g (1.57psf) (0.2 L/s.m² at 75 pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680 or ASTM E283; or 3. Testing the completed building and demonstrating that the air leakage rate of the building envelope does not exceed 0.40 cfm/ft² at a pressure differential of 0.3 in w.g. (1.57 psf) (2.0 L/s.m² at 75 pa) in accordance with ASTM E779 or an equivalent approved method. <p>Individual materials and assemblies of materials that can demonstrate compliance with the air barrier testing requirements must be installed according to the manufacturer's instructions and a HERS rater shall verify the integrity of the installation. Below are example materials meeting the air permeance testing performance levels of 1 above. Manufacturers of these and other product types must provide a specification or product data sheet showing compliance to the ASTM testing requirements to be considered as an air barrier.</p> <ul style="list-style-type: none"> -- Plywood – minimum 3/8 inch -- Oriented strand board – minimum. 3/8 inches -- Extruded polystyrene insulation board – minimum. ½ inch -- Foil-back polyisocyanurate insulation board – minimum. ½ inch -- Extruded polystyrene insulation board – minimum ½ inch -- Foil backed urethane foam insulation (1 inch) -- Closed cell spray polyurethane foam with a minimum density of 2.0 pcf and a minimum thickness of 2.0 inches -- Open cell spray polyurethane foam with a minimum density of 0.4 to 1.5 pcf and a minimum thickness of 5½ inches <ul style="list-style-type: none"> -- Exterior or interior gypsum board - minimum 1/2 inch -- Cement board - minimum 1/2 inch -- Built up roofing membrane -- Modified bituminous roof membrane -- Particleboard-minimum1/2 inch -- Fully adhered single-ply roof membrane -- Portland cement/sand parge ,or gypsum plaster minimum 5/8 inch -- Cast-in-place and precast concrete. -- Fully grouted uninsulated and insulated concrete block masonry
------------------------	---

	-- Sheet steel or aluminum
--	----------------------------

2. Insulation Installation

All insulation shall be installed properly throughout the entire building and when this credit is shown to be taken on compliance documentation a third-party HERS rater is required to verify the integrity of the installed insulation. The installer shall provide evidence with compliance documentation that all insulation specified on compliance documentation is installed to meet specified R-values and assembly U-factors.

General insulation types are shown in Table 3-9 below. More detailed explanation is provided in the wall insulation discussion of Section XXX and in Reference Appendices, Residential Appendix RA3.5.

Documentation of insulation R-values and assembly U-factors includes product data sheets, manufacturer specifications and installation guidelines, insulation product and assembly testing information, and U-factor calculations following the procedures specified in Reference Appendices, Joint Appendix JA4, through use of the EZ-Frame Assembly Calculator, or from results of approved performance compliance computer software. The third-party HERS rater shall verify that all insulation has been installed properly and is integral with the air barrier being used throughout the building.

Table 3-9: Insulation Types

Insulation Types-- framed assemblies	<p>There are four basic types of insulation, or insulation "systems", installed in residential buildings and their use varies based on the design and type of construction:</p> <ol style="list-style-type: none"> 1. Batt and Blanket: Batt and blanket insulation is made of mineral fiber and mineral wool -- either processed fiberglass, rock or slag wool; natural wool products—animal wool or cotton based products; or cellulose materials. These products are used to insulate below floors, above ceilings, below roofs, and within walls. 2. Loose-fill: Loose-fill insulation includes loose fibers or fiber pellets that are blown into building cavities or attics using special equipment. Loose-fill insulations typically are produced using mineral fiber, mineral or natural wool (animal or cotton based products), or cellulose. They are installed in walls, floors, attics and below roofs using a dry-pack process or a moist-spray technique, and may include a netting material. 3. Rigid Board: Rigid board insulation sheathing is made from fiberglass, expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate, or polyurethane. This type of insulation is used for above roof decks, exterior walls, cathedral ceilings, basement walls, as perimeter insulation at concrete slab edges, and to insulate special framing situations such as window and door headers, and around metal seismic bracing. Rigid board insulation may also be integral to exterior siding materials. 4. Spray Polyurethane Foam (SPF): A two-part liquid foamed plastic (such as polyurethane or modified urethane) material formed by the reaction of an isocyanurate and a polyol that uses a blowing agent to develop a cellular structure when spray applied onto a substrate. SPF insulation is a two-component reactive system mixed at a spray gun or a single-component system that cures by exposure to humidity. The liquid is sprayed through a nozzle into wall, roof/ceiling, and floor cavities. SPF insulation can be formulated to have specific physical properties (i.e., density, compressive strength, fire resistance and R-value). There are two types of SPF insulation: <ol style="list-style-type: none"> a. <i>Low Density Open-Cell SPF (ocSPF) Insulation:</i> A spray applied polyurethane foam insulation having an open cellular structure resulting in an installed nominal
--------------------------------------	---

	<p>density of 0.4 to 1.5 pounds per cubic foot (pcf).</p> <p>b. <i>Medium Density Closed-Cell SPF (ccSPF) Insulation:</i> A spray applied polyurethane foam insulation having a closed cellular structure resulting in an installed nominal density of greater than 1.5 to less than 2.5 pounds per cubic foot (pcf).</p>
<p>Insulation Types--non-framed assemblies</p>	<p>There are five basic types of non-framed wall systems that provide structural as well as thermal resistance and their use varies based on the design and type of construction:</p> <ol style="list-style-type: none"> 1. Structural Insulated Panel (SIP): A composite building material consisting of an insulating layer of rigid polymer foam sandwiched between two layers of structural board. The board can be sheet metal, plywood, cement or oriented strand board (OSB) and the foam is either expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane foam. SIPs combine several components of conventional building, such as studs and joists, insulation, vapor barrier and air barrier. They can be used for many different applications, such as exterior walls, roofs, floors, and foundation systems. 2. Insulated Concrete Form (ICF): A system of formwork for concrete that stays in place as permanent building insulation and is used for cast-in-place, reinforced above and below-grade concrete walls, floors, and roofs. ICFs are interlocking modular units that can be dry-stacked (without mortar) and filled with concrete as a single concrete masonry unit (CMU). ICFs lock together externally and have internal metal or plastic ties to hold the outer layer(s) of insulation to create a concrete form for the structural walls, roof/ceilings, or floors of a building. ICFs are manufactured from several materials including: expanded and extruded polystyrene foam, polyurethane foam, cement-bonded wood fiber, and cement-bonded polystyrene beads. 3. Mass Walls: <ol style="list-style-type: none"> a. Masonry types include clay and concrete units, which may be solid or hollow, and glazed or unglazed. Other masonry unit types include cast stone and calcium silicate units. Concrete masonry units (CMU) are made from a mixture of portland cement and aggregates under controlled conditions. Concrete masonry units can be manufactured in different sizes and with a variety of face textures. b. Concrete and concrete sandwich panels typically use a pre-cast form by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. Precast stone is distinguished from precast concrete by using a fine aggregate in the mixture giving the appearance of naturally occurring rock or stone. 4. Log Walls: Log walls are typically made from trees that have been cut into logs that have not been milled into conventional lumber. Logs used for walls, roofs and/or floor systems may be milled and or laminated by the manufacturer or supplier to meet specific dimensions and fitting and finishing conditions. 5. Straw Bale: Straw bale construction is a building method that uses bales of straw (commonly wheat, rice, rye and oat straw) as structural and insulating elements of the building.

2. Reduced Building Air Leakage

Reference Appendices, Residential Appendix RA3.8

An energy credit is allowed through the performance approach when the building's rate of envelope air leakage is less than the air leakage rate assumed for the standard design building. A third-party HERS rater shall verify the air leakage rate shown on compliance documentation through diagnostic testing of the building's air leakage.

