3. Building Envelope Requirements

This chapter describes the requirements for the design of the building envelope for residential buildings. The building energy use is affected by the heating and cooling load, due to heat loss and heat gain needed to maintain the buildings desired temperature. Heating load calculations to determine the HVAC needs of the space being heated or cooled. The principal components of heating loads are infiltration through the building envelope and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows and doors. Cooling loads, however, are dominated by solar gains through the windows and skylights and from internal gains due to lighting and occupancy use.

This chapter is organized by building system or building envelope component, as follows:

a. Overview
   - a What's new for 2013

b. Fenestration, includes windows, glazed doors, dynamic glazing and skylights

c. Mandatory Requirements
   - Air Leakage
   - Insulation
   - Roofing Products
   - Radiant Barrier
   - Fire Places, Decorative Gas Appliances and Gas Logs

d. Roof/Ceiling
   - Insulation
     - Mandatory Measures
     - Prescriptive Measures
   - Roofing Products
     - Prescriptive Measures
   - Radiant Barrier
     - Prescriptive Measures
   - Ventilation
   - Advanced Assembly Systems
     - Roof deck insulation
     - Unvented Attics
       - Air Leakage

DICS

High Heal Truss

Solar PV & Solar Ready

e. Walls

- Insulation
  - Mandatory Measures
  - Prescriptive Measures
- Thermal Mass
  - Mandatory Measures
  - Prescriptive Measures
- Vapor Retarder and Moisture Protection
  - Mandatory Measures

- Advanced Assembly Systems
  - Air Leakage and Quality Insulation Installation
  - Knee wall
  - Walls
    - Double & Staggered Wall Systems
    - Non-standard Framed Wall systems
    - Non-framed Wall systems

f. Floors

- Insulation
  - Mandatory Measures
  - Prescriptive Measures
- Thermal Mass
  - Mandatory Measures
  - Prescriptive Measures
- Slab Edge Insulation
  - Mandatory Measures
  - Prescriptive Measures

- Advanced Assembly Systems
  - Controlled ventilated crawl space
  - Radiant Floors

g. Compliance and Enforcement
   - Design
   - Construction
   - Field Verification and/or Diagnostic Testing

h. Glossary/Reference

1. Overview

The Standards have both mandatory measures and prescriptive requirements that affect the design of the building envelope. The mandatory measures and prescriptive requirements establish a minimum performance level, which can be exceeded by other design measures and construction practices resulting in greater energy savings.

Common strategies for exceeding the minimum energy performance level include the use of better components such as more insulation, more efficient windows, use of thermal mass, reducing air leakage through the building, radiant barriers, cool roofs, 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 with each envelope feature.

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 predominate thermal energy needs. Passive solar strategies encompass several advanced high performance envelope techniques, such as:

- carefully choosing the size, type and placement of fenestration, shading
- have the ability to allow fresh air ventilation during the day or night
- have internal and external thermal mass components that help store useful heat and cooling energy
- have well insulated envelope assemblies
- use radiative energy performing roofing materials (cool roofs) and radiant barriers
- have low air leakage
- have mechanism to control and provide internal ventilation

Other innovative designs and practices can be recognized at any time by the Energy Commission. Section 10-109 of the Standards allows for the introduction of new compliance options which cannot be properly accounted for in the current approved compliance approaches. This process for approval of compliance options for new products, materials, and calculation methods helps to improve building efficiency levels set by the Building Energy Efficiency Standards.

New compliance options affect the Standards in several ways but can generally be viewed as:

- Those that affect a change in compliance through a change in the scope of the requirements, and
- Those that affect a change in compliance through enhancement of the current compliance process.

Compliance options typically are alternate uses or an enhancement of materials, products, designs, or procedures that are not explicitly addressed by either the mandatory, prescriptive, or performance requirements. In many cases, approved compliance options represent "advanced systems" that have not been recognized by the performance compliance method because of complexities in determining their performance dynamics. When the Energy Commission approves a new compliance option it is listed in the Special Cases section of the Energy Commission's website: http://www.energy.ca.gov/title24/2008standards/special_case_appliance/.

Some measures included as part of an Advanced Assembly System require installation procedures, 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 actually makes its way to the energy benefit of the homeowner.

3.1.2 What's New for 2013

A. An updated equation to calculate the aged solar reflectance for field-applied coatings (cool roof), §110.8(i)2.

B. Minimum mandatory insulation requirement for insulation installed between a 2x6 inch and grater wall framing, §150.0(c).

C. Introduced an alternative method to meet the prescriptive insulation requirement, TABLE 150.1-A.

D. A prescriptive requirement for low and steep-sloped roofing products (cool roof), §150.1(c)11.

E. In alterations, insulation tradeoff is allowed in the prescriptive requirements, §150.2(b)1H .

F. The 2013 update to the Standards, the fenestration U-factor and SHGC has been reduced for Package A formally Package D. Introduction of Dynamic Glazing and Window Films for alterations to existing buildings.

3.1.3

California Energy Commission Default Label XYZ Manufacturing Co.		
Frame Type	**Product Type:**	**Product Type:**
☐ Metal ☐ Non-Metal ☐ Metal, Thermal Break	☐ Operable	☐ Clear
	☐ Fixed	☐ Tinted
	☐ Greenhouse/Garden Window	☐ Single-Pane
	☐ Doors	☐ Double-Pane
Key Features:	☐ Skylight	☐ Glass Block
☐ Air space 7/16 in. or greater		
California Energy Commission Default U-factor 0.61	**California Energy Commission** Default SHGC 0.53	**California Energy Commission** **Default VT 0.51**

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

Sample of Temporary Label

2. Fenestration

Fenestration

Windows, glazed doors, dynamic glazing, skylights and window film have a significant impact on energy use in a home. They may account for up to 50 percent of residential space heating loads, and for homes that are air-conditioned, up to 50 percent of the cooling 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 the occupants.

DYNAMIC GLAZING

Internal Shading System

Dynamic Glazing products are either internal shading system or electro-chromatic devices and are considered a fenestration product. Internal shading systems include blinds positioned between glass panes that can open and close. 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-????.

Figure 3-??? Dynamic Glazing Internal Shading Device NFRC Label

INTERNAL SHADING DEVICE GLAZING COMPLIANCE

To receive Internal Shading Device credit the fallowing must be met:

- Optional Prescriptive and Performance Approach Compliance;
- Automatic controls must be used to receive best rating values or Default to Table 150.1-A U-factor and SHGC;
- NFRC Internal Shading Device Label is required; otherwise, use the Default Table 110.6-A and 110.6-B values.

Chromatic Glazing

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-??? 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.
- The Variable Arrow – If the product can operate at intermediate states, a dual directional arrow, (↔), with the word “Variable” underneath 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.

CHROMATIC GLAZING COMPLIANCE

To receive chromatic glazing credit the fallowing must be met:

- Optional Prescriptive and Performance Approach Compliance;
- Automatic controls must be used to receive best rating values or Default to Table 150.1-A U-factor and SHGC;
- NFRC Chromatic Glazing Compliance Label is required; otherwise, use the Default Table 110.6-A and 110.6-B values.

WINDOW FILMS

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 low temperature resistances. Polyester film offers crystal clarity and can be pre-treated to accept different types of coatings such as adhesives. 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 applied to the interior surface of the glass, unless is a film specially designed to go on the exterior or outside window surface.

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 dyed, or metalized by either a vacuum coating, sputtering, or reactive deposition to produce an array of colored and spectrally selective films. There are three basic categories:

1. Clear (Non-Reflective);

2. Dyed (Non-Reflective); and

3. Vacuum Coated (Reflective), which can be metalized or sputtered.

- Clear films are used as safety films and to reduce ultraviolet (UV) light fading damaging rays; however, they are not used for solar control or energy savings.
- Dyed films reduce both heat and light transmission, mostly through increased absorptance and can be used in applications where glare control is desired.
- Reflective films are the preferred film in most energy savings applications, since they reduce transmission 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 understands the contrast in energy performance of Window Films. See Window Films Figure 3-?? below.

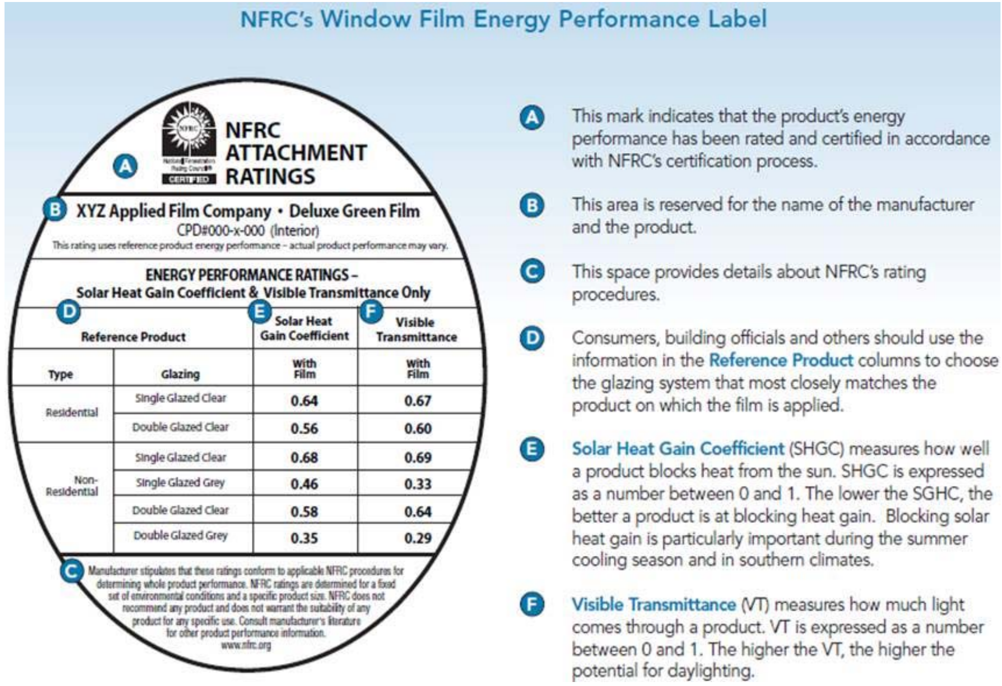


Figure 3-?? Window Film Energy Performance Label

WINDOW FILM COMPLIANCE

To receive window film credit the fallowing must be met:

- The Performance Approach must be used;
- Only use 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.
- Window Films to be used shall have a 10 year warranty or better

3.1.4 Relevant Sections in the Standards

The Standards deal with fenestration in several ways and places:

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

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

C. §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.

D. §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.

E. §110.6(b) has default U-factors, SHGC and VT values that are to be used for field-fabricated fenestration and exterior doors that do not have an NFRC rating.

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

G. §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 ft^2 or 0.5% of the conditioned floor area to exceed 0.58 U-factor.

H. §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.

I. §150.1(c)3A Exception 1 allows each dwelling unit to have up to 3 ft^2 of glazing installed in doors and up to 3 ft^2 of tubular skylight with dual-pane diffusers to have an assumed U-factor and SHGC equivalent to the Package requirements.

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

K. §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.

L. §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.

M. §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.

N. §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.

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

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

3.1.5 Mandatory Measures

The Standards define three types of fenestration products that face different mandatory measures, and establish a mandatory maximum U-factor:

A. **Manufactured products** are delivered pre-assembled from the factory. This is the most common type of fenestration in residential construction.

B. **Site-built products** are glazed or assembled on site using factory prepared systems. These are more common in nonresidential construction and include storefront and curtainwall systems. The glazing contractor may also pre-assemble site-built fenestration at his or her shop before final installation. For unlabeled site-built fenestration use default values from Standards TABLE 110.6-A for U-factor and TABLE 110.6-B for SHGC, otherwise, select site-build fenestration from NFRC's Certified Products Directory. See http://www.NFRC.org.

C. **Field-fabricated products** are built on site using standard dimensional lumber or other materials not intentionally prepared for use as a fenestration product. For field-fabricated fenestration use default values from Standards TABLE 110.6-A for U-factor and TABLE 110.6-B for SHGC.

D. Mandatory maximum U-factor is set by §150.0(q) for fenestration and skylights of 0.58. While there is an allowance for weight-averaging, this will limit the use of single pane products. Up to 10 ft^2 or 0.5% of the conditioned floor area (whichever is greater) can exceed the maximum 0.58 U-factor.

Complete definitions can be found in the Reference Joint Appendices JA1.

3.1.6 Air Leakage

- *§110.6(a)1*

Manufactured Fenestration Products. Manufactured fenestration products, including exterior doors, must be tested and certified to leak no more than 0.3 cubic feet per minute (cfm) per ft^2 of window area. For a window that has an area of 10 ft^2, the maximum leakage would be 10 ft^2 times 0.3 cfm/ft^2 or a total leakage of 3 cfm. This is equal to about 86 in^3 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 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:

A. 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.

B. They must comply with the requirements of §110.7, as described below in "Joints and Other Openings," e.g., they must be caulked and weatherstripped if field-fabricated.

C. Any door whose surface area is more than one-half glass is a fenestration product and must comply with the mandatory and prescriptive measures and other Standards requirements for fenestration products.

3.1.7 U-factor, SHGC and VT Ratings

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

A. *Manufactured Fenestration Products.* The mandatory measures require that the U-factor, Solar Heat Gain Coefficient (SHGC) and the VT of manufactured fenestration products be determined from NFRC's Certified Product Directory or from Energy Commission-approved default values. At the time of inspection, the actual fenestration U-factor and SHGC values as shown on NFRC labels or in the default tables must result in equal or lower overall energy consumption than the values indicated on the compliance documents. The default U-factors are contained in Standards TABLE 110.6-A, and the default SHGC values are contained in Standards TABLE 110.6-B (also in Appendix B of this compliance manual). While there is no minimum VT value, the value is shown on the temporary label based on NFRC testing or default values from Nonresidential Reference Appendix NA6. A directory of NFRC certified ratings is available at http://www.NFRC.org.