The air leakage testing process (i.e., blower door) involves closing all the windows and doors, pressurizing the house with a special fan, usually positioned in a doorway (see Figure 3-28), and measuring the leakage rate, measured in cubic feet per minute at a 50 Pa pressure difference (CFM50). This measurement procedure is described in the Reference Appendices, Residential Appendix RA3.8. It is derived from the Residential Energy Services Network's (RESNET) Mortgage Industry National Home Energy Rating Standards, Standard 800, which is based on ASTM E779 air tightness measurement protocols. This procedure requires the use of software consistent with ASTM E779. This test method is intended to produce a measure of the air tightness of a building envelope for determining the energy credit allowance for reduced building air leakage. Further explanations are described below:

- This procedure shall only be used to verify the building air leakage rate before the building construction permit is finalized when an energy credit for reduced air leakage is being claimed on compliance documentation.
- The Home Energy Rating System (HERS) rater shall measure the building air leakage rate to ensure measured air leakage is less than or equal to the building air leakage rate stated on the Certificate of Compliance, and all other required compliance documentation. HERS verified building air leakage shall be documented on compliance forms.
- This is a whole building credit; therefore, no credit is allowed for the installation of individual envelope measures that may help in reducing the building's air leakage rate, such as for an exterior air retarding wrap, or for an air barrier material or assembly meeting the requirements describe in Table 3-8 above.



Source: California Energy Commission

Figure 0-8 – Blower Door Testing

B. Conventional and Non-Conventional/Advanced Assemblies

1. Roof Assembly

The construction techniques described below are assemblies that can be used in residential construction to help exceed minimum prescriptive requirements, particularly when using the performance compliance approach. This section describes typical constructions for roof deck insulation and raised heel trusses (also called “energy trusses”).

a. Roof Deck Insulation

An assembly and insulation alternative that helps augment conventional attic insulation that can achieve an energy compliance credit is to install insulation either directly above or directly below the roof deck. Roof deck insulation is not a prescriptive requirement but can be an inexpensive choice that improves the thermal integrity of the roof system. In addition, using roof deck insulation, either with conventional attic insulation that is laid horizontally over the bottom cord of the roof truss, or roof deck insulation (above or below the roof deck) without conventional horizontal attic insulation, can provide an energy tradeoff with other prescriptive measures or used to help meet high performance building energy codes in local jurisdictions, Tier 1 and Tier 2 of the CalGreen Code, or other energy efficiency targets, such as LEED® for Homes and Energy Star.

Roof deck insulation can be particularly effective when air conditioning ducts are located in the attic, since roof deck insulation considerably lowers the attic temperature during the cooling season.

Vented and Unvented Attic

Below the roof deck insulation of R-13 or R-15 batt insulation can be placed between the truss members and pinned in place. Other options that can provide somewhat higher R-values are to install loose fill glass fiber or cellulose between roof trusses which has netting underneath. In both cases, the attic can be conventionally vented using soffit, eave, and ridge vents, or other acceptable means.

Above deck insulation can also add effective R-value to the thermal integrity of the roof system. Using rigid board insulation with a minimum of R-4 helps provide additional R-value when conventional ceiling insulation is also installed and an energy credit can be taken even with a vented attic.

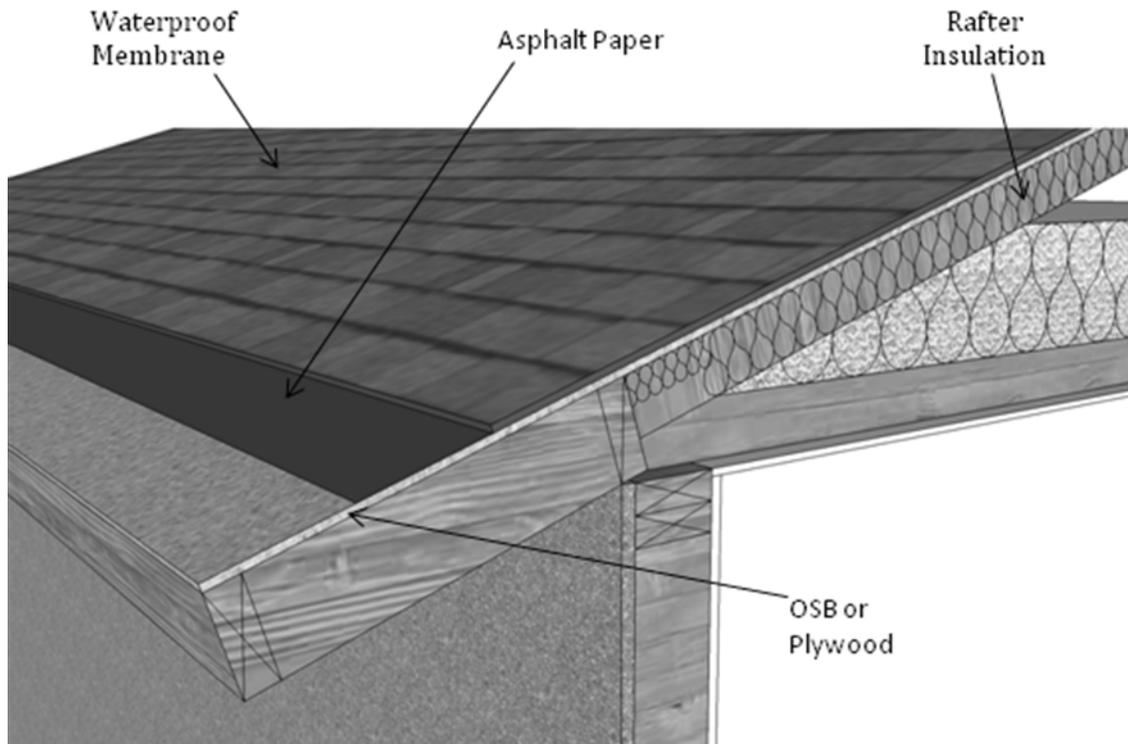


Figure 0-9 – Below Roof Deck Insulation.

NEED GRAPHIC OF UNVENTED ATTIC

In some climates, placing insulation directly below the roof deck can create a condensation plane on the underside of the roof deck during the winter months. Whenever the outside air temperature is well below the dewpoint temperature of the indoor air (about 40°F to 45°F) there is potential for moisture to condense. For climate zones 11, 12, 13, 15 and 16, above deck insulation may be a better choice, particularly with a vented attic. R-8 of continuous insulation above the roof deck is approximately thermally equivalent to a R-13 batt insulation below the roof deck. When above deck insulation is used, the requirement for the energy benefits of a radiant barrier must still be met.

Compliance software can model the thermal effects and energy benefits of both above deck and below deck insulation, and the effects of a vented versus unvented attic.

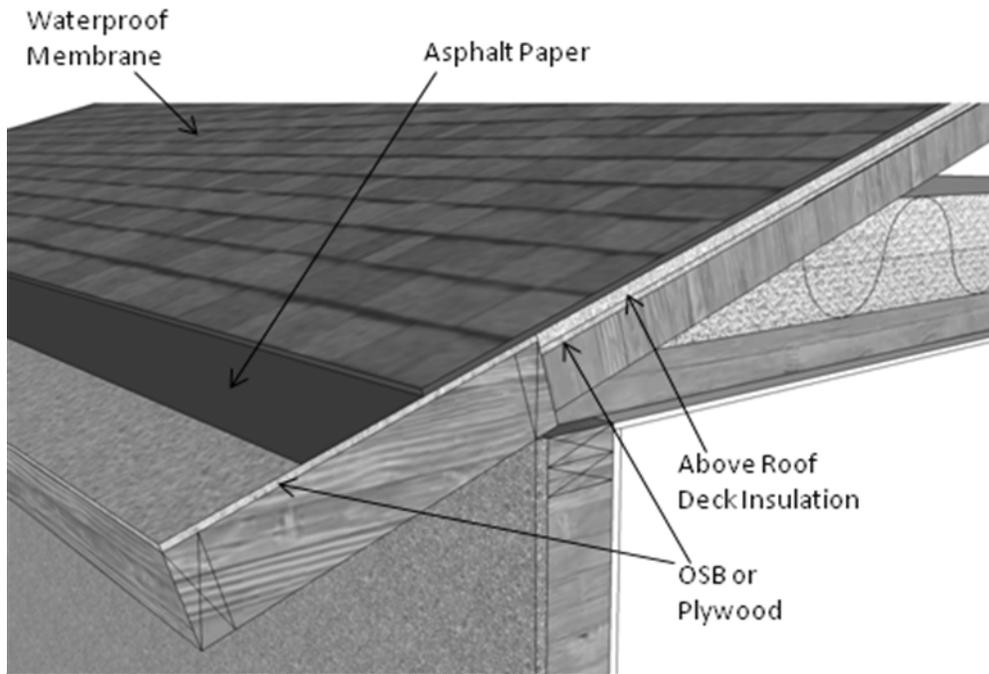


Figure 0-30 – Above Roof Deck Insulation.

b. *Raised Heel Truss*

An advanced assembly system that improves the overall R-value of conventional attic insulation is a raised heel truss. With a conventional truss, the attic insulation is compressed near the eaves, reducing its effectiveness. A raised heel truss allows the full depth of insulation to be installed out to the perimeter top plate.

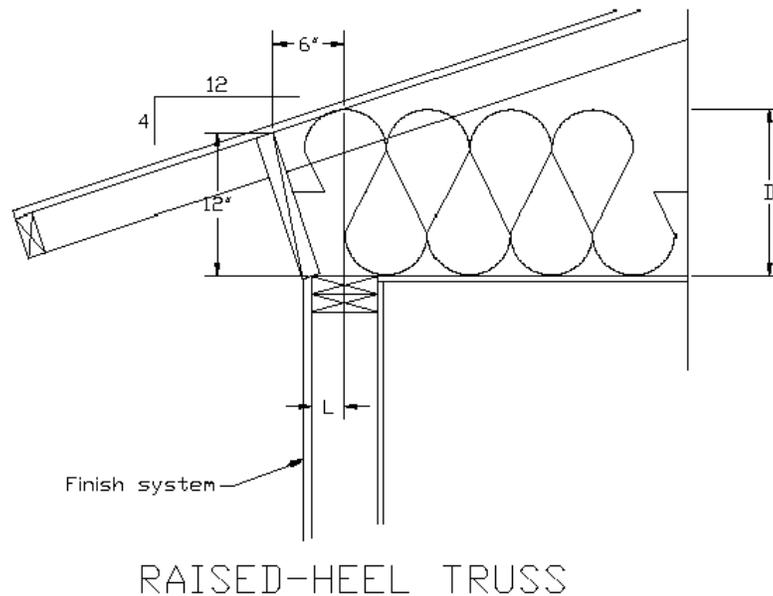


Figure 0-31 – Raised Heel Truss

Other design options that can be used to accommodate close to the full depth of insulation at the perimeter wall are cantilevered trusses and a raised rafter plate.

The compliance software accounts for the effect of the raised heel truss by using an alternate U-factor, published in Reference Joint Appendix 4.

Most truss manufacturers can readily construct a raised heel truss and their expense is fairly minimal. The height of the raised heel is an important design consideration depending on the R-value specified, and is typically 8 to 16 inches. Several high performance building programs, such as Energy Star, require that raised heel trusses or similar framing techniques elevate the truss to allow insulation to be installed all the way to the building's perimeter. Other advantages of a raised heel truss are the additional space to allow for attic ventilation and much easier access and space provided for installing the HVAC duct system.

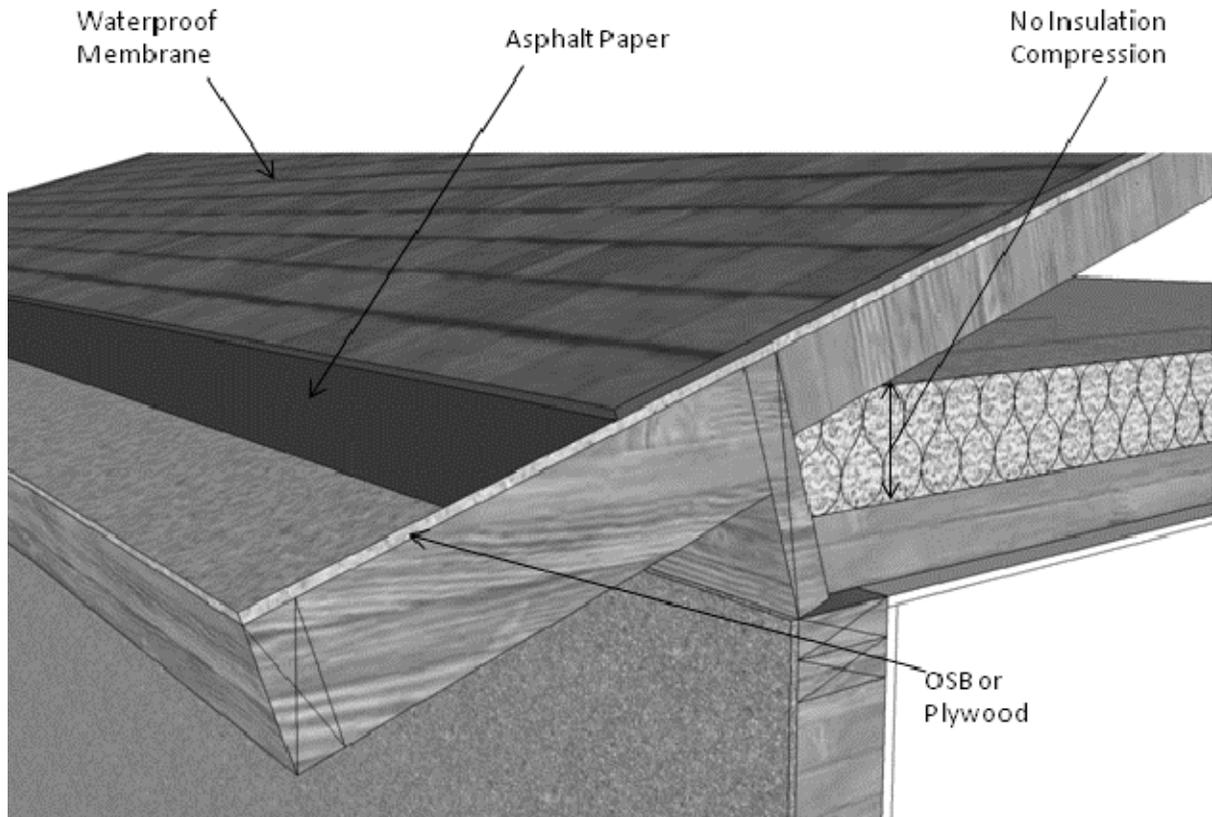


Figure 3-32: Raised Heel Truss

2. Attic Ventilation

Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation (See Figure 3-33). The baffle should extend beyond the height of the ceiling insulation and should have sufficient clearance between the baffle and roof deck at the top. There are a number of acceptable methods for maintaining ventilation air, including pre-formed baffles made of either cardboard or plastic. In some cases, plywood baffles are used.

The California Building Code (CBC) requires a minimum vent area to be provided in roofs with attics, including enclosed rafter roofs creating cathedral or vaulted ceilings.

Check with the local building jurisdiction to determine which of the two CBC ventilation requirements are to be followed:

- CBC, Title 24, Part 2, Vol. 1, Section 1203.2 requires that the net free ventilating area shall not be less than 1/300 of the area of the space ventilated.
- CBC, Title 24, Part 2, Vol. 2.5, Section R806.2 requires that the net free ventilating area shall not be less than 1/150 of the area of the space ventilated. This ratio may be reduced to 1/300 if a ceiling vapor retarder is installed.

In either situation, a minimum of 50% of the vents must be located in the upper portion of the space being ventilated at least 3 feet above eave or cornice vents.

Ventilated openings are covered with corrosion resistant wire cloth screening or similar mesh material. When part of the vent area is blocked by meshes or louvers, the resulting “net free area” of the vent must be considered when meeting ventilation requirements.

Many jurisdictions in California are covered by Wildland Urban Interface (WUI) regulations where specific measures for construction materials must be used to improve fire resistance for the building. These regulations require special vents that are expressly tested to resist the intrusion of flame and burning embers. Check with the building department to ensure compliance with local codes.

Wood Rafter Constructions

Ventilating framed rafter spaces is more difficult than ventilating attics because each framing cavity requires its own vent openings. It is common practice with loose-fill insulation material to completely fill the cavity so that there is no ventilation at all. With batt insulation it is possible to ventilate above the insulation using higher density (cathedral ceiling) batts because this material is specifically manufactured to allow a minimum of 1 inch above the top of the insulation to allow for ventilation. If spray polyurethane foam is used, it is applied to the underside of the roof deck leaving no ventilation space.

Attic ventilation, particularly in hotter climate zones, can provide an energy benefit. However, no energy credit is allowed for reducing the ventilation area below building code requirements.