Energy Commission default values in both Standards TABLE 110.6-A and TABLE 110.6-B are on the poor side of the performance range for windows. To get credit for advanced 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 3-1shows an example of an NFRC-approved temporary fenestration label.

Figure 3-1 – NFRC Temporary Label

Requiring that U-factor, SHGC and VT 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. The test procedure for U-factor is NFRC 100, and the test procedure for SHGC is NFRC 200, the test procedures for VT are NFRC-200 or ASTM E972, and NFRC-203 for tubular skylights.

B. *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 minimum VT value, the value is shown on the temporary label based on NFRC testing or default values from Nonresidential Reference Appendix NA6. Note that different alternative default values apply to nonresidential projects; default values may be found in the Reference Nonresidential Appendices NA6.

C. *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 Table 3-1. Acceptable methods of determining SHGC are shown in Table 3-2.

Table 3-1 – 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)	✓	✓	N/A	N/A
NFRC-100	✓	✓	N/A	N/A
Standards Table 110.6-A	✓	✓	✓	✓
NA6		✓		N/A

Table 3-2 – 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)	✓	✓	N/A	N/A
NFRC-200	✓	✓	N/A	N/A
Standards Table 110.6-B	✓	✓	✓	✓
NA6		✓		N/A

Table 3-3 – Methods for Determining Visible Transmittance (VT)

	Fenestration Category			
SHGC Determination Method	Manufactured Windows	Site-Built Fenestration	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA)	✓	✓	N/A	N/A
Test procedures for VT are NFRC-200 or ASTM E972, and NFRC-203 for tubular skylights.	✓	✓	N/A	N/A
NA6	✓*	✓	✓	N/A
* Non NFRC rated windows				

3.1.8 Temporary and Permanent Labels

- *§10-111(a)*
- *§110.6(a)5*

A. *Manufactured Fenestration Products.* The Standards require that manufactured windows have both temporary and permanent labels that show the NFRC performance characteristics. 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 number or code to allow tracking back to the original information on file with the certifying organization. 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.

B. *Site-Built Fenestration Products.* 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.

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

Example 3-1

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 3-2

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 3-3

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 3-4

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 3-5

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 the 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 3-6

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 3-7

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 3-8

Question

What constitutes a “double-pane” window?

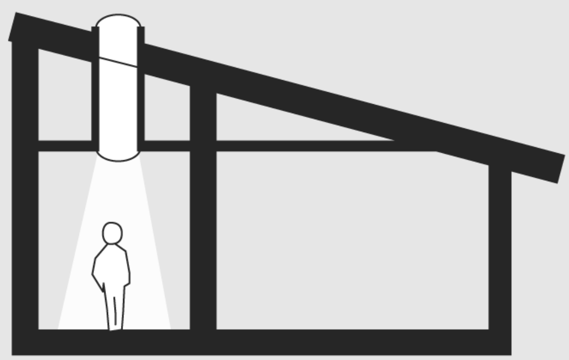
Answer

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 3-9

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 ¼-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 x 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 x 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 3-10

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 ft^2 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).

3.1.9 Prescriptive Requirements

Prescriptive requirements described in this chapter typically refer to Package A, Tables 150.1-A of the Standards (also in Appendix B of this document).

The prescriptive requirements specify a maximum U-factor of 0.32, and in climate zones 2, 4, and 6-16 where air conditioning is common, a maximum SHGC of 0.25. In addition, the prescriptive requirements limit total glass area to a maximum of 20 percent of the conditioned floor area 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 (§151(c)3C).

3.1.10 Fenestration U-factor (should be 3.2.7)

With the 2013 update, the maximum U-factor required by prescriptive Package A for all climate zones is 0.32 or lower. 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 (see Table 3-4). The requirements apply to the fenestration product without consideration of insect screens or interior shading devices. With some exceptions, the U-factor and SHGC of windows, doors and skylights can be weight-averaged to meet the prescriptive requirement using Form WS-2R in Appendix A.

While a low-e coating is the most common way to comply with the SHGC requirements, the Standards offer other options: use an exterior shade screen or louver on the outside of the window or, for south facing windows, use a properly sized overhang. Both sunscreens and overhangs are discussed in the Compliance Options section.

Aside from the Exceptions in Section 3.2.8, U-factors and SHGCs for skylights can be significantly higher than they are for windows. This means that unless a weighted average calculation shows a 0.32 or lower U-factor and 0.25 SHGC or lower when applicable dwellings with large amounts of skylights may not comply with the prescriptive requirements, and the performance approach must be used.

3.1.11 Fenestration Prescriptive Exceptions (should be Section 3.2.8)

In each dwelling unit, up to 3 ft^2 of the glazing installed in doors and up to 3 ft^2 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 Exception1 §150.1(c)3A.

Each new dwelling unit may have up to 16 ft^2 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 is excluded from the area-weighted calculations for U-factor and SHGC. See Exception 2 §150.1(c)3A.

If a dwelling unit includes a type of dynamic glazing that is chromogenic (see Glossary Section 3.9), 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 §150.1(c)3A

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.

Table 3-4 – 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%

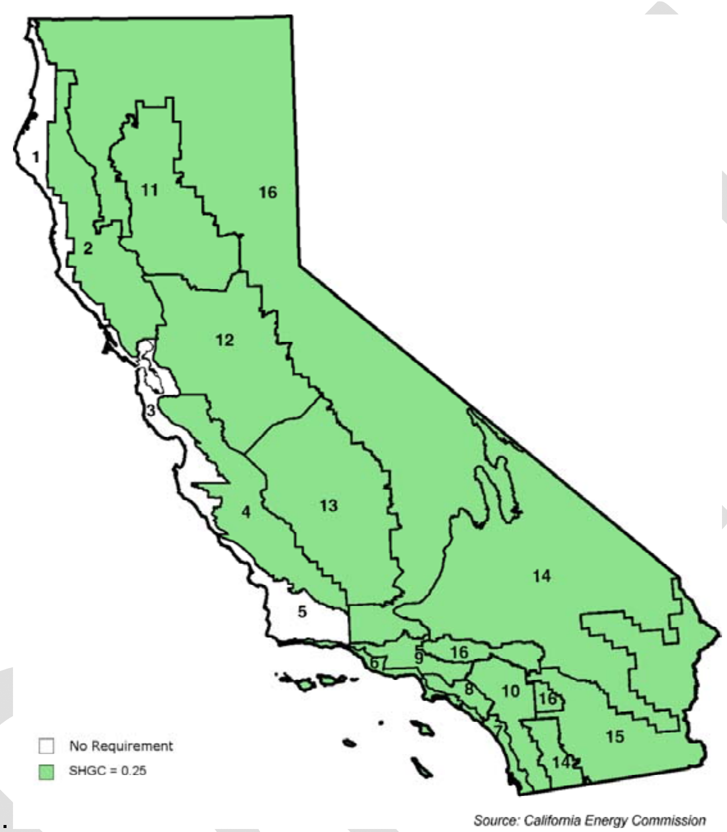


Figure 3-2 – Package A SHGC Criteria by Climate Zone

3.1.12 Window Area (should be 3.29)

- *§100.1(b)*
- *§150.1(f)3C*
- *§150.1(e)*

With the prescriptive requirements of Package AA, window area is limited to a maximum of 20 percent of the conditioned floor area in all climate zones. 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.

3.1.13 Rules for Glazed Doors

- *§110.6*

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

A. 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.

B. In the prescriptive and performance approach, doors with less than 50 percent glass area, up to 3 sf^2 is exempt from the U-factor and SHGC. Glass area greater than 3 ft^2 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.

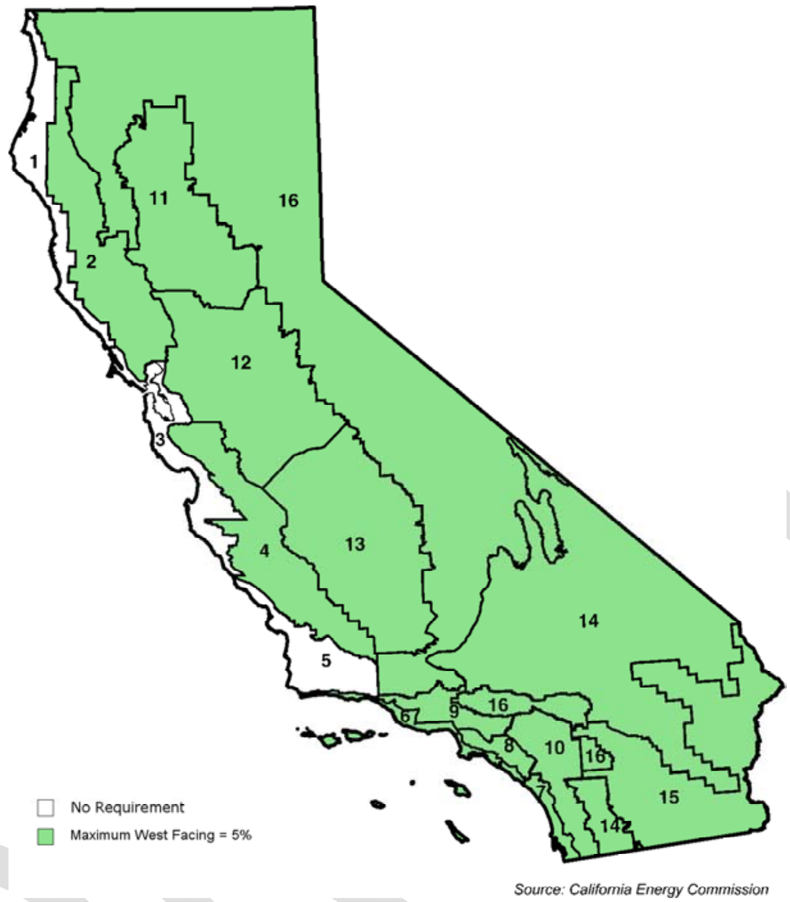


Figure 3-3 – Package A, Prescriptive West-Facing Window Area Limits by Climate Zone

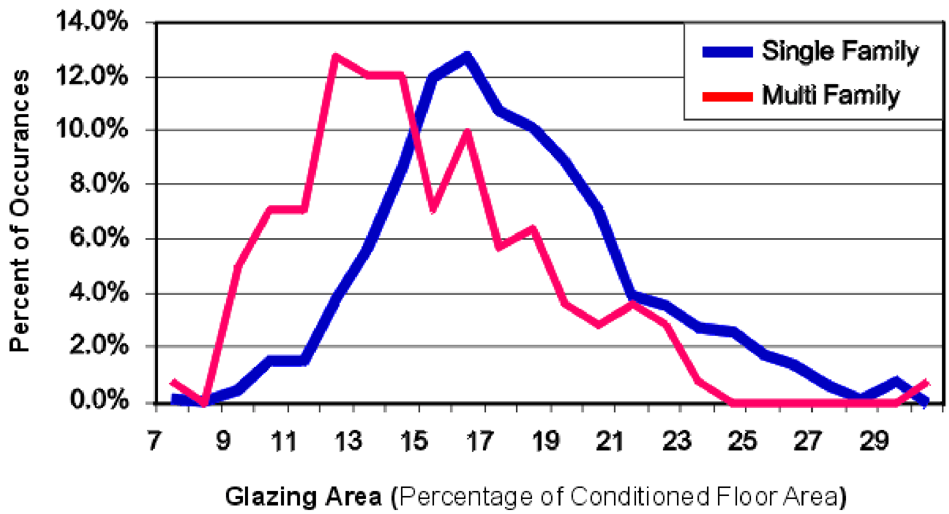
3.1.14 Compliance Options

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 7). 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 Figure 3-4. The variations in fenestration areas, has little to do with energy efficiency.



(Source: Residential New Construction Database)

Figure 3-4 – Glass Area in Single Family and Multifamily Residence

Based on data shown in Figure 3-4, 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 20013 update, the currency 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 20013 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:

a. 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.

b. 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.

c. Gap Width (i.e., the distance between panes).

d. Window type (i.e., casement versus double hung).

e. Spacer material (i.e., the type of material separating multiple panes of glass).

f. 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 3-5). 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.

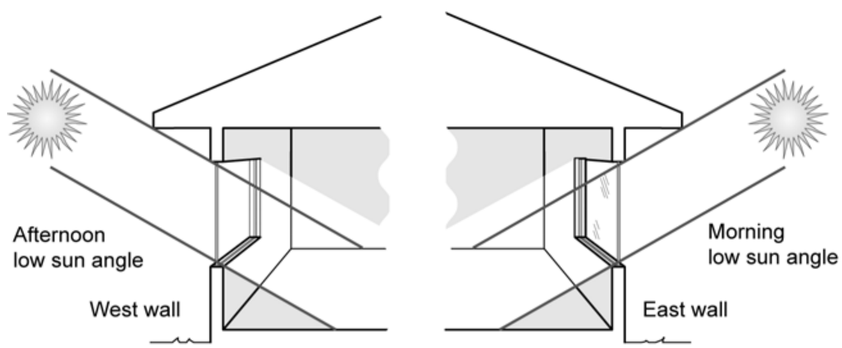


Figure 3-5 – Difficulty of Shading East- and West-Facing Windows

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 3-6. 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.