Unvented Attic Assemblies

Attic ventilation is the traditional way of controlling temperature and moisture in an attic. In an unvented attic (conditioned attic) assembly insulation is applied directly at the roofline of the building, either above or below the structural roof sheathing. The roof system becomes part of the insulated building enclosure. For this case, the thermal boundary of the building results in an unconditioned attic space between the ceiling gypboard and the insulated roof above.

The provisions of CBC, Title 24, Part 2, Vol. 2.5, Section R806.4 describes conditions for insulation placed at the roof of the building as opposed to on top of the horizontal ceiling. Unvented attic assemblies are allowed provided that:

- Air-impermeable insulation is used below and in direct contact with the underside of the roof sheathing, or
- Air-permeable insulation is used below and in direct contact with the underside of the roof sheathing and rigid board or sheet insulation of at least R-4 is used above the roof sheathing, or
- Air-impermeable insulation is used below and in direct contact with the underside of the roof sheathing and an additional layer of air-permeable insulation is installed directly under the air-impermeable insulation.

Check with the local building jurisdiction to determine their specific requirements for unvented attic conditions.

A building that employs an unvented attic with above or below roof deck insulation can attain significant energy credits due to the increased thermal benefits of the insulation R-value, plus the reduction of duct conduction and leakage losses (bringing ducts within the conditioned space). Combining this with the additional design improvement of low air leakage for the rest of the building would achieve significant energy savings and compliance energy credit.

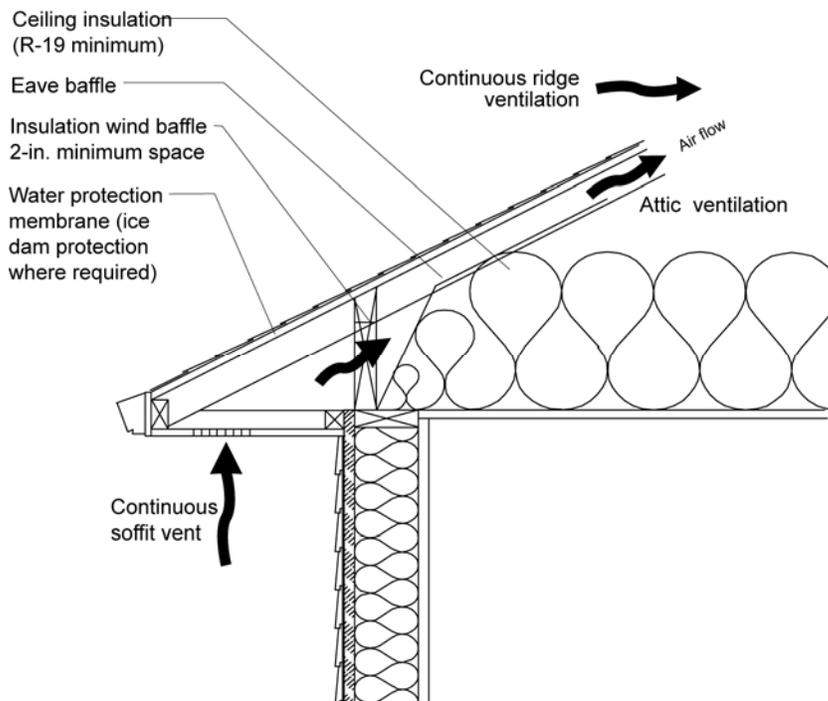
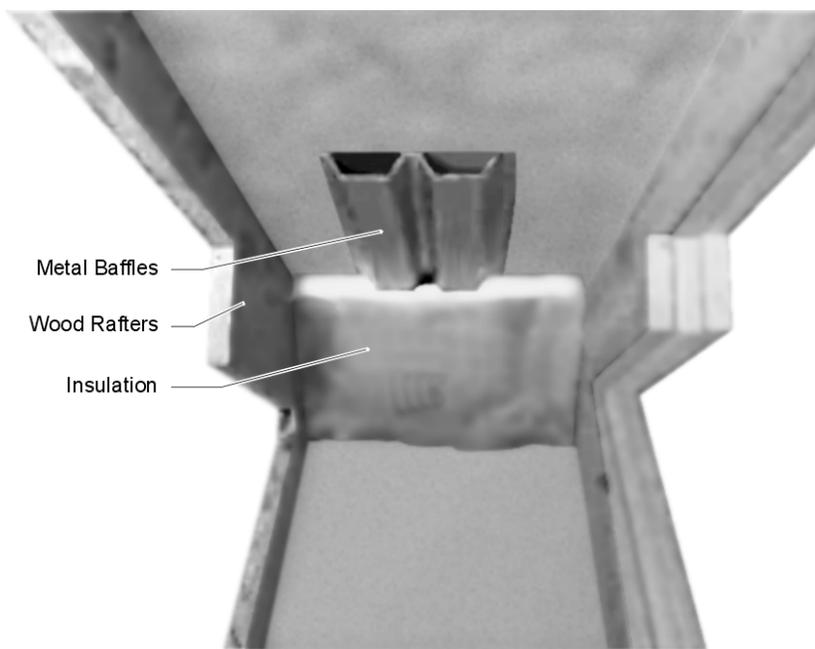


Figure 0-33 – Ceiling Insulation Construction Detail



Source: California Energy Commission

Figure 0-34 – Baffles at the Eave in Attics

3. Wall Assembly

See Energy Commission videos

More insulation is almost always better than less. Insulation is one of the least expensive measures to improve building energy efficiency. Insulation requires no maintenance, helps improve indoor comfort, and provides excellent sound control. Builders and designers who tout meeting minimum insulation requirements for new buildings are not providing consumers and homeowners with a home of great value. Buildings that comply minimally with the standards represent the worst buildings allowed by code. Adding extra insulation at a later time is much more expensive than simply maximizing insulation levels at the beginning of construction.

a. Thermal Batts

Thermal batts of glass fiber, mineral and natural wool, and cotton material are some of the most widely used insulation in the marketplace. They offer ease of installation with R-values set by the manufacturer based on size and thickness. They are available with facings, some as vapor retarders, and have flanges to aid in installation to framed assemblies. They also are available as unfaced material and can be easily friction-fitted into framed cavities. Thermal batts have more testing for sound attenuation than any other insulation type. However, in some instances manufacturers of blown or sprayed insulation material may have testing information supporting their product's sound performance for special applications with higher values typically found for thermal batts.

Thermal batts allow easy inspection and installation errors can readily be identified and remedied, including breeches in the air barrier system allowing air leakage. Nevertheless, care should always be taken to install the insulation properly, filling the entire cavity, and butting ends or sides of the batt material to ensure uniformity of the installation. Thermal batts must be split to allow for wiring, plumbing, and other penetrations within the framed cavity area.

b. Blown or Sprayed Insulation

Blown or sprayed wall insulation can be an effective way to deal with the irregularities of wall and ceiling cavities, especially the spaces around pipes, electric cables, junction boxes, and other equipment that is embedded in cavities. There are several commonly used types of insulation that have a blown or sprayed process for its installation, including: cellulose, fiberglass, and spray polyurethane foam (SPF). The R-value of blown or sprayed wall insulation material is determined by the applicator at the site. This differs from manufactured products such as fiberglass or mineral wool batts whose R-value has been tested and arrives at the construction site in preformed lengths with set R-value thicknesses.

Blown or sprayed wall insulation must be thoroughly checked to insure the R-value is achieved. Line of sight down a wall section can deceptively hide imperfections in the installation leading to underachieving stated R-values. Depressions and voids within the insulated cavity are areas lacking in their R-value performance. Where netting is used, over-spraying can result in a higher installed density (higher R-value) but can be troublesome for attaching gypsum board to wall framing. Where cavities have been under-sprayed, there may be voids or “soft” areas under the netting. These areas are often re-sprayed again, or the area is removed of its insulation material and a thermal batt is installed in its place.

Loose Fill Cellulose Insulation

Cellulose is basically paper that has been treated for flame- and insect-resistance. The product is similar to the loose fill cellulose that is commonly used in attic application. For walls, the cellulose material is typically mixed with a water- and starch-based binder. The binder causes the insulation to adhere to itself and stick to the surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off with a special tool and recycled into the insulation hopper with fresh material for further installations. R-value is dependent on the installed density of the material at the building site and the building official should ensure the installed density meets manufacturer specifications. Cellulose insulation that dislodges from the cavity is often re-sprayed again, or the area is removed of cellulose and a thermal batt is installed in its place.