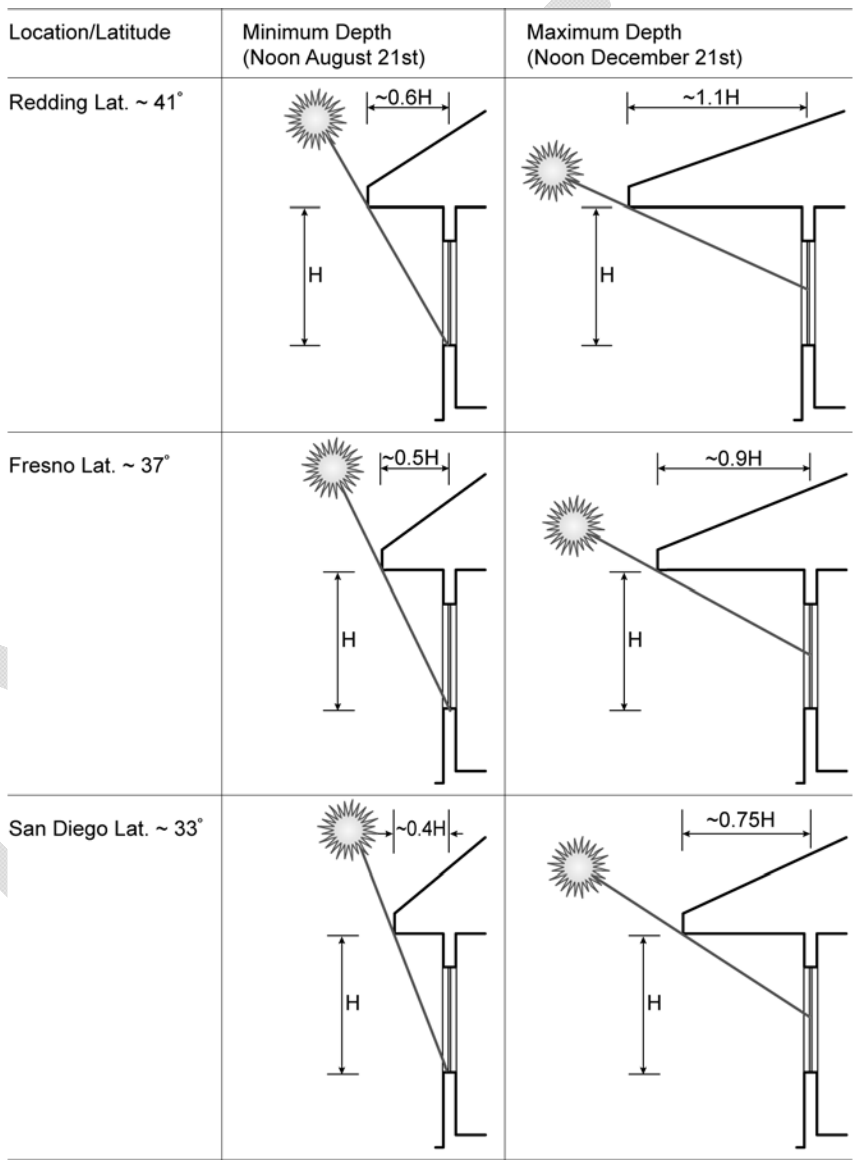


Figure 3-6 – South-Facing Overhang Dimensions for Prescriptive Compliance

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 devices and their SHGC values are shown in Table 3-5. 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 AA may be met for all climate zones without calculations. Several exterior shading device other than bug screens listed in Table 3-5 will achieve compliance when used in combination with any allowed fenestration product.

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:

Equation[1]: $SHGC_{combined} = (0.2875 \times SHGC_{max} + 0.75) \times SHGC_{min}$

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 0.32 and an insect screen with an SHGC of 0.76 (see Error! Reference source not found.). 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, $SHGC_{combined}$ is 0.24. This means that any combination of window SHGC and exterior SHGC that results in an $SHGC_{combined}$ 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 $SHGC_{combined}$ 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.

[1] The equation can be found in the 20138 Residential Compliance Manual and it is included in WS-3R in Appendix A.

Table 3-3 – Qualifying 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 1/8th inch double strength (DSS) glass. Use WS-3R Worksheet for calculation.	

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 NRFC 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 and in §150.0(c). 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 Windows

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 0. Also see Section 4.6 for mechanical ventilation requirements.

3.1.15 Compliance and Enforcement Should be Section 3.2.12

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

3. Envelope Assembly

This section of the building envelope chapter addresses the requirements for insulating the opaque portion of the building shell. Components of the building shell include the walls, the floor, and the roof or ceiling. Windows and doors are addressed in Section 2, Fenestration.

Sloping surfaces are considered either a wall or a roof, depending on their slope (see ??). 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 the windows in walls and any skylights in roofs.

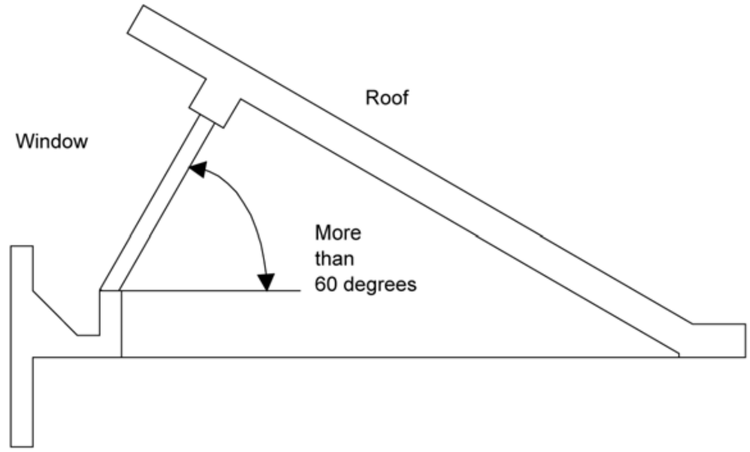


Figure 3-7 – Slope of a Wall or Window (Roof or Skylight slope is less than 60°)

The window is considered part of the wall because the slope is over 60°. Where the slope less than 60°, the glazing indicated as a window would be a skylight.

3.1.16 Overview

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.

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 due to leakage from garages or attics. An air barrier that inhibits air leakage is critical to good building design. Energy credit is offered through the performance compliance method for options that reduce building envelope air leakage.

Ventilation is the *intentional* replacement of conditioned air with unconditioned air through open windows or mechanical ventilation. Ventilation in residential buildings can be achieved by opening windows either to provide natural ventilation for cooling purposes or to reduce stuffiness or odors. Energy Commission sponsored research in California homes has shown that a significant number of home occupants do not regularly open their windows for ventilation. The Standards require ventilation requirement of ASHRAE 62.2—mechanical ventilation and minimum operable window areas. See Section 4.6 for mechanical ventilation requirements.

Requirements of the Standards that target controlling and reducing building air leakage are discussed below.

3.1.17 Mandatory Measures

A. Fenestration Air Leakage

- *§110.6(a)1*

Manufactured fenestration products, including exterior doors, must be tested and certified to leak no more than 0.3 cubic feet per minute (cfm) per ft^2 of window area. For a window that has an area of 10 ft^2, the maximum leakage would be 10 ft^2 times 0.3 cfm/ft^2 or a total leakage of 3 cfm. This is equal to about 86 in^3 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.

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

Further discussion of mandatory measures for air leakage for fenestration products are covered in Section 3.1.5.

B. Joints and Other Openings

- *§110.7*

Air leakage through joints, penetrations, cracks, holes and opening 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 (see):

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:

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

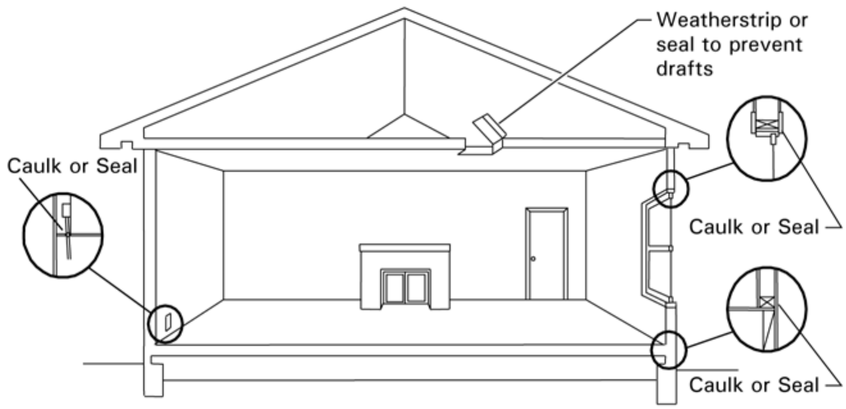


Figure 3-8 – Caulking and Weatherstripping

Compliance and Enforcement

The compliance and enforcement process should ensure that all potential sources of infiltration and exfiltration in the building envelope (listed above and on the previous page), joints and openings are caulked, gasketed, or otherwise sealed. For more information on Compliance and Enforcement on joints and openings, please see chapter 2 of this manual.

C. 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 3-9) 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 inch^2 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 inch^2 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.

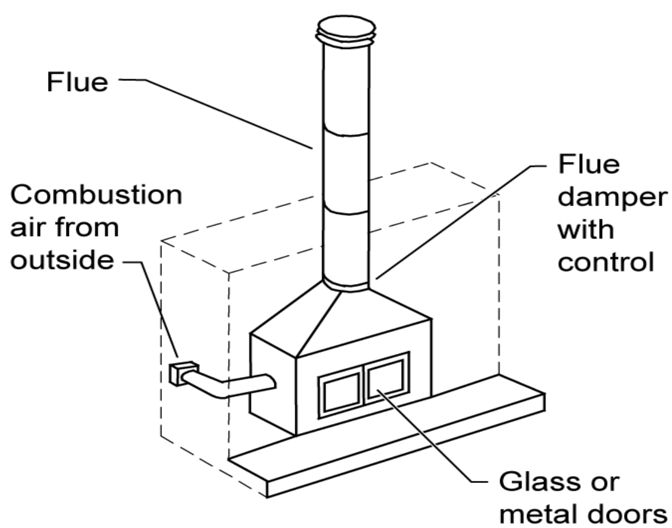


Figure 3-9 – Fireplace Installation

D. 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).

E. 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 ft^2). 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.

F. 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.

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

G. Insulation General Mandatory Measures

§110.8

A number of mandatory measures apply to insulation in general, and those are covered in this section:

Other mandatory measures apply to specific applications, and they are covered in the sections on ceiling/roof insulation, wall insulation, floor insulation, and slab insulation.

H. Certification of Insulating Materials

§110.8(a)

The California Standards for Insulating Materials, which became effective on January 1, 1982, 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 and 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 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.

I. 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.

J. Flame Spread Ratings 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, or floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications.

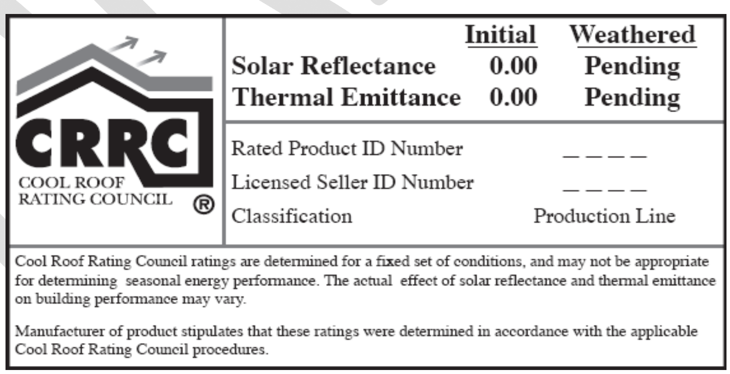
Flame spread ratings and smoke density ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

K. Roofing Products (Cool Roof)

§110.8(i)

Roofing Products Solar Reflectance and Thermal Emittance

Roofing products with high solar reflectance and thermal emittance are referred to as “cool roof” which is the outer layer of a roof. As the term implies, the temperature of a cool roof is lower on hot sunny days than for a conventional roof, reducing cooling loads and the energy required to provide air conditioning. Cool roofs are a prescriptive requirement for both low-sloped and steep-sloped roof application on residential buildings. To be considered a cool roof the roofing products manufacturer must have its roofing product tested for solar reflectance and thermal emittance, and be listed in the Cool Roof Rating Councils (CRRC) Rated Product Directory (see http://www.coolroofs.org) and be labeled according to CRRC procedures. Figure 3-29 provides an example of an approved CRRC product label.



or

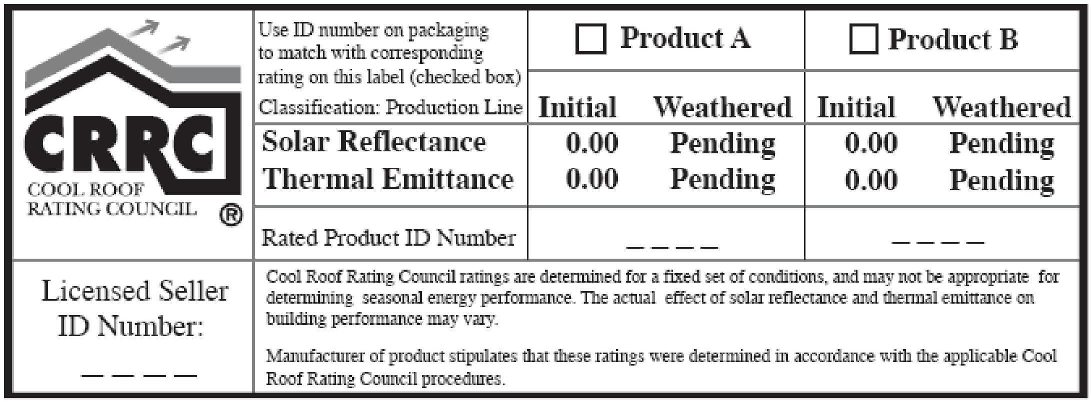


Figure 3-29- CRRC Product labels and information

If the aged value for the reflectance is not available in the CRRC's Rated Product Directory then the equation below can be used until the aged rated value for the reflectance is posted in the directory.