Loose Fill Fiberglass Insulation

Loose fill fiberglass insulation is made up of small glass fibers. The product is similar to loose fill fiberglass that is commonly used in attics, but for walls it can be installed behind a netting fabric or mixed with a water based adhesive. The adhesive causes the insulation to adhere to itself and stick to surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off and recycled. R-value is dependent on the installed density of the material at the building site and the building official should ensure the installed density meets manufacturer specifications. Loose fill fiberglass installed behind a netting that doesn't reach its installed density may fill soft or spongy. These areas are often re-sprayed again, or the area is removed of the loose fill material and a thermal batt is installed in its place.

Spray Polyurethane Foam (SPF)

Spray polyurethane foam insulation is a foamed plastic formed by the combination of chemicals and a blowing agent applied using a spray gun. SPF insulation is spray applied to fully adhere to the joist and other framing faces to form a complete air seal within the construction cavities. R-value is dependent on the installed thickness and the building official should ensure the thickness and uniformity of the SPF material within each cavity space of framed assemblies meets manufacturer specifications. When installed on the underside of the roof deck and exposed to the attic space below SPF must be separated from the interior of the building by an approved thermal barrier consisting of 1/2-inch (12.7 mm) gypsum wallboard or equivalent thermal barrier material (Section 316.4, CBC).

There are two types of SPF insulation: medium-density closed cell (ccSPF), and light-density open cell (ocSPF) insulation. They have different insulating properties and compliance requirements as described below:

- ccSPF has been assigned a default R-value of 5.8 per inch for compliance purposes and a nominal density of greater than 1.5 to less than 2.5 pounds per cubic foot (pcf). The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the foam insulation's surface shall not be greater than 1/2-inch of the required thickness at any given point of the surface area being insulated. ccSPF is not required to fill the cavity.
- ocSPF has been assigned a default R-value of 3.6 per inch for compliance purposes and a nominal density of 0.4 to 1.5 pounds per cubic foot (pcf). ocSPF insulation is sprayed then expands to fill the framed cavity. Excess insulation is removed with a special tool. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the foam insulation surface shall not be greater than 1 inch of the required thickness provided these depressions do not exceed 10% of the surface area being insulated. ocSPF must fill the cavity of 2x4 framing.

Table 3-10: Required Thickness of SPF Insulation to Achieve Default R-values

Thickness of SPF Insulation	R11	R13	R15	R19	R21	R22	R25	R30	R38
Required thickness of ccSPF Insulation (inches)	2.00	2.25	2.75	3.50	3.75	4.00	4.50	5.25	6.75
Required thickness of ocSPF Insulation (inches)	3.0	3.5	4.2	5.3	5.8	6.1	6.9	8.3	10.6

Alternatively, the total R-value may be calculated based on the thickness of insulation multiplied by the "tested R-value per inch" as listed in the Table of R-values or R-value Chart from the manufacturer's current ICC Evaluation Service Report (ESR) that shows compliance with *Acceptance Criteria for Spray-Applied Foam Plastic Insulation--AC377*. Overall assembly U-factors are determined by selecting the assembly type, framing configuration, and cavity insulation from the appropriate Reference Joint Appendix JA4 table or other approved method specified in Section JA4 of the Reference Appendices.

Air Barrier

- ccSPF installed as an air barrier shall be a minimum of 2.0 inches in thickness; alternatively, ccSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m² at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.

- ocSPF installed as an air barrier shall be a minimum of 5.5 inches in thickness; alternatively, ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m² at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.



Source: California Energy Commission

Figure 0-35 – Cellulose Insulated Wall

c. Metal Framing

A change from wood framing to metal framing can significantly affect compliance. Metal framed assemblies are often chosen where greater structural integrity is necessary, or in climate conditions where greater durability is desired from the affects of excessive moisture exposure. Metal framed wall construction generally requires a continuous layer of rigid insulation to meet the mandatory minimum wall insulation levels and/or the prescriptive requirements since metal is more conductive than wood. In Reference Joint Appendix JA4, Tables 4.2.4 and 4.2.5 have U-factors for metal-framed ceiling/roof constructions. Table 4.3.4 has U-factors for metal-framed walls. Tables 4.4.4 and 4.4.5 have U-factors for metal-framed floors.

To comply prescriptively, a non-wood framed assembly, such as a metal framed assembly, must have an assembly U-factor that is equal or less than the U-factor of the wood framed assembly for that climate zone. Compliance credit is available through the performance approach for metal framed assemblies that exceed the prescriptive requirements of the equivalent wood framed assemblies.

d. Log Homes

Log homes are an alternative construction type used in some parts of the state. Log home companies promote the aesthetic qualities of solid wood construction and can "package" the logs and deliver them directly to a building site. Some companies provide log wall, roof, and floor systems with special insulating "channels" or other techniques to minimize the effect of air infiltration between log members and to increase the thermal benefit of the logs.

Log walls do not have framing members like conventional wood stud walls. Therefore, the mandatory requirement for a minimum of R-13 wall insulation does not apply.

Otherwise, in prescriptive compliance log walls must meet the same thermal requirements as other construction types. For performance compliance, consult the compliance software vendor's documentation for any unique modeling requirements for mass walls using values from Reference Appendices. In prescriptive compliance, the walls will qualify as either light mass or heavy mass walls depending on the thickness – remember a heat capacity (HC) of 8.0 Btu/°F-ft² is equivalent to a heavy mass wall (40 lb/ft³). The prescriptive requirements for heavy mass walls are less stringent than the criteria for wood-framed walls. Reduced insulation is allowed because the effects of the thermal mass (interior and exterior) can compensate for less insulation.

The thermal performance of log walls is shown in Reference Joint Appendix JA4, Table 4.3.11. The U-factor ranges from 0.133 for a 6-inch wall to 0.053 for a 16-inch wall. The U-factor of an 8-inch wall is 0.102, which complies with the R-13 prescriptive requirements. U-factors for other log wall constructions (not shown in Reference Joint Appendix JA4) would have to be approved by the Energy Commission through the exceptional methods process.

Log walls have a heat capacity that is in excess of conventional construction. Reference Joint Appendix JA4 [Table 4.3.11 Thermal Properties of Log Home Walls] shows that a 6-inch wall has an HC of 4.04 which increases to 10.77 for a 16-inch wall. The thermal mass effects of log home construction can be accounted for within the performance approach.

Air infiltration between log walls can be considerably different among manufacturers depending upon the construction technique used. For purposes of compliance, infiltration is always assumed to be equivalent to a wood-frame building. However, the builder should consider using a blower door test to find and seal leaks through the exterior walls.

e. Straw Bale

Straw bale construction is regulated within the CBC and specific guidelines are established for moisture content, bale density, seismic bracing, weather protection, and other structural requirements.

The Energy Commission has determined specific thermal properties for straw bale walls and thermal mass benefits associated with this type of construction. The performance compliance approach can be used to model the heat capacity characteristics of straw bales.

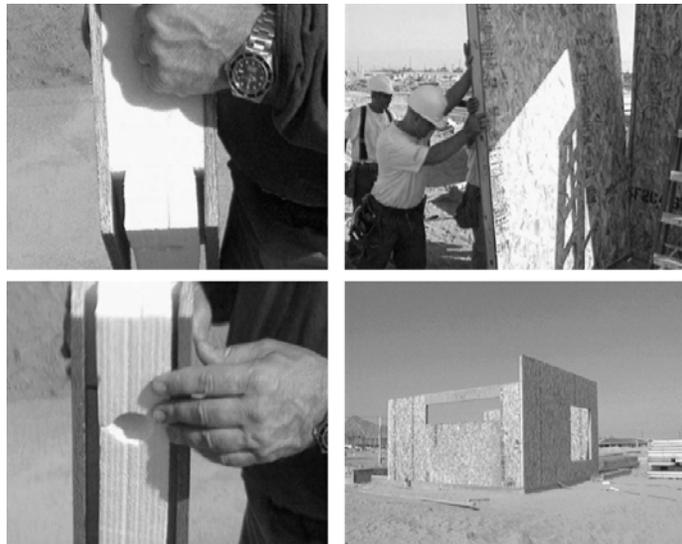
Straw bales that are 23 inch by 16 inch are assumed to have a thermal resistance of R-30, whether stacked so the walls are 23 inch wide or 16 inch wide. The minimum density of load bearing walls is 7.0 lb/ft³, and this value or the actual density may be used for modeling straw bale walls in the performance approach. Specific heat is set to 0.32 Btu/lb-°F. Volumetric heat capacity (used in some computer programs) is calculated as density times specific heat. At a density of 7 lb/ft³, for example, the volumetric heat capacity is 2.24 Btu/ft³-°F.

The minimum dimension of the straw bales when placed in the walls must be 22 inch by 16 inch and there are no restrictions on how the bales are stacked. Due to the higher resistance to heat flow across the grain of the straw, a bale laid on edge with a nominal 16-inch horizontal thickness has the same R-Value (R-30) as a bale laid flat.

f. Structural Insulated Panels (SIPS)

Structural Insulated Panels (SIPS) are a non-framed advanced construction system that consists of rigid insulation (usually expanded polystyrene) sandwiched between two sheets of OSB or plywood. Little or no structural framing penetrates the insulation layer. Panels are typically manufactured at a factory and shipped to the job site in assemblies that can be as large as 8 ft by 24 ft.

In the field, the SIPS panels are joined in one of three ways: (1) single or double 2x splines, (2) I-joists, or (3) with OSB splines. The choice of these options affects thermal performance and structural capacity. The 2x and I-joist spline types each fit in a recess of the foam core, between the two layers of plywood or OSB. Reference Joint Appendix JA4, Table 4.2.3 contains U-factors for roof/ceiling assemblies, Table 4.3.2 has U-factors for SIPS wall assemblies and Table 4.4.3 has U-factors for SIPS floor constructions. U-factors used for compliance must be taken from these tables, through the EZ-Frame assembly calculator, or by using approved performance compliance software.



Source: California Energy Commission

Figure 0-36 – Methods of Joining SIPS Panels

g. Insulating Concrete Forms (ICF)

Insulating Concrete Forms (ICFs) are a concrete forming system that uses stay-in-place panels made from a variety of insulating materials for constructing cast-in-place solid concrete walls. Three factors contribute to the energy efficiency of buildings using an ICF wall: (1) continuous rigid insulation on both sides of a high-mass core, (2) elimination of thermal bridging from wood framing components, and (3) a high degree of air-tightness inherent to this method of construction.

Climate zones with large daily temperature fluctuations have the greatest potential to benefit from the time lag and temperature dampening effects of these high-mass envelope systems. However, this combination of mass and insulation is beneficial in almost all climates with the possible exception of mild coastal climate zones.

There are three basic types of ICFs: flat wall, waffle-grid and screen-grid. A flat wall ICF results in a wall with a consistent and continuous thickness of concrete. A waffle-grid ICF creates a concrete waffle pattern, an uninterrupted-grid, with some concrete sections thicker than others. A screen-grid ICF consists of a discrete post-and-beam structure with the concrete completely encapsulated by the foam insulation, except at the intersection of posts and beams. The insulating panels for all three ICF types are most commonly made from expanded polystyrene (EPS) and extruded polystyrene (XPS) rigid insulation boards. Insulating panels are also made from polyurethane, composites of cement and EPS, and composites of cement and shredded wood fiber, although these tend to be proprietary materials developed by the ICF manufacturer.

Plastic or metal cross-ties, consisting of two flanges and a web, separate the insulating panels and provide structural integrity during the concrete pour resulting in a uniform wall thickness. A variety of wall thicknesses can be obtained by changing the length of the web. The area of attachment of the cross-ties to the insulating form provides a secure connection surface located at standard spacings for mechanical attachment of finish materials to the interior and exterior of the wall. ICFs can be used to construct load-bearing and non-load bearing walls, above- and below-grade walls, and can be designed to structurally perform in any seismic zone.

The ICF system is modular and stackable with interlocking edges. The materials can be delivered as pre-assembled blocks or as planks that require the flanges and web to be assembled during construction. The forms vary in height from 12" - 24" and are either 4' or 8' long. Vertical panels come in similar modules, but are stacked vertically. ICF panels are typically available with core thickness ranging from 4" to 12".

The thermal aspects of ICFs are represented in the Reference Joint Appendix JA4, Table 4.3.13.

h. Advanced Wall System (AWS)

Advanced Wall Systems (AWS), also known as Optimum Value Engineering (OVE), refers to a set of framing techniques and practices that minimize the amount of wood and labor necessary to build a structurally sound, safe and durable, energy efficient building. AWS improves energy and resource efficiency while reducing first costs.

Reducing the amount of wood in wood framed exterior walls improves energy efficiency, allowing more insulation to be installed, and has greater resource efficiency for the materials being used. In addition, fewer framing studs reduces the effects of "thermal bridging" and increases the amount of insulation in the wall, resulting in a more energy efficient building envelope. The framing factor assumed for calculating the energy performance of a wood framed 2x4 wall at 16"oc is 25%. When AWS is used the framing factor is reduced to 17%, reflecting the improved energy performance of the wall system.

While AWS represents a range of practices, it must be adequately inspected to ensure framing contractors have adhered to all best practice construction throughout the exterior envelope. Examples of construction practices for AWSs that should be followed and that can be used as a general guide for enforcement are provided below:

- a. Use at a minimum 2x6 at 24" on-center wall framing
- b. Use precise engineering of headers on load-bearing walls
- c. Install 2x4, 2x6, or I-joist headers on exterior non-load-bearing walls

Eliminate cripple studs at window and door openings less than 4 feet in width

- d. Align window/door openings with standard stud spacing
- e. The king stud, on at least one side of the window/door opening, must take the place of an on-layout AWS stud
- f. Use two-stud corners instead of 3-stud corners
- i. Nailing for interior gypsum board can be accomplished with drywall clips, 1x nailer strip, recycled plastic nailing strip. Drywall clips reduce the potential for drywall cracking
- g. Ladder block where interior partitions intersect exterior walls, instead of 3-stud channels
- h. Eliminate unnecessary double floor joists underneath non-bearing walls
- i. Use metal let-in T-bracing or other methods on non-shear walls to allow full insulation
- j. Include detailed framing plans and elevations on the construction permit plan set
- k. Optimize house design for efficient material use (e.g. reducing header spans, designing exterior surfaces in two foot modules, designing clear spans to eliminate interior bearing walls)
- l. Build with “insulated headers” (a “sandwich” of two solid or engineered lumber components with a layer of foam insulation in the middle or on one or both sides of the header)
- m. Use engineered lumber. Examples include: “I”-joists, open web floor trusses; 2x “raised heel” roof trusses, glulam beams, laminated veneer lumber (LVL), laminated strand lumber (LSL), parallel strand lumber (PSL), oriented strand board (OSB)
- n. Eliminate trimmers at window and door opening headers less than 4 feet in width, only when rated hangers are utilized and noted on the plans.
- o. Use 2x4 or 2x3 interior non-load-bearing walls
- p. Integrate framing design with HVAC system
- q. Use “inset” shear wall panels

The graphic below is a description of a typical AWS and the assembly characteristics that are used in the prescriptive and performance compliance approaches to support it use. But note, the building official must ensure during the framing inspection that all elements of AWS have been met.