Aged Reflectance $_{calculated}$=(0.2+β[$\rho_{initial}$ – 0.2])

Where $\rho_{initial}$ = Initial Reflectance listed in the CRRC Rated Product Directory. β = soiling resistance which is listed in Table 3-1

PRODUCT TYPE	β
Field-applied coating	0.65
Other	0.70

Table 3-1 – Values Of Soiling Resistance β By Product Type

In lieu of meeting a thermal resistance and an aged solar reflectance requirement, compliance can be shown by meeting a minimum Solar Reflectance Index (SRI).To calculate the SRI the 3-year aged value of the roofing product must be used in conjunction with the thermal emittance. 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; alternately, SRI can be used to demonstrate compliance by trading off a lower aged solar reflectance with a higher thermal emittance.

Compliance credit may be taken when a cool roof is installed when using the performance approach. The credit is available only if there is no radiant barrier installed. In the performance method calculations, the cooling benefit of a cool roof is assumed to be equal to that of a radiant barrier. There is no heating impact calculated for a cool roof (while there is some heating benefit assumed for a radiant barrier).

The benefit of a high reflectance surface is obvious: while dark surfaces absorb the sun's energy (visible light, invisible infrared. and ultraviolet radiation) and become hot, light-colored surfaces reflect solar energy and stay cooler. However, high emittance is also important. Emittance refers to the ability of heat to escape from a surface once it is absorbed. Surfaces with low emittance (usually shiny metallic surfaces) contribute to the transmission of heat into the roof components under the roof surface. However, due to increase of heat, the building's air conditioning load will result in an increased of the air conditioning load and less comfort for the occupants. High-emitting roof surfaces give off absorbed heat relatively quickly through the path of least resistance—upward and out of the building.

Example 3-11

Question

Is a cool roof required in new residential construction or in residential alterations or additions?

Answer

Yes, for the 2013 Standards cool roof is required when using the prescriptive package in new residential construction, additions or alterations. Cool roof applies to both low-slope and steep-slope residential roofs. Also, the cool roof requirement is different per climate zone. If one wishes not to install a cool roof then they must meet the Standards using the performance method where tradeoffs can be done.

Example 3-12

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 3-13

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 3-14

Question

I've heard the words reflectivity, reflectance, emissivity, and emittance? Can you explain?

Answer

"Reflectivity" and "reflectance" denote the same thing, but the Standards use only "reflectance" to avoid confusion. "Emissivity" and "emittance" denote the same thing, and again the Standards use only "emittance."

Example 3-15

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.

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 Insulation[2] 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 in the factory. Oriented strand board (OSB) is the most common material available with 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 to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material. The gable ends also need to have 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. The minimum spacing requirements do not apply to this installation since it is considered a “laminated” system.

Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces when sheathing is installed that does not include a laminated foil. Foil 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 for drawings of radiant barrier installation methods.

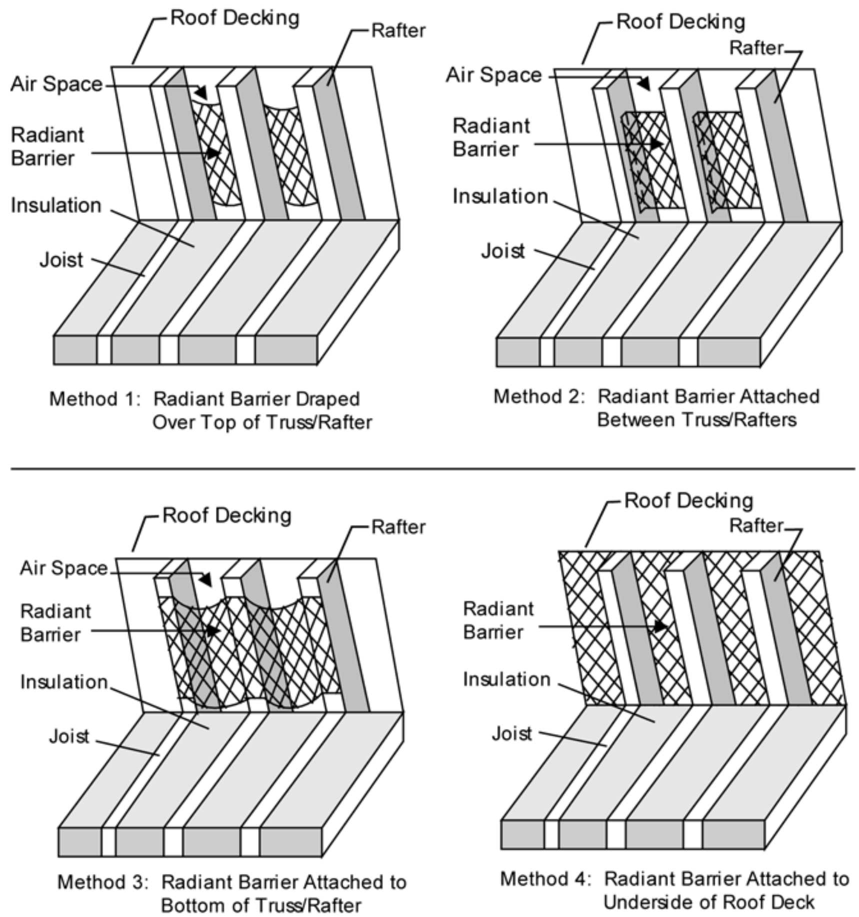


Figure 3-10 – Methods of Installation for Radiant Barriers

3.1.18 Assembly

A. **Ceiling/Roof**

a. Mandatory Measures

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

The following mandatory measures apply specifically to roof and ceiling insulation:

b 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.

c 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 lain 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.

Example 3-16

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 3-17

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.

b. Prescriptive Requirements

d Insulation

§150.1(c)1A

The following paragraphs discuss Component Package-A, as it is the basis for the performance calculation methods. The prescriptive package, Alternative 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 the 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 (see Figure 3-11).

There are three ways to meet the prescriptive insulation requirement. The first 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 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 is to use the Energy Commission's EZ-Frame assembly calculator to calculate the U-factor of the different assembly components than those listed for Reference Joint Appendix JA4.

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.

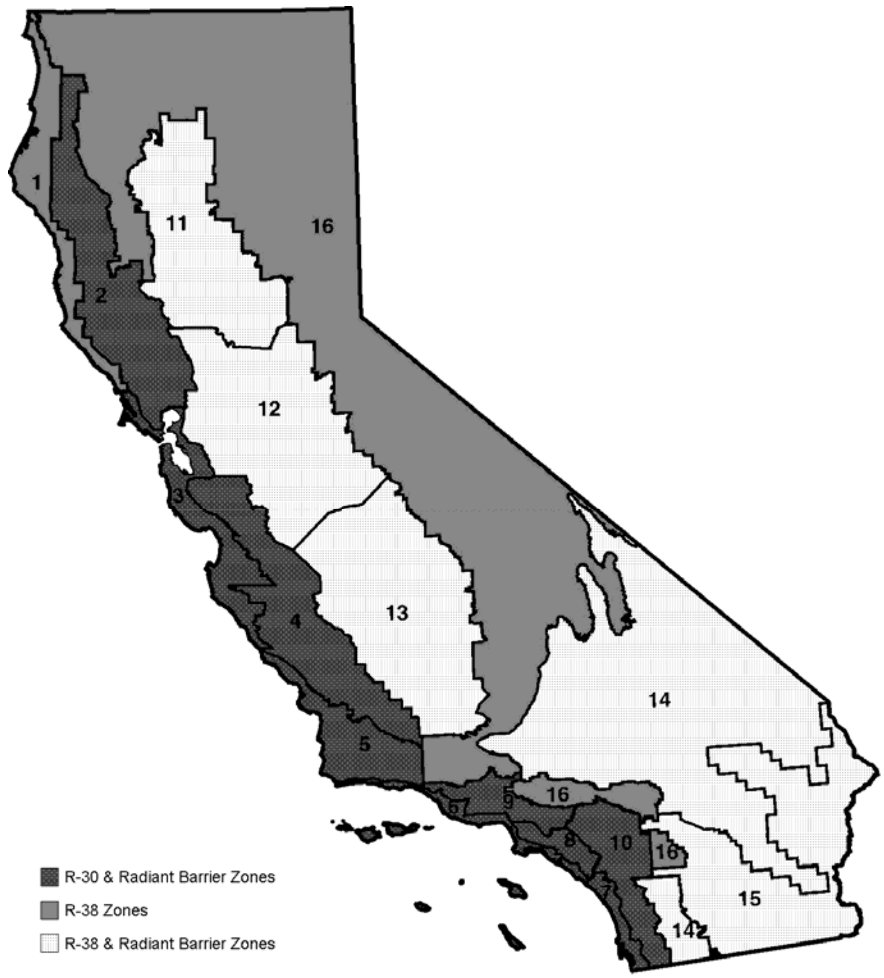
Compliance and Enforcement

The compliance and enforcement process should ensure that the ceiling/roof insulation R-value modeled on the CF-1R form is specified on the building plans and that the same value for the actual installed ceiling/roof insulation meets or exceeds the R-value on the CF-1R form. For more information on Compliance and Enforcement on Ceiling/roof, please see chapter 2 of this manual.

e Radiant Barrier Requirements

§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. 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.



Source: California Energy Commission

Figure 3-11 – Package A Prescriptive Ceiling/Roof Insulation Requirements

Compliance and Enforcement

The compliance and enforcement process should ensure that a certified radiant barrier material is properly installed when modeled on the CF-1R form, or when the Prescriptive Approach is used to demonstrate compliance in climate zones 2 through 15. For more information on Compliance and Enforcement on radiant barrier, please see chapter 2 of this manual.

f Roofing Products (Cool Roof)

§150.1(c)11
Prescriptive Standards Roofing Product

The prescriptive requirements call for a cool roof in both low-slope and steep-slope 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 new 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.

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*, please see chapter 2 of this manual.

c. Construction Practice

g *Insulation Coverage*

Ceiling insulation 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 if the flow of air is blocked, moisture may build up in the attic and water vapor may 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 Figure 3-12.

h *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-6R). 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.

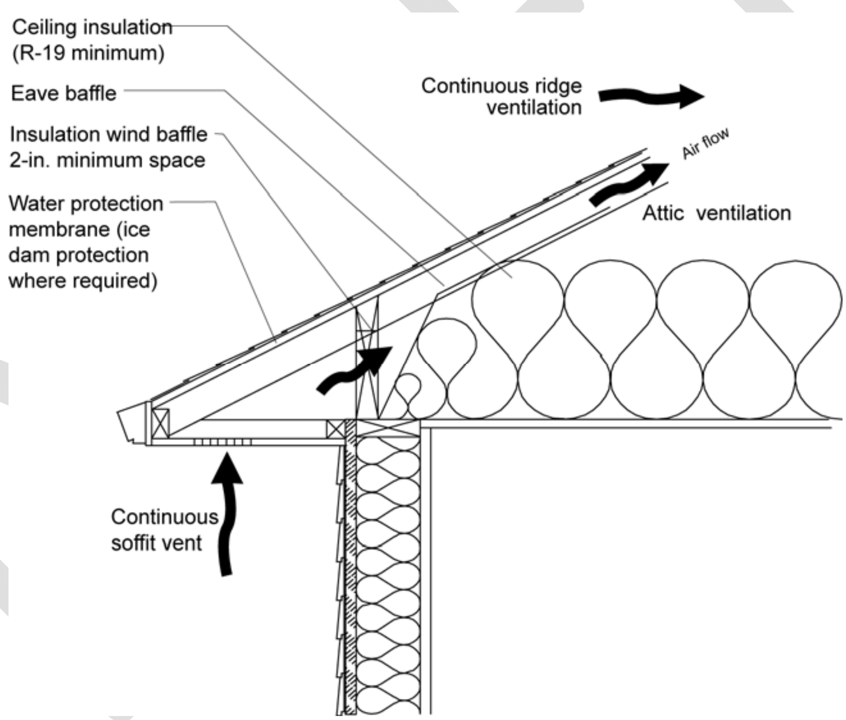
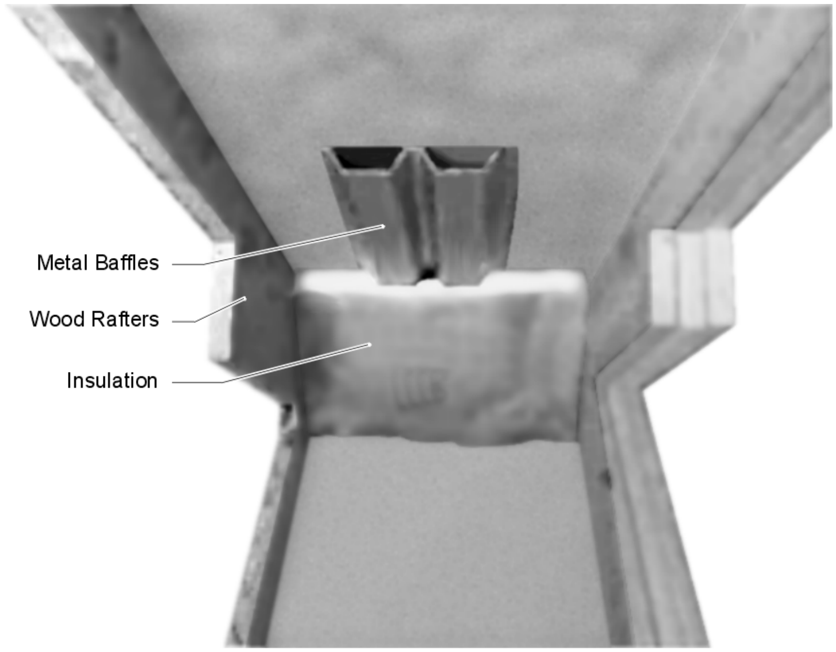


Figure 3-12 – Ceiling Insulation Construction Detail



Source: California Energy Commission

Figure 3-13 – Baffles at the Eave in Attics

i *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 3-13.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 CBC requires a minimum vent area of 1 ft² for each 150 ft² of attic floor area. This ratio may be reduced to 1 to 300 if a ceiling vapor retarder is present or if high (for example, ridge or gable vents) and low (soffit vents) attic ventilation is used.

When part of the vent area is blocked by meshes or louvers, the net free area of the vent must be considered when meeting ventilation requirements.

j *Wood Rafter Constructions*

Ventilating solid rafter spaces is more difficult than ventilating attics because each framing cavity requires its own vent openings. However, the requirement for ventilation is at the discretion of the local building official. It is common practice with cellulose insulation, for instance, to completely fill the cavity so that there is no ventilation at all. Also, if spray polyurethane foam is used, it is applied to the underside of the roof deck leaving no ventilation space. With batt insulation, it is possible to ventilate above the insulation using eave baffles, ridge vents, and careful installation.

k *Light Fixtures and Recessed Equipment*

§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 Figure 3-14).
- The luminaire must have a label certified as per §100.0(h)3 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. For more information see Section 6.10 of this manual.

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

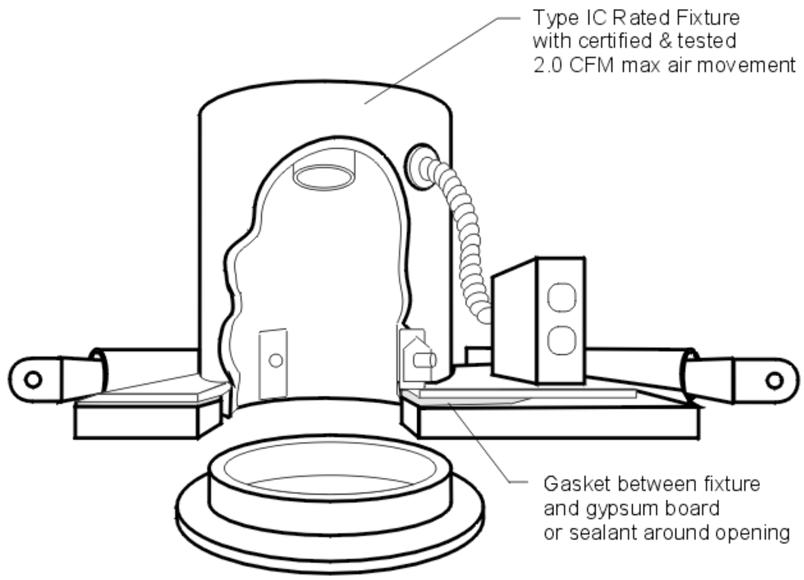


Figure 3-14 – IC-Rated Luminaire (Light Fixture)

3.1.19

a. **Advance Assembly Credit**

The Energy Commission encourages the use of energy saving techniques and designs for showing compliance with the Standards. When the performance compliance method is used, an energy credit can be taken for design strategies that reduce building energy load. Some strategies may require third-party verification by a HERS rater, others do not.

l Quality Insulation Installation (QII)

Reference Residential Appendix RA3.5

See Advance Assembly Credit Quality Insulation Installation (QII) in section 3.1.23 within this chapter.

m Roof Assembly

The construction techniques described below are advanced assembly systems that can be used in residential construction to exceed minimum prescriptive requirements. This section describes typical constructions for roof deck insulation and raised heel trusses (also called “energy trusses”).

n *Roof Deck Insulation*

An advanced assembly and alternative towards achieving 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 used to tradeoff with other prescriptive measures or used to help achieve Reach Code targets. This mitigates the heat transfer into the attic and reduces the air conditioning load. Below the roof deck, R-11 or R-13 batt insulation can be placed between the truss members and pinned in place. Another option that provides a higher R-value is to install closed-cell spray foam insulation between the truss members. In both cases, the attic is vented as required by code (through soffit and ridge vents or other acceptable means).

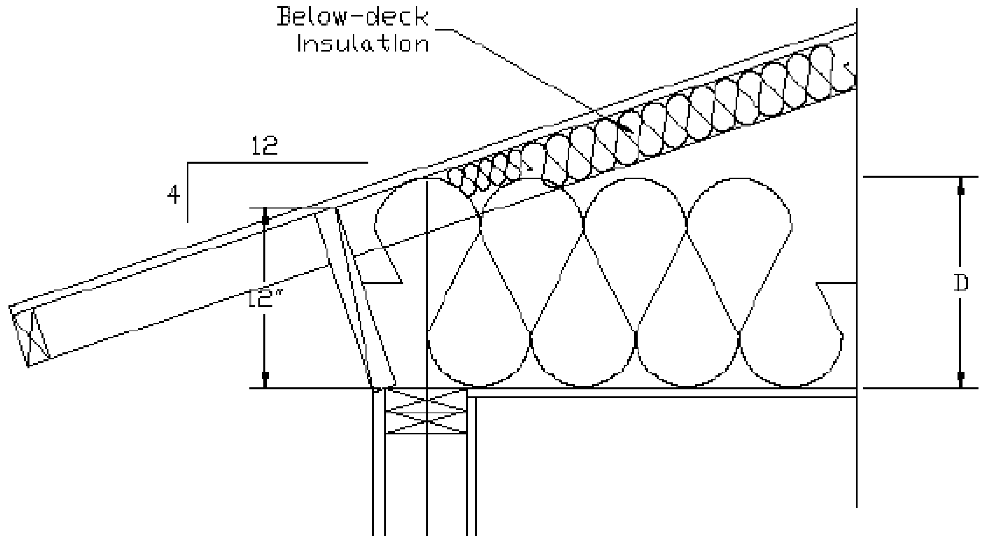


Figure 3-15 – Below Deck Insulation.

Insulation can't extend all the way to the eaves of a standard truss.

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

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 is recommended as an advanced assembly system. R-8 of continuous insulation above the roof deck is approximately thermally equivalent to R-13 batt insulation below the roof deck. The above deck insulation will require a nailable base such as oriented strand board (OSB), adding some cost. With above deck insulation, a radiant barrier is recommended to reduce radiant heat transfer to the attic.

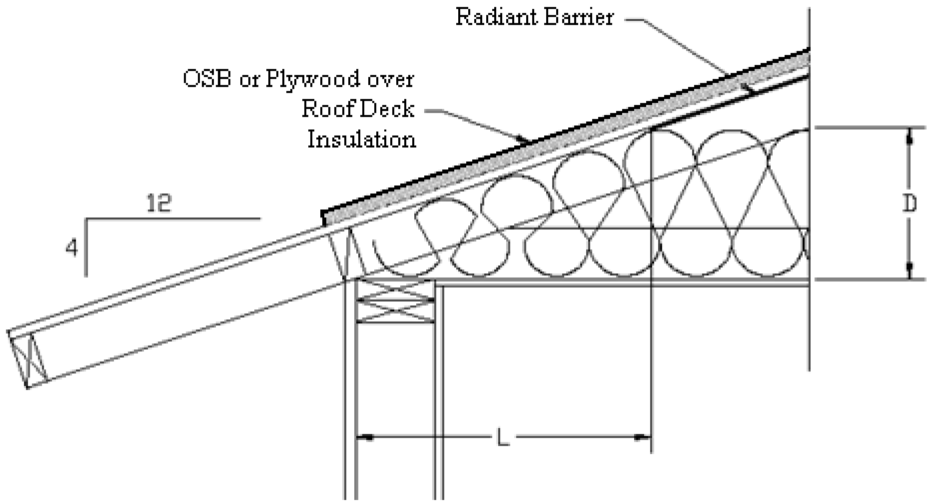
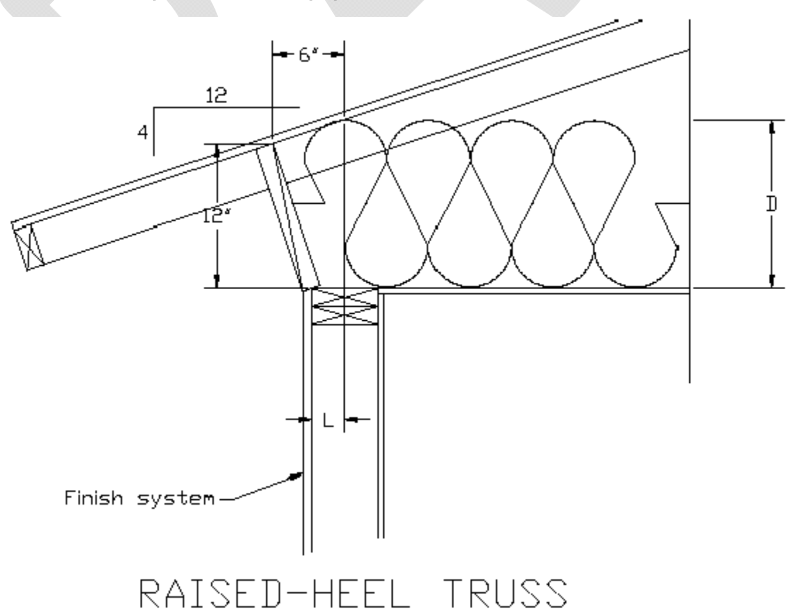


Figure 3-16 – Above Deck Insulation.

Compliance software can model the thermal effects and energy benefits of both above deck and below deck insulation.

- *Raised Heel Truss*

Another advanced assembly system 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.



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. The height of the raised heel is an important design consideration, and is typically 8 to 16 inches. (EnergyStar requires that raised heel trusses or similar framing techniques elevate the truss to allow insulation to be installed at the perimeter to be at least 75% of the insulation depth of the rest of the attic.) For raised heel trusses, structural blocking may be required to transfer loads to the shear wall[2], to prevent shear and rotation. Several methods of blocking are possible. One includes providing dimensional framing between truss members, while allowing for ventilation.

3.1.20 Wall Insulation

A. Mandatory Measures

§150.0(c)1 and 2

The mandatory measures have two requirements depending on frame size:

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.

The 2x6 inch or greater wood-framed walls above grade shall have at least R-19 insulation installed in the cavities between a 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:

a. 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.

b. Existing wood-framed walls of an addition that are already insulated with

[2] The 2012 International Residential Code requires structural blocking when the raised heel exceeds 15 ¼ inches in height.

R-11 insulation need not comply with the mandatory R-13 wall insulation. See the Exception §150.2(a)2B.

c. Rim joists between the stories 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 carefully fitted between the joists.

Figure 3-17 – Package A Prescriptive Wall Insulation Requirements

B. **Prescriptive Requirements**

d. 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.

e. Package A Mass Walls

§150.1(c)

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

The prescriptive requirements have separate criteria for mass wall interior and mass wall exterior 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.

p 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.

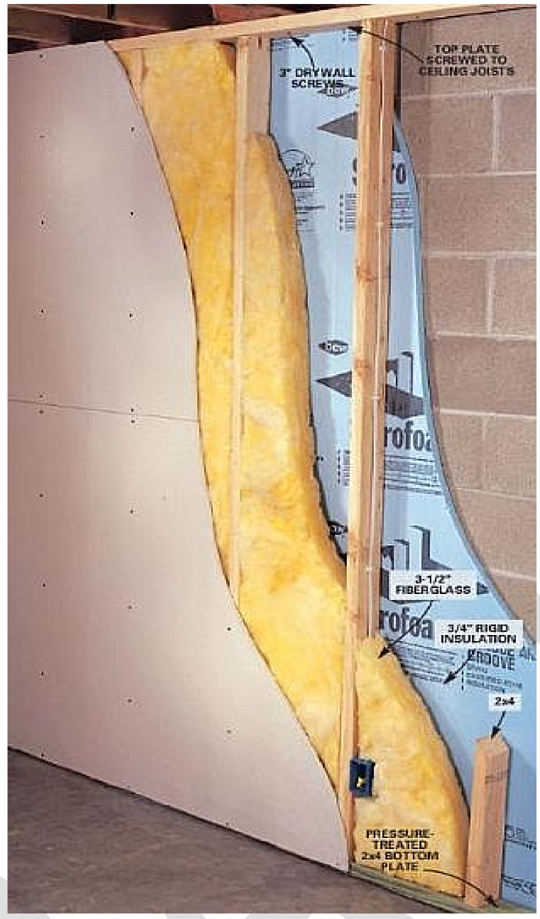


Figure 3-18 – Brick wall with furring details

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;

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

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

c. 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

d. 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.

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*, please see chapter 2 of this manual.

B. **Advance Assembly Credit**

The Energy Commission encourages the use of energy saving techniques and designs for showing compliance with the Standards. When the performance compliance method is used, an energy credit can be taken for design strategies that reduce building energy load. Some strategies may require third-party verification by a HERS rater, others do not.

a. Quality Insulation Installation (QII)

Reference Residential Appendix RA3.5

See Advance Assembly Credit Quality Insulation Installation (QII) in section 3.1.23 within this chapter.

C. **Construction Practice**

a. 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.

b. 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.