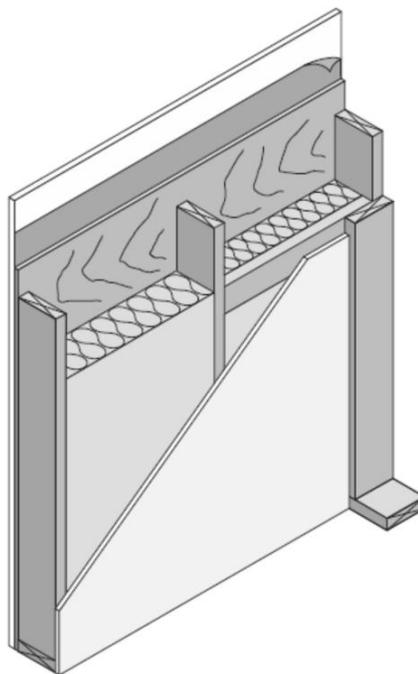


Figure 3-37 Wood Framed Wall, 2x6 @ 24" oc, AWF with 2-stud corners

Table 3-11 Assumptions

Layer	Assembly Type: Wall 2x6 @ 24" oc AWS	R-Value	
	Framing Material: Wood	Framing Factor	17
	Assembly Components	Cavity (R_c)	Frame (R_f)
1	Outside air film	0.17	0.17
2	7/8 inch 3-coat stucco	0.18	0.18
3	3/8 inch sheathing	0.47	0.47
4	R-21 insulation	21	--
5	2x6 doug fir framing @ R-1.086/inch	--	5.973
6	1/2 inch gypboard	0.45	0.45
7	Inside air film	0.68	0.68
	Subtotal	23.01	7.983
	$[1/R_c \times (1 - \text{Frame}\% / 100)] + [(1/R_f) \times (\text{Frame}\% / 100)] =$ Assembly U-factor	Assembly U-factor	0.057

Assumptions: Values in Table 3-11 were calculated using the parallel heat flow calculation method, documented in the 2009 ASHRAE Handbook of Fundamentals. The construction assembly assumes an exterior air film of R-0.17, a 7/8 inch layer of stucco of R-0.18 (SC01), building paper of R-0.06 (BP01), a sheathing or continuous insulation layer if present, the cavity insulation / framing layer, 1/2 inch gypsum board of R-0.45 (GP01), and an interior air film 0.68. The framing factor is assumed to be 25 percent for 16 inch stud spacing, 22 percent for 24 inch spacing, and 17 percent for Advanced Wall System (AWS).

Actual cavity depth is 3.5 inch for 2x4, 5.5 inch for 2x6. The thickness of the stucco is assumed to be reduced to 3/8 inch (R-0.08) when continuous insulation is applied.

i. Double and Staggered Wall Assemblies

Double wall and staggered wall systems were developed to better accommodate electrical and plumbing systems, allow higher levels of insulation, and provide greater sound attenuation. The advantages of these types of wall systems are that:

- Smaller dimensional lumber can be used
- Easier to install installation properly
- Eliminates thermal bridging through the framing
- Reduces sound transmission through the wall

With double walls, insulation may be on one side of the wall or on both (higher R-values). It is not uncommon to find double walls with insulation installed within the outside wall cavities, leaving the inside wall sections open for wiring and plumbing purposes.

With staggered walls, thermal batt insulation may be installed horizontally or vertically, butting the sides of the insulation until the cavity across the entire wall section is completely filled.

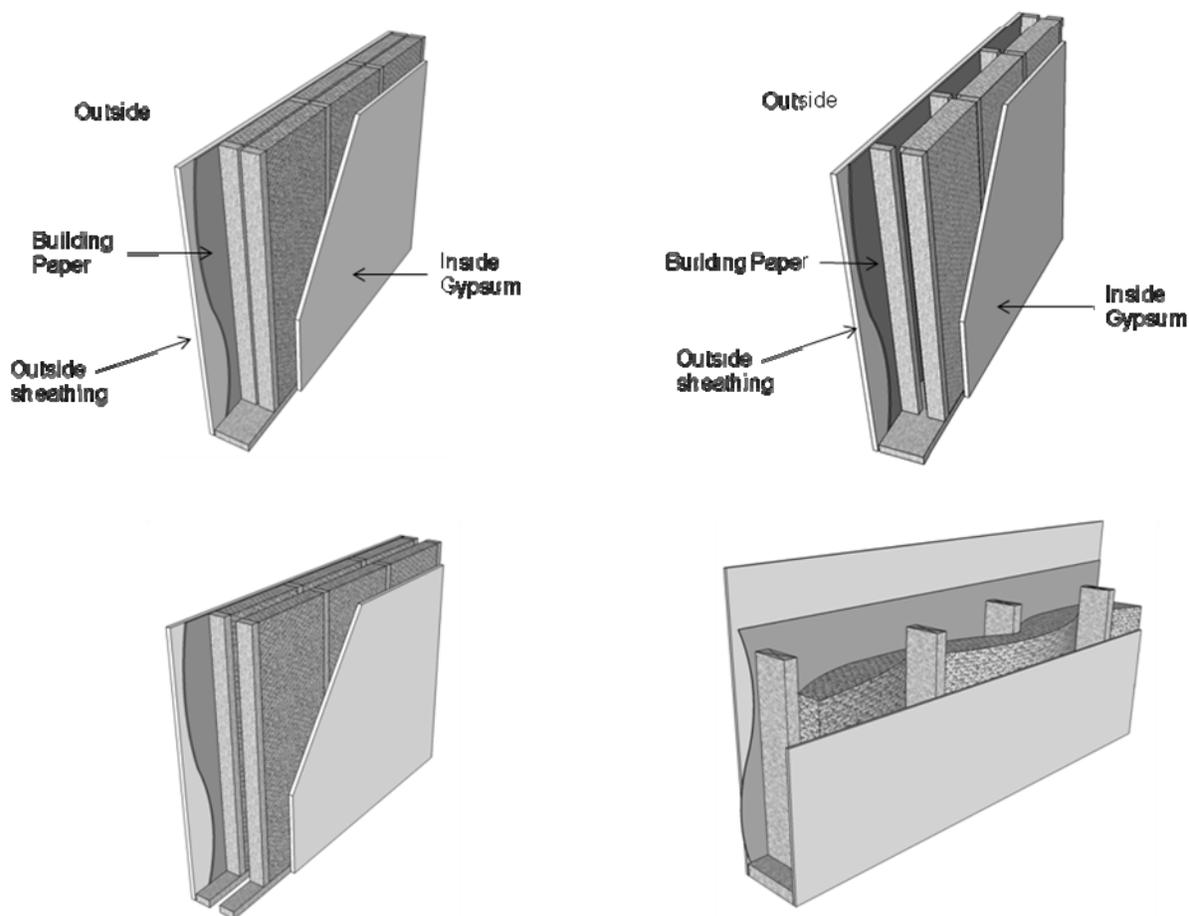


Figure 3-38 Typical Double and Staggered Wall Systems

4. Floor Assembly

a. Controlled Ventilation Crawlspace (CVC)

CVC Eligibility Criteria in 2013 Reference Appendices, Residential Appendix RA4.5.1

Buildings having crawlspace foundations must meet mandatory and prescriptive requirements for insulation of a raised floor separating the unconditioned crawlspace from conditioned space above (§150.0(d) and §150.1(c)1C). An alternative to under floor insulation is insulating the stem wall of the foundation crawlspace. Insulating the crawlspace foundation can improve the thermal efficiency of the floor system by:

- Reducing heat transfer into the unconditioned crawlspace,
- Reducing moisture buildup in the crawlspace, and
- Minimizing insulation exposed to adverse weather prior to enclosure of the building shell

An energy credit can be taken in performance compliance software for Controlled Ventilation Crawlspace (CVC). This credit requires insulating the foundation stem wall, the use of automatically controlled crawlspace vents, and vapor retarder covering the entire ground soil area for moisture control on the crawlspace floor (see Section 3.3. V, Vapor Retarder).

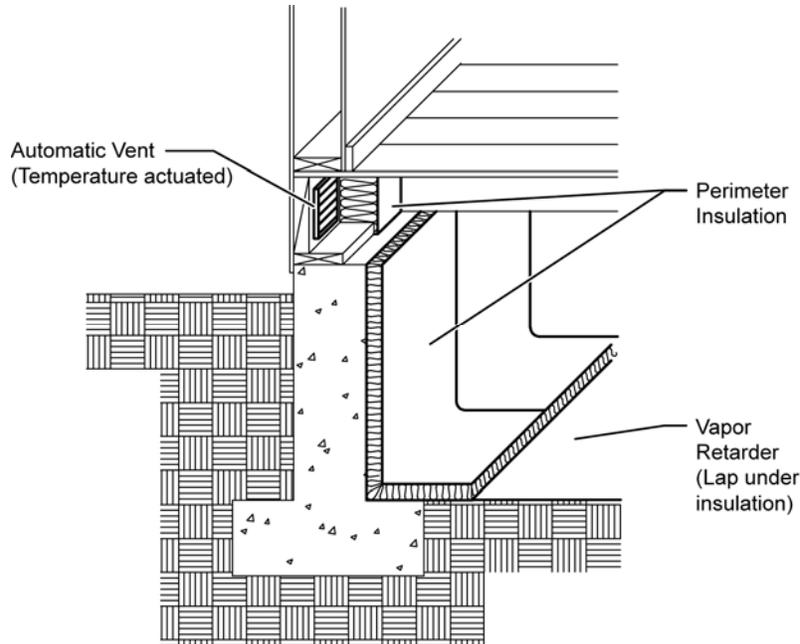


Figure 0-10 – Controlled Ventilation Crawl Space

All building designs should ensure that proper site engineering and drainage away from the building is maintained, this includes landscaping techniques that emphasize sound water management strategies.