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

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

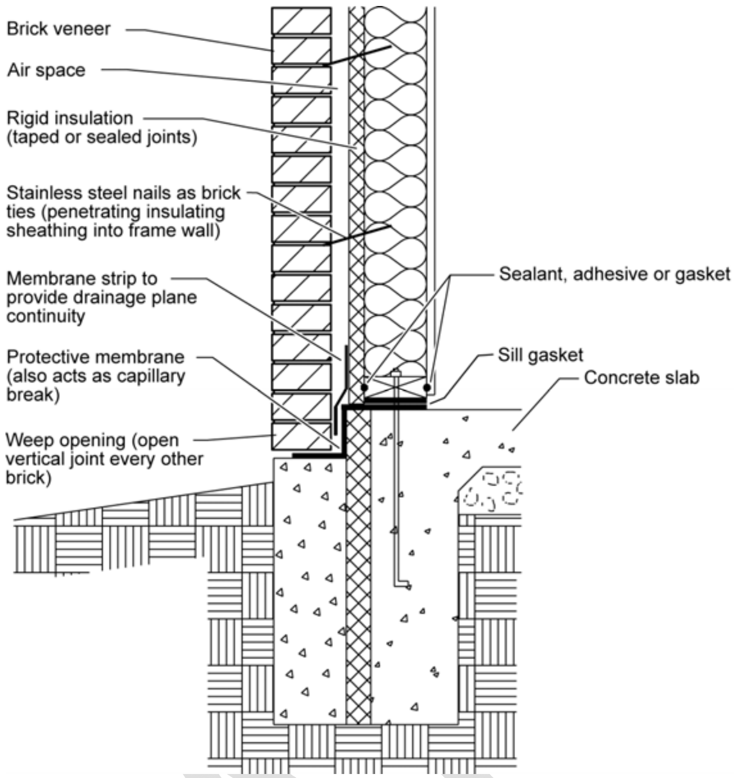


Figure 3-19 – Brick Wall Construction Details

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

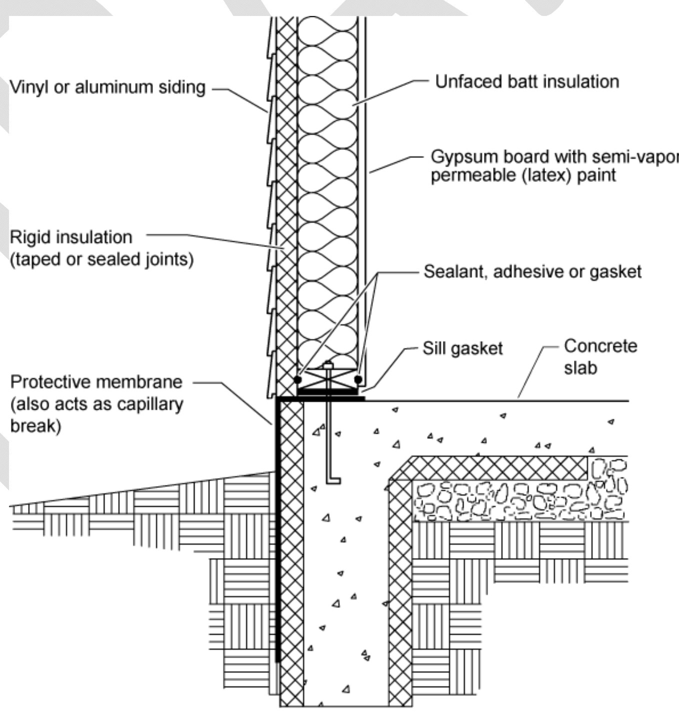


Figure 3-20 – Wall Construction Detail

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

Example 3-18

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 3-14

Question

If 2-inches of medium density foam are used in combination with R-11 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 Framing (AWF) techniques may be used to reduce the framing factor, or continuous insulation may be added.

3.1.21 Floor Insulation

A. Mandatory Measures

§150.0(d)

Raised floors must meet minimum insulation requirements (see Figure 3-21). 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 and no 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 these maximum U-factors. In all cases, some areas of the floor can have a U-factor that fails the requirements as long as other areas have a U-factor that exceeds the requirements and the area-weighted average U-factor is less than described above.

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

Table 4.4.1 from Reference Joint Appendix JA4 has U-factors for floors located over a crawlspace, and JA4 Table 4.4.2 has U-factors for floors located over ambient conditions. The difference is that R-6 insulation is added to approximate the buffering effect of the crawlspace. The additional R-6 is also included when modeling floors over crawlspaces with the performance method.

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.

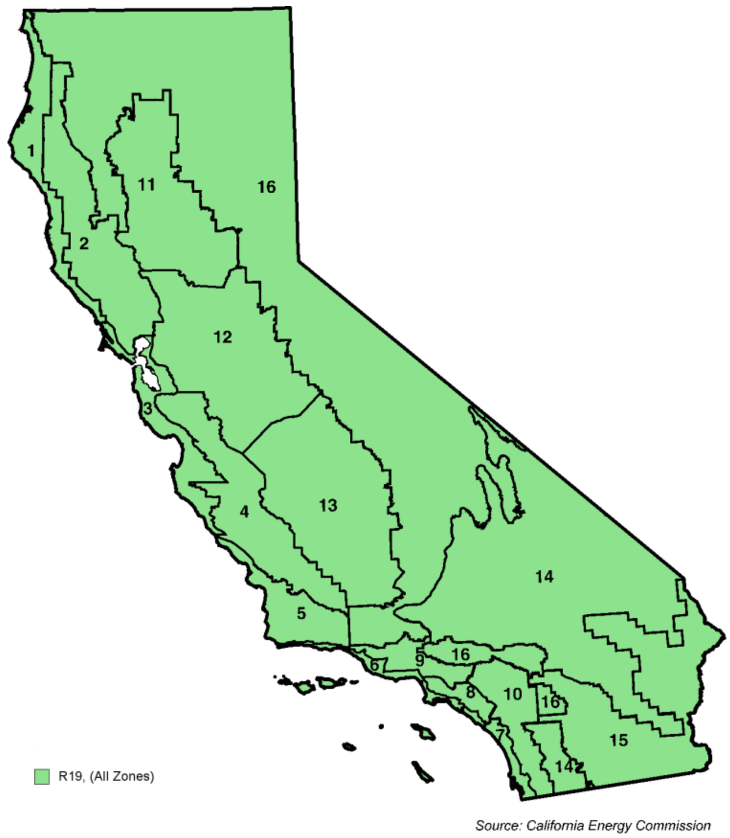


Figure 3-21 – Raised Floor Insulation Requirements by Climate Zone

B. Prescriptive Requirements

a. Insulation

§150.1(c)1C

Package AA prescriptive requirement 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 Table 3-4 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 3-4 – 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

C. Advanced Envelope Credit

The Energy Commission encourages the use of energy saving techniques and designs for showing compliance with the Standards. When the performance compliance method is used, an energy credit can be taken for design strategies that reduce energy building energy below levels assumed for the standard design building. Some strategies may require third-party verification by a HERS rater, others do not.

b. Controlled Ventilation Crawlspace (CVC)

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

Buildings having crawlspace foundations shall 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:

1. Reducing heat transfer into the unconditioned crawlspace,
2. Reducing moisture buildup in the crawlspace, and
3. 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 moisture control on the ground soil surface of the crawlspace floor. See .

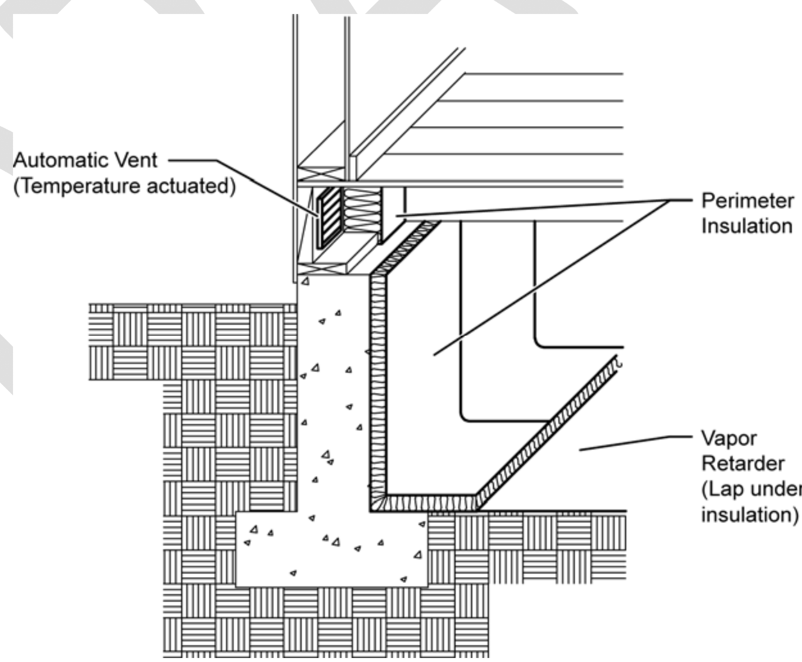


Figure 3-22 – *Controlled Ventilation Crawl Space*

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: Crawlspace 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).

   c. **Vapor Retarder (Ground Cover):** A polyethylene ground cover having a minimum 6 mil thickness (0.006 inch) or approved equal shall be laid entirely over the ground soil area within the crawlspace (Note: foundation stem wall insulation shall be laid above/on top of the ground cover).

      q The vapor retarder shall 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.

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

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

      t 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.

- u 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.
- v The vapor retarder shall be shown on the plans.

D. Construction Practice

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.

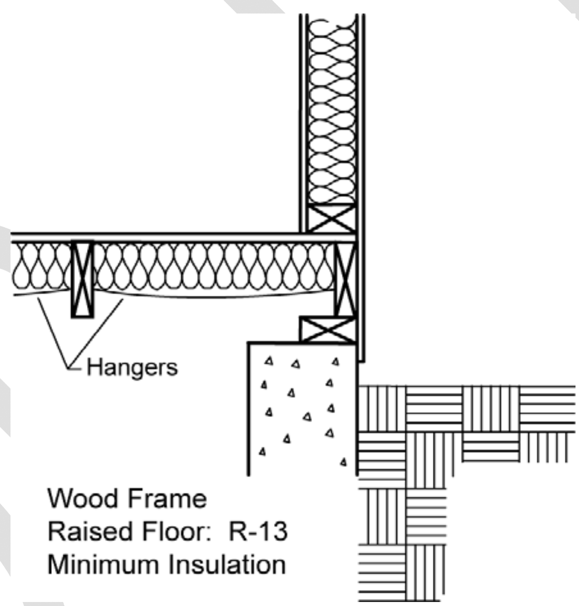


Figure 3-23 – Raised Floor Insulation

3.1.22 Slab Insulation

A. Mandatory Measures

§150.0(l)
§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.

B. Prescriptive Requirements

§150.1(c)1D

Prescriptive Table 150.1-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 Figure 3-24).

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.

Example 3-19

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)

C. Construction Practice

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.

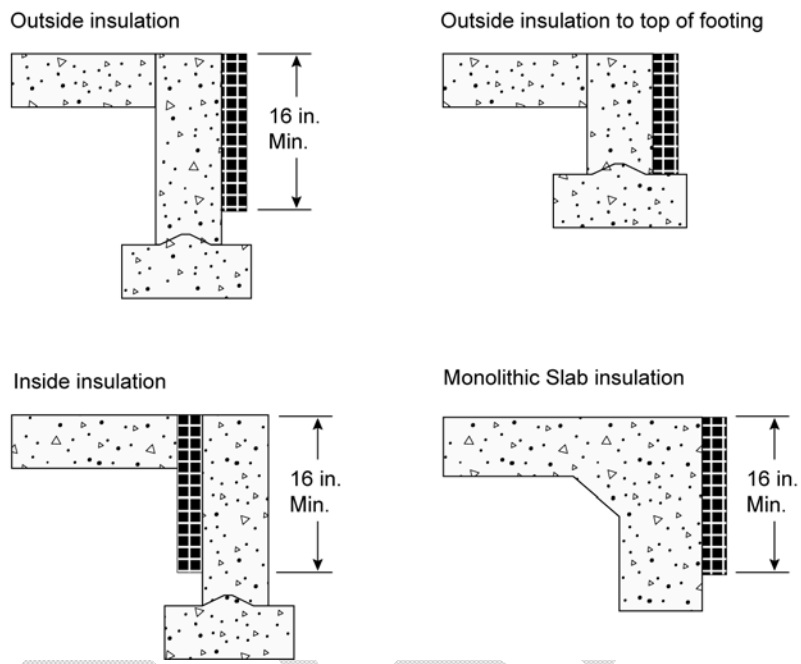


Figure 3-24 – Allowed Slab Edge Insulation Placement

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.

3.1.23 Advance Assembly Systems

The Energy Commission encourages the use of energy saving techniques and designs for showing compliance with the Standards. When the performance compliance method is used, an energy credit can be taken for design strategies that reduce building air leakage below levels assumed for the standard design building. 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:

a. There is an inadequate air barrier in the building envelope, or holes and gaps within the air barrier system inhibits its ability to limit air leakage.

b. 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.

c. 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.

d. The insulation is compressed, creating a gap near the air barrier and/or reducing the thickness of the insulation.

An energy credit for correctly installing an air barrier and insulation to eliminate or reduce the problems described above are provided in the Reference Appendices, Residential Appendix RA3.5. This compliance credit applies to framed non-framed 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. Non-framed 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 explanations are described below:

1. Compliance credit is not allowed for walls alone; or for roofs/ceilings but not walls also.
2. 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.

3. Combinations of insulation types (hybrid systems) are allowed.
4. An air barrier shall be installed for the entire envelope.
5. Compliance credit is allowed for additions to existing buildings where energy compliance has been demonstrated for the “addition alone” (§150.2(a)2A).
6. 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.

B. **Air Barrier**

This energy compliance credit requires that an air barrier is installed for 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 XXX 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 XXX: Continuous Air Barrier

Continuous Air Barrier	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: 1. Using individual materials that have an air permeance not exceeding 0.004cfm/ft^2 under a pressure differential of 0.3in. w.g. (1.57psf) (0.02 L/s.m^2 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.m^2 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 leaka the building envelope does not exceed 0.40 cfm/ft^2 at a pressure differ in w.g. (1.57 psf) (2.0 L/s.m^2 at 75 pa) in accordance with ASTM E779 equivalent approved method.

Individual materials and assemblies of materials that can demonstrate with the air barrier testing requirements must be installed according to manufacturer's instructions and a HERS rater shall verify the integrity o installation. Below are example materials meeting the air permeance t performance levels of 1 above. Manufacturers of these and other prod must provide a specification or product data sheet showing compliance ASTM testing requirements to be considered as an air barrier.

-- 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 thickness of 2.0 inches

-- Open cell spray polyurethane foam with a minimum density of 0.4 to1.5 pcf minimum thickness of 5½ inches

-- 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

C. **Insulation Installation**

This energy compliance credit requires that all insulation is installed properly for 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 XXX 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, Section XXX. 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 XXX: Insulation Types

Insulation Types--framed assemblies	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: 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: a. *Low Density Open-Cell SPF (ocSPF) Insulation*: A spray applied polyurethane foam insulation having an open cellular structure resulting in an installed nominal density of 0.4 to 1.5 pounds per cubic foot (pcf). b. *Medium Density Closed-Cell SPF (ccSPF) Insulation*: 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).
Insulation Types--non-framed	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:

assemblies	1. **Structural Insulated Panel (SIP):** A composite building material cons of an insulating layer of rigid polymer foam sandwiched between two laye structural board. The board can be sheet metal, plywood, cement or orie strand board (OSB) and the foam is either expanded polystyrene foam (E extruded polystyrene foam (XPS) or polyurethane foam. SIPs combine s components of conventional building, such as studs and joists, insulation barrier and air barrier. They can be used for many different applications, exterior walls, roofs, floors, and foundation systems. 2. **Insulated Concrete Form (ICF):** A system of formwork for concrete t stays in place as permanent building insulation and is used for cast-in-pla reinforced above and below-grade concrete walls, floors, and roofs. ICFs interlocking modular units that can be dry-stacked (without mortar) and fil concrete as a single concrete masonry unit (CMU). ICFs lock together ex and have internal metal or plastic ties to hold the outer layer(s) of insulatio create a concrete form for the structural walls, roof/ceilings, or floors of a building. ICFs are manufactured from several materials including: expan and extruded polystyrene foam, polyurethane foam, cement-bonded woo and cement-bonded polystyrene beads. 3. **Mass Walls**: a. Masonry types include clay and concrete units, which may be solid or and glazed or unglazed. Other masonry unit types include cast stone a calcium silicate units. Concrete masonry units (CMU) are made from a mixture of portland cement and aggregates under controlled condition Concrete masonry units can be manufactured in different sizes and wi variety of face textures. b. Concrete and concrete sandwich panels typically use a pre-cast form casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted i place. Precast stone is distinguished from precast concrete by using a aggregate in the mixture giving the appearance of naturally occurring r stone. 4. **Log Walls**: Log walls are typically made from trees that have been cut into lo have not been milled into conventional lumber. Logs used for walls, roofs an floor systems may be milled and or laminated by the manufacturer or supplie meet specific dimensions and fitting and finishing conditions. 5. **Straw Bale**: Straw bale construction is a building method that uses bales of (commonly wheat, rice, rye and oat straw) as structural and insulating elemen the building.

D. ***Field Verification and Diagnostic Testing of*** **Building Air Leakage**

Reference Appendices, Residential Appendix RA3.8

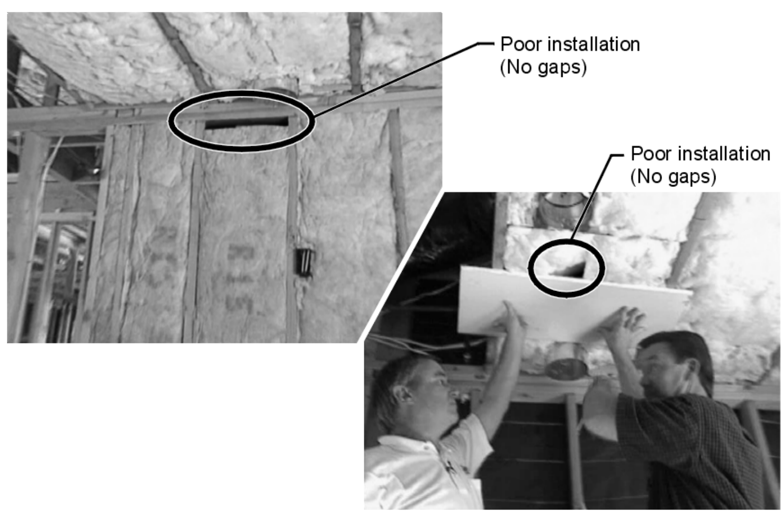
An energy credit is allowed through the performance approach when the building’s rate of envelope air leakage is less than the air leakage rate assumed for the standard design building. A third-party HERS rater shall verify the air leakage rate shown on compliance documentation through diagnostic testing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

1. 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.
2. 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.
3. 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 XXX above.

Source: California Energy Commission

Figure 3-25 – Blower Door Testing



Source: California Energy Commission

Figure 3-26 – Examples of Poor Quality Insulation Installation

B. Sprayed Wall Insulation

See Energy Commission videos.

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 types of sprayed insulation, including cellulose (see Figure 3-27), fiberglass and spray polyurethane foam (SPF). 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 insulation retrofits, but for walls it is mixed with a water- and starch-based binder. The binder causes the insulation to 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 hopper with the fresh insulation.

a. 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 water based adhesive. The adhesive causes the insulation to adhere to surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off and recycled. Loose fill fiberglass insulation shall use batt insulation assembly U–factors listed in Reference Joint Appendix JA4. See Reference Residential Appendix RA3.5.5.2 for more Quality Insulation Installation (QII) requirements.

b. 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.

There are two types of SPF insulation; medium density, or closed cell, and low density, or open cell insulation. They have different insulating properties, and compliance requirements as described below.

Medium density, closed cell SPF has been assigned an R-value of 5.8 per inch for compliance purposes and a nominal density of 2.0 ±0.5 pounds per cubic foot.

Medium density is not required to fill the cavity. The insulation thickness shall be verified by using probes capable of penetrating the full thickness of the insulation with measurements marked by eighth inch increments Measurements shall be accurate to within ±1/8 inch. The probes shall be used by HERS Raters to verify proper thickness of insulation has been applied.

Low density SPF open cell insulation has an R-value of 3.6 per inch and a density of 0.5 lbs/ft2. Low density, open cell SPF insulation is sprayed into the cavity then expands to fill the cavity. Excess insulation is removed with a special tool. Low density SPF insulation shall use spray insulation assembly U-factors listed in Reference Joint Appendix

JA4. No quality insulation installation compliance credit is allowed for low density SPF insulation.

U-factors for sprayed insulation are provided in *Reference Joint Appendix JA4* (Tables 4.2.2, 4.2.5, 4.3.1, 4.3.3, and 4.3.4) for both framed walls (wood or metal) as well as for rafter roofs (wood or metal).

Source: California Energy Commission

Figure 3-27 – Cellulose Insulated Wall

C. Metal Framing

A change from wood framing to metal framing can significantly affect compliance. Metal and wood framing are not interchangeable.

a. 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.

b. To comply prescriptively, a non-wood framed assembly, including 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 path for metal framed assemblies that exceed the prescriptive requirements of the equivalent wood framed assemblies.

D. Log Homes Compliance Option

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-ft^2 is equivalent to a heavy mass wall (40 lb/ft^3). 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 Construction

In 1995, the California Legislature passed AB1314, a bill that authorizes all California jurisdictions to adopt building codes for houses with walls constructed of straw bales. The bill provided guidelines for moisture content, bale density, seismic bracing, weather protection, and other structural requirements.

Several years ago, the Energy Commission, in conjunction with research and testing facilities, determined the thermal properties needed for straw bale walls to comply with the Standards. The thermal mass benefit of straw bale construction can be credited only through the use of the computer performance compliance approach by modeling straw bale construction using the heat capacity characteristics of the straw bales given below.

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. Performance data on other sizes of bales is not available. The minimum density of load bearing walls is 7.0 lb/ft^3, 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/ft^3, for example, the volumetric heat capacity is 2.24 Btu/ft^3-°F.

The minimum dimension of the straw bales when placed in the walls must be 22 inch by 16 inch 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.

For performance compliance, consult the compliance program's documentation for any unique modeling requirements for mass walls using values from Reference Appendices RA5.

F. Structural Insulated Panels (SIPS)

Structural Insulated Panels (SIPS) are an 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: Single or double 2x splines, I-joists, or 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. Of the three spline types, 2x splines, similar to studs in a framed wall, allow for the most thermal bridging. The web of an i-joist is thinner and less thermally conductive than a full thickness 2x, so has less thermal bridging. With an OSB spline, the insulation is notched or routed just in back of the OSB panels on each side. An OSB strip is then inserted into the pocket on each side of the panel and the assembly is fastened together with wood screws. This method, which only applies to wall and roof/ceilings, avoids thermal bridging entirely, but for structural reason is not always suitable on roof SIPS panels with thicknesses greater than 10". Floor systems typically require an additional 7/16" OSB layer on top of the SIP OSB layer. Reference Joint Appendix JA4, Table 4.2.3 has 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. If manufacturers develop SIPS assemblies that are not adequately represented by choices in these tables, they may obtain approval of these assemblies through the Energy Commission's exceptional methods process.

The credits for Quality Insulation Installation do not apply for SIPS construction.


Source: California Energy Commission

Figure 3-28 – 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: continuous rigid insulation on both sides of a high-mass core, elimination of thermal bridging from wood framing components, and high degree of air-tightness inherent to the method of construction.

Climate zones with large daily temperature fluctuations have the greatest potential to benefit from the time lag and temperature damping 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 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”.

If manufacturers develop ICFs that are not adequately represented by the choices found in Reference Joint Appendix JA4, Table 4.3.13, they may obtain approval of those assemblies through the Energy Commission’s exceptional methods process.

E. Advanced Wall Framing (AWF)

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

Reducing the amount of wood in wood-framed exterior walls improves energy efficiency, when the insulation is installed correctly. Having fewer wood studs reduces the effects of “thermal bridging” and increases the amount of insulation in the wall, resulting in a more energy efficient building envelope. However, despite the rising cost of lumber, in California the trend is toward an increasingly high percentage of wood in wood-framed walls. In recognition of this fact, the framing factor used in calculating the energy performance of wood-framed walls in the Residential ACM was increased from 15% to 25% for the 2005 Standards. When AWF is chosen as a compliance option in the Standards, the framing factor is reduced to 17%, reflecting the improved energy performance of the wall.

While AWF represents a range of practices, to qualify for the AWF compliance credit in Title 24, verification of Quality Insulation Installation (QII) by a HERS rater is required, based on insulation type, and all of the following practices must be followed:

a. Use 2 x 6 at 24” on-center wall framing; and

b. Use Precise engineering of headers on load-bearing walls; and

c. Install 2 x 4 headers on non-load-bearing walls; and

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

e. Align window/door openings with standard stud spacing. The king stud, on at least one side of the window/door opening, must take the place of an on-layout AWF stud; and

f. Use two-stud corners instead of 3-stud corners. 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; and

g. Ladder block where interior partitions intersect exterior walls, instead of 3-stud channels; and

h. Eliminate unnecessary double floor joists underneath non-bearing walls; and

i. Use metal let-in T-bracing on non-shear walls; and

j. Include detailed framing plans and elevations on permit set

Additional AWF “best practices” are encouraged (but have no impact on compliance credit):

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)

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 2 x 3 interior non-load-bearing walls

p. Integrate framing design with HVAC system

q. Use “inset” shear wall panels

4. 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 acts for temperature much like a flywheel – it tends to keep things warmer when it is cold outside and keep things cooler when it is hot outside. 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 Figure 3-29.

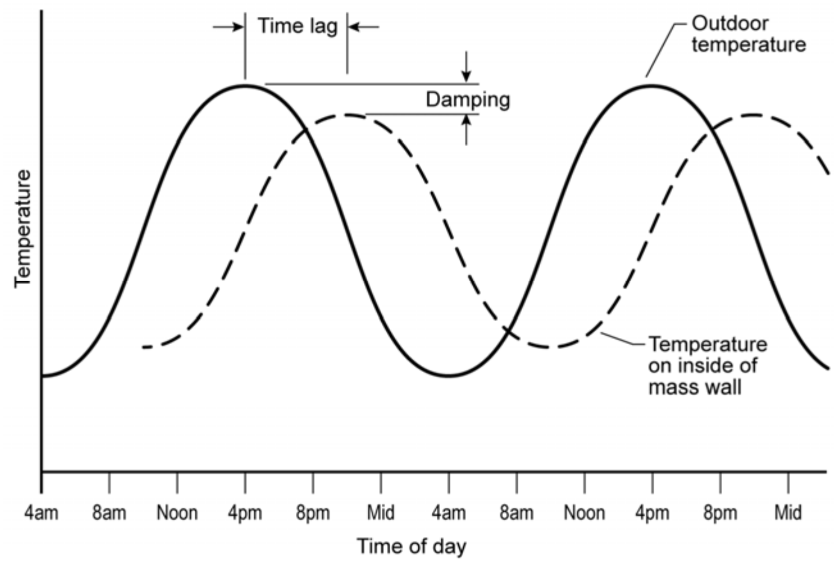


Figure 3-29 – Thermal Mass Performance

3.1.24 Mandatory Measures

There are no mandatory measures for thermal mass.

3.1.25 Advanced Assembly Systems

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 2 inch-(50 mm) thick concrete. This procedure is automated in Energy Commission approved computer programs so there is no need to perform the calculations by hand.