- **Drainage:** Crawlspaces buildings in particular are susceptible to moisture ponding when good drainage and/or moisture removal designs are not employed.
- **Ground water and soils:** Local ground water tables at maximum winter recharge elevation should be below the lowest excavated elevation of the site foundation. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem wall insulation strategy. However, allowance for this alternative insulating technique is entirely at the building officials' discretion. The building permit applicant should be prepared to provide supporting information that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential moisture concerns.

The following eligibility criteria (see Reference Appendices, Residential Appendix RA4.5.1) are required in order to use the CVC energy credit:

1. **Ventilation:** All crawlspace vents must have automatic vent dampers. Automatic vent dampers must be shown on the building plans and installed. Dampers shall be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross-ventilation consisting of the required vent area shall be distributed between opposing foundation walls.
2. **Insulation:** The R-value of insulation placed on the foundation stem wall shall be equal to or greater than the wall insulation above the raised floor. Stem wall insulation shall run vertically along the stem wall and horizontally across the crawlspace floor for a distance of 2 feet (24 inches).

- a. Direct Earth Contact—Foam plastic insulation used for crawlspace insulation having direct earth contact shall be a closed cell water resistant material and meet the slab edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory requirements (§110.8(g)1).

A Class I or Class II vapor retarder must be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with Reference Residential Appendix RA4.5.2. This requires essentially a polyethylene type ground cover having a minimum 6 mil thickness (0.006 inch) or approved equal. The vapor retarder must be overlapped a minimum of 6 inches at joints and shall extend over the top of footings and piers. All overlapping of joints shall be sealed with tape, caulk or mastic.

Penetrations, tears and holes in the vapor barrier shall be sealed with tape, caulk or mastic.

The vapor retarder shall be Class I or Class II and rated as 1.0 perm or less.

Edges of the vapor retarder shall be turned up a minimum of 4 inches at the stem wall and securely fastened before insulation is installed.

In sloping crawlspace ground soil areas, the vapor retarder shall be securely held in place, such as spiked with 5 inch gutter nails then have proper sealing of penetration holes.

The vapor retarder shall be shown on the plans.

- b. **Other Assemblies**

1. **Thermal Mass**

Thermal mass consists of exposed tile floors over concrete, mass walls such as stone or brick, and other heavy elements within the building envelope that serve to stabilize indoor temperatures. Thermal mass helps temper interior temperature, storing heat or cooling for use at a later time. In California's central valley and desert climates, the summer temperature range between night and day can be 30°F or more and thermal mass can be an effective strategy to reduce daytime cooling loads.

When thermal mass exists in exterior walls, it works to stabilize temperatures in two ways. First, there is a time delay between when the outside temperature of the wall reaches its peak and when the inside of the wall reaches its peak. For an 8-inch to 12-inch concrete wall, this time delay is on the order of 6 to 10 hours. Second, there is a dampening effect whereby the temperature range on the inside of the house is less than the temperature range on the outside of the house. These effects are illustrated in the following figure.

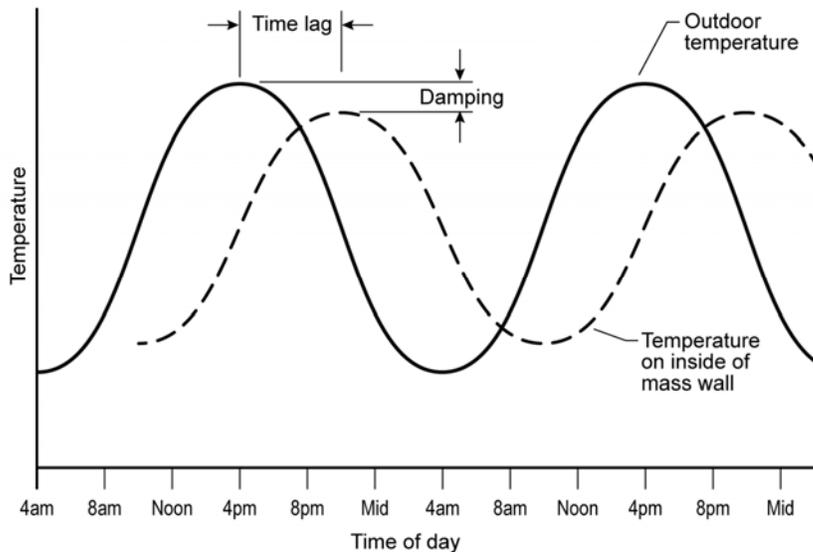


Figure 0-40 – Thermal Mass Performance

When the performance method is used, credit is offered for increasing thermal mass in buildings. However, credit for thermal mass in the proposed design may be considered only when the proposed design qualifies as a high mass building. A high mass building is one with thermal mass equivalent to having 30 percent of the conditioned slab floor exposed and 15 percent of the conditioned non-slab floor exposed with the equivalent of 2 inch-(50 mm) thick concrete. This procedure is automated in Energy Commission approved computer.

3.8 Compliance and Enforcement

For buildings for which the Certificate of Compliance (CF-1R) requires HERS field verification for compliance with the standards, a HERS rater must visit the site to perform field verification and diagnostic testing, to complete the applicable Envelope portions of a Certificate of Field Verification and Diagnostic Testing (CF-3R).

- A. The following measures require field verification and diagnostic testing if they are used in the proposed design for compliance, and are listed on the CF-1R as special features requiring HERS rater verification:

Building Envelope Sealing

Quality Insulation Installation (QII)

Field verification is necessary only when credit is taken for the measure. For example, Building Envelope Sealing need only be HERS verified if Building Envelope Sealing was used to achieve credit in the proposed design.

Registration of the CF-3R is required. The HERS rater must submit the CF-3R information to the HERS provider data registry as described in Chapter 2. For additional detail describing HERS verification and the registration procedure, refer to Reference Residential Appendix RA2.

Design

The initial compliance documentation consists of the Certificate of Compliance (CF-1R). With the 2008 update, MF-1R is no longer a checklist, but a statement of the mandatory features to be included with the CF-1R forms. The mandatory features are also included in the CF-2R forms. The CF-1R must be filed on the plans and specifications. Included on the CF-1R is a section where special envelope features are listed. The following are envelope features that should be listed in this section if they exist in the proposed design:

- Inter-zone ventilation
- Radiant barriers
- Multiple Orientation
- Controlled ventilation crawlspace
- Non-standard ventilation height differences
- Standard free ventilation area greater than 10 percent of the window area
- Metal-framed walls
- Sunspace with interzone surfaces
- Roofing products (Cool roof)
- Air retarding wrap

Plan checkers should verify that insulation levels, fenestration U-factors, and SHGCs listed on the CF-1R are consistent with the plans and specifications.

If registration of the CF-1R is required (see Chapter 2 for requirements), the building owner, or the person responsible for the design must submit the CF-1R to the HERS provider data registry for retention following the procedures described in Chapter 2 and in Reference Residential Appendix RA2.

Construction

During the construction process, the contractor and/or the sub-contractors complete the necessary sections of the Certificate of Installation (CF-2R):

Fenestration/Glazing. The glazing contractor lists all the fenestration products that are installed in the building along with the model number, the manufacturer number, the U-factor and the SHGC. Ensure dynamic glazing controls are functional with Energy Management Systems or similar.

Building Envelope Leakage Diagnostics. This is applicable only if the builder/contractor does blower door testing to reduce building envelope leakage.

Insulation Installation Quality Certificate. The insulation contractor documents the insulation installation quality features that have been followed as shown on the CF-2R checklist.

Description of Insulation. The insulation contractor documents the insulation materials installed in the walls, roofs, and floors along with the brand name of the materials and the thermal resistance.

The building official (field inspector) will visit the site multiple times during the construction process. The purpose of these visits is to verify that the equipment and materials installed are consistent with the plans and specifications.

If registration of the CF-2R is required, the licensed person responsible for the installation must submit the portion of the CF-2R information that applies to the installation to a HERS provider data registry using procedures described in Chapter 2 and in Reference Residential Appendix RA2.