Example 3-20 – 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 openable area of the window, not the window unit, be 4% of the floor area, or 14ft x 12ft x 0.04 = 6.7 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 openable 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 3-21 – Ventilation Opening Louvers

Question

There are fixed wooden louvers over a window in a bedroom. The louvers have slats that are 1/8 in thick, and they are spaced 1 inch apart. What is the reduction in openable 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 x (1inch – 1/8 inch)/1inch = 7/8 inch of the original opening area.

Example 3-22

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 3-20

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 3-23

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 3-24

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 3-25

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.

A. Reduced Duct Leakage

If compliance credit is not taken for reduced building envelope air leakage through diagnostic testing (as described in detail below), a special "default" compliance credit can be taken for building envelope leakage reduction. To qualify for this credit all requirements for reduced duct leakage (see Section 4.4.3 of this manual), including diagnostic testing, must be met. A "default" reduction in SLA of 0.50 is allowed for this credit. This adjustment reduces the standard SLA from 4.3 to 3.8.

5. Vapor Barriers and Moisture Protection

A vapor barrier or retarder is a special covering over framing and insulation that protects the wall 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.

3.1.26 Mandatory Measures

§150(g)

Reference Residential Appendix RA4.5.2

In climate zones 14 and 16, a continuous vapor barrier, lapped or joint sealed, must be installed on the conditioned space side of all insulation in all exterior walls, on the floors of unvented attics, and on floors over unvented crawl spaces to protect against moisture condensation.

If a building has a controlled ventilation crawl space (see Section 3.1.23), a vapor barrier 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.

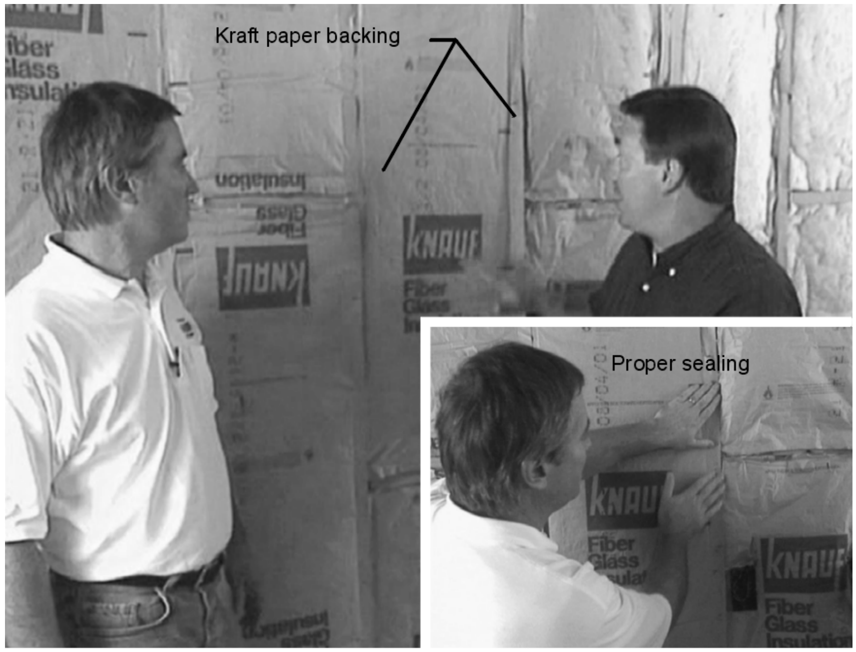
The Standards define a vapor barrier as material with a permeance of one perm or less. A perm is a measure of resistance to the transmission of water vapors and is equal to one grain of water vapor transmitted per ft^2 per hour per inch of mercury pressure difference. The Energy Commission has determined that interior painted surfaces may qualify for meeting the vapor barrier requirement if the paint product is tested to have a rating of one perm or less. For all types of vapor barriers, care should be taken to seal penetrations such as electric outlets on exterior walls.

Products such as a continuous polyethylene sheet or wall board with foil backing qualify as vapor barriers, if according to the appropriate testing procedure, they meet the vapor barrier permeance rating of one perm or less. Kraft paper backing on batt insulation, under certain circumstances, may be used to meet the continuous vapor barrier requirement. Specifically, the paper backing must meet the vapor barrier permeance rating, and the product must be installed properly.

For proper installation of batt insulation with Kraft paper backing (see Figure 3-30):

a. The Kraft paper should *not* be stapled to the sides of framing members; instead, the Kraft paper tabs on each side of the insulation batt must be fastened to the face of the conditioned side of the framing member, and

b. At the ends of the insulated cavity, the Kraft paper must overlap the framing members to create a continuous barrier at the wall cavity. Also see Wall Insulation in Reference Residential Appendix RA3.5 and RA3.5.4 for further insulation procedures.



Source: California Energy Commission

Figure 3-30 – Vapor Barriers with Kraft Paper

6. Compliance and Enforcement

Chapter 2 addresses general compliance and enforcement issues, the roles and responsibilities of each of the major parties, the compliance forms, and the process for field verification and/or diagnostic testing. This section highlights some of the compliance and enforcement issues specifically for the building envelope.

3.1.27 Design

A. 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-6R 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:

a. Inter-zone ventilation
b. Radiant barriers
c. Multiple Orientation
d. Controlled ventilation crawlspace
e. Non-standard ventilation height differences
f. Standard free ventilation area greater than 10 percent of the window area
g. Metal-framed walls
h. Sunspace with interzone surfaces
i. Roofing products (Cool roof)
j. 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.

3.1.28 Construction

During the construction process, the contractor and/or the sub-contractors complete the necessary sections of the Certificate of Installation (CF-6R):

a. 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.
b. Building Envelope Leakage Diagnostics. This is applicable only if the builder/contractor does blower door testing to reduce building envelope leakage.
c. Insulation Installation Quality Certificate. The insulation contractor documents the insulation installation quality features that have been followed as shown on the CF-6R checklist.
d. 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-6R is required, the licensed person responsible for the installation must submit the portion of the CF-6R information that applies to the installation to a HERS provider data registry using procedures described in Chapter 2 and in Reference Residential Appendix RA2.

3.1.29 Field Verification and/or Diagnostic Testing

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-4R).

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:

a. Building Envelope Sealing

b. 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-4R is required. The HERS rater must submit the CF-4R 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.

7. Glossary/Reference

The Reference Joint Appendices JA1 contains a glossary of terms. For definitions of terms used in this manual refer to that section of the Reference Joint Appendices. The following terms either expand on those definitions or are not listed there.

A. Fenestration Terminology

The following terms are used in describing fenestration products.

c. **Center of Glass U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT).** The U-factor, SHGC and VT are measured only through glass at least 2.5 inches from the edge of the glass or dividers.

d. **Clear.** Little if any observable tint. An IG unit with an SHGC of 0.5 or greater.

e. **Divider (Muntin).** An element that actually or visually divides different lites of glass. It may be a true divided lite, between the panes, and/or applied to the exterior or interior of the glazing.

f. **Dynamic Glazing** are glazing systems that have the ability to reversibly change their performance properties, including U-factor, Solar Heat Gain Coefficient (SHGC), and/or Visible Transmittance (VT) between well-defined end points.

g. **Chromogenic** is a class of switchable glazing which includes active materials (e.g. electrochromic) and passive materials (e.g. photochromic and thermochromic) permanently integrated into the glazing assembly.

h. **Integrated shading systems** is a class of fenestration products including an active layer: e.g. shades, louvers, blinds or other materials permanently integrated between two or more glazing layers.

i. **Fixed.** The fenestration product cannot be opened.

j. **Gap Width.** The distance between glazings in multi-glazed systems (e.g., double-or triple-glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit thickness which is measured from outside surface to outside surface.

k. **Grille.** See Divider.

l. **IG Unit**. Insulating glass unit. An IG unit includes the glazings, spacer(s), films
(if any), gas infills, and edge caulking.

m. **Hard Coat.** A pyrolytic low-e coating that is generally more durable but less effective than a soft coat. See separate glossary term for low-e coating.

n. **Light or Lite.** A layer of glazing material, especially in a multi-layered IG unit. Referred to as panes in §116 when the lites are separated by a spacer from inside to outside of the fenestration.

o. **Low-e Coating.** A transparent or semitransparent metallic coating applied to glazing that reduces the emittance of the surface and that usually affects the solar heat gain of the glass. Low-e stands for low-emissivity. The coating (or film) is generally between glazings in double-pane or triple-pane fenestration products.

p. **Mullion.** A frame member that is used to join two individual windows into one fenestration unit.

q. **Muntin.** See Dividers.

r. **Nonmetal Frame.** Includes vinyl, wood, or fiberglass. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics. Non-metal frames may have metal strengthening bars entirely inside the frame extrusions or metal-cladding only on the surface.

s. **Operable.** The fenestration product can be opened for ventilation.

t. **Soft Coat.** A low-e coating applied through a sputter process. See separate glossary term for low-e coating.

u. **Spacer or Gap Space.** A material that separates multiple panes of glass in an insulating glass unit.

v. **Thermal Break Frame.** Includes metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl or urethane, with a significantly lower conductivity.

w. **Tinted.** Darker gray, brown or green visible tint. Also, low-e or IG unit with an SHGC less than 0.5.

x. Visible Transmittance(VT). The ratio of visible light transmitted through the fenestration. The higher the VT rating, the more light is allowed through a window.

y. Window Film are composed of a polyester substrate to which a special scratch resistant coating is applied on one side, with a mounting adhesive layer and protective release liner applied to the other side.

B. Low-e Coatings

Low-emissivity coatings are special coatings applied to the second or third surfaces in double-glazed windows or skylights. As the name implies the surface has a low emittance. This means that radiation from that surface to the surface it “looks at” is reduced. Since radiation transfer from the hot side of the window to the cool side of the window is a major component of heat transfer in glazing, low-e coatings are very effective in reducing the U-factor. They do nothing, however, to reduce losses through the frame.

In the residential market, there are two kinds of low-e coatings: low solar gain and high solar gain. Low-solar gain low-e coatings are formulated to reduce air conditioning loads. Fenestration products with low solar gain low-e coatings typically have an SHGC of 0.40 or less. Low-solar gain low-e coatings are sometimes called spectrally selective coatings because they filter much of the infrared and ultra-violet portions of the sun’s radiation while allowing visible light to pass through. High solar gain low-e coatings, by contrast, are formulated to maximize solar gains. Such coatings would be preferable in passive solar applications or there is little air conditioning.

Another advantage of low-e coatings, especially low solar gain low-e coatings, is that when they filter the sun’s energy, they generally remove between 80 percent and 85 percent of the ultraviolet light that would otherwise pass through the window and damage fabrics and other interior furnishings. This is a major advantage for homeowners and can be a selling point for builders.

C. National Fenestration Rating Council

The National Fenestration Rating Council (NFRC) is the entity recognized by the Energy Commission to supervise the rating and labeling of fenestration products. NFRC list the Certified Product Directory, containing NFRC certified U-factors and SHGC values for thousands of residential fenestration products see http://www.nfrc.org

Fenestration product performance data used in compliance calculations must be provided through the NFRC rating program and must be labeled by the manufacturer with the rated U-factor and SHGC in accordance with

§10-111 procedures.

D. R-value

R-value is a measure of a material's thermal resistance, expressed in $ft^2(hr)°F/Btu$. R-value is the inverse of U-factor. A higher R-value and lower U-factor indicate higher energy efficiency.

The rated R-value of fiberglass (batt) insulation is based upon its fully expanded thickness and may be obtained from the Reference Joint Appendices JA4, Table 4.6.2 or from the manufacturer's literature. When the insulation is compressed, the R-value is reduced. The most common insulation compression occurs with R-19 and R-22 insulation batts installed in locations with a nominal 6-inch framing that is actually only 5.5 in. thick. To achieve its rated insulation value, an R-19 batt of insulation expands to a thickness of six and one quarter inches. If it is compressed into 2x6 framing with an actual depth of 5.5 inches, the insulation R-Value is lowered to 17.8.

E. Solar Heat Gain Coefficient

Solar heat gain coefficient (SHGC) is a measure of the relative amount of heat gain from sunlight that passes through a fenestration product. SHGC is a number between zero and one that represents the ratio of solar heat that passes through the fenestration product to the total solar heat that is incident on the outside of the window. A low SHGC number (closer to 0) means that the fenestration product keeps out most solar heat. A higher SHGC number (closer to 1) means that the fenestration product lets in most of the solar heat.

$SHGC_c$ is the SHGC for the center of glazing area; SHGC or $SHGC_t$ is the SHGC for the total fenestration product and is the value used for compliance with the Standards.

F. U-factor of Fenestration Products

U-factor is a measure of how much heat passes through a construction assembly or a fenestration product. The lower the U-factor, the more energy efficient the product is. The units for U-factor are Btu of heat loss each hour per ft^2 of window area per degree °F of temperature difference ($Btu/hr\text{-}ft^2\text{-}°F$). U-factor is the inverse of R-value.

The U-factor considers the entire product, including losses through the center of glass, at the edge of glass where a metal spacer typically separates the double-glazing panes, losses through the frame, and through the mullions. For metal-framed windows, the frame losses can be significant.

$U\text{-}factor_c$ is the U-factor for the center of glazing area; $U\text{-}factor_t$ is the U-factor for the total fenestration product and is the value used for compliance with the Building Energy Efficiency Standards.

Estimating the rate of heat transfer through a fenestration product is complicated by the variety of frame configurations for operable windows, the different combinations of materials used for sashes and frames, and the difference in sizes available in various applications. The NFRC rating system makes the differences uniform, so that an entire fenestration product line is assumed to have only one typical size. The NFRC rated U-factor may be obtained from a directory of certified fenestration products, directly from a manufacturer's listing in product literature, or from the product label.