

## Table of Contents

3.1	Organization.....	1
3.2	What's New for 2016.....	2
3.3	Compliance Options.....	2
3.3.1	Mandatory Features and Devices.....	2
3.3.2	Prescriptive Compliance Approach.....	3
3.3.3	Performance Compliance Approach.....	3
3.4	Key Envelope Compliance Terms.....	3
3.5	Fenestration.....	8
3.5.1	Fenestration Types.....	8
3.5.2	Relevant Sections in the Energy Standards for Fenestration.....	10
3.5.3	Mandatory Measures, Features and Devices.....	11
3.5.3.1	Air Leakage.....	11
3.5.3.2	U-Factor and SHGC Rating Mandatory Requirements.....	12
3.5.3.3	Labeling Mandatory Requirements.....	14
3.5.3.4	Fenestration U-Factor.....	19
3.5.4	Prescriptive Requirements.....	20
3.5.5	Fenestration Prescriptive Exceptions.....	21
3.5.6	Fenestration Shading Types.....	22
3.5.7	Dynamic Glazing Device.....	24
3.5.8	Compliance Alternatives.....	26
3.5.8.1	Fenestration Area.....	26
3.5.8.2	Orientation.....	26
3.5.8.3	Improved Fenestration Performance.....	27
3.5.8.4	Fixed Permanent Shading Devices.....	27
3.5.8.5	Reserved.....	28
3.5.8.6	Exterior Shading Devices.....	28
3.5.8.7	Interior Shading.....	29
3.5.8.8	Bay Windows.....	29
3.5.8.9	Natural Ventilation Through Fenestration.....	30
3.5.8.10	Construction Practice/Compliance and Enforcement.....	30
3.6	Envelope Features.....	30
3.6.1	Mandatory Requirements.....	30
3.6.1.1	Joints and Other Openings.....	30
3.6.1.2	Certification of Insulation Materials.....	31
3.6.1.3	Urea Formaldehyde Foam Insulation.....	32

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3.6.1.4	Flame Spread Rating of Insulation .....	32
3.6.1.5	Insulation Requirements for Heated Slab Floors .....	32
3.6.1.6	Wet Insulation Systems.....	33
3.6.1.7	Roofing Products Solar Reflectance and Thermal Emittance .....	34
3.6.1.8	Radiant Barriers .....	36
3.6.1.9	Ceiling and Attic Roof Insulation.....	36
3.6.1.10	Loose Fill Insulation .....	36
3.6.1.11	Wall Insulation.....	37
3.6.1.12	Raised-Floor Insulation .....	37
3.6.1.13	Fireplaces, Decorative Gas Appliances, and Gas Logs.....	38
3.6.1.14	Slab Insulation .....	40
3.6.1.15	Vapor Retarder .....	40
3.6.1.16	Recessed Luminaires in Ceilings .....	42
3.6.1.17	Ventilation for Indoor Air Quality.....	43
3.6.1.18	Ventilation Openings .....	43
3.6.2	Prescriptive Approach.....	43
3.6.2.1	Roof/Attic .....	43
3.6.2.2	Walls.....	60
3.6.2.3	Floor/Slab .....	65
3.6.3	Performance Approach.....	68
3.6.3.1	Roof Assembly.....	68
3.6.3.2	Wall Assembly .....	73
3.6.3.3	Floor Assembly .....	80
3.6.3.4	Quality Insulation Installation (QII).....	81
3.7	More Information on Insulation and Assemblies .....	88
3.7.1	Insulation Installation in Framed Assemblies.....	88
3.7.2	Thermal Mass .....	94
3.7.3	Alternative Construction Assemblies .....	95
3.8	Compliance and Enforcement .....	96
3.8.1	Design .....	96
3.8.2	Construction .....	97
3.9	References.....	97
3.9.1	Building Orientation .....	97
3.9.2	Fenestration Terminology .....	98

## 3. Building Envelope Requirements

This chapter describes the requirements that affect the design of the building envelope for low-rise residential buildings. The design and choices made for individual components for the building can significantly affect the energy demand needed to meet heating and cooling loads to maintain the desired inside comfort temperature of the building. Heating and cooling load calculations are used to determine the mechanical system design needed for space heating and cooling. The principal components of heating loads are infiltration and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors. Cooling loads, on the other hand, are dominated by solar gains through windows, skylights, and roof/attic assemblies.

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### 3.1 Organization

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

#### **Section 3.2** What's New for 2016

- Changes for 2016 include more flexibility for prescriptive compliance and changing the minimum mandatory insulation level to R-22 for roof/ceiling.
- Provisions allowing the Energy Commission to approve new products, methods, and procedures for compliance

#### **Section 3.3** Compliance Options

- A summary of the general requirements affecting compliance with the *2016 Building Energy Efficiency Standards*

#### **Section 3.4** Key Envelope Compliance Terms

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

#### **Section 3.5** Fenestration

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

#### **Section 3.6** Envelope Features

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

#### **Section 3.7** Advanced Assembly Systems

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

#### **Section 3.8** Compliance and Enforcement

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

#### **Section 3.9** Glossary/References

- Key terms and reference information most often used for the building envelope

## 3.2 What's New for 2016

The *2016 Building Energy Efficiency Standards* for residential buildings include increased efficiencies for several envelope measures, and there are improvements that have been made to better aid the designer, builder, and building official.

1. Mandatory minimum roof/ceiling construction insulation level must be at least R-22 (maximum U-factor of 0.043).
2. Increased flexibility for prescriptive compliance.
3. The prescriptive requirement of high-performance attics, which includes:
  - a. Insulation installed either above or below the roof deck. (This dramatically lowers the attic temperature, which can typically exceed 150° F by preventing the heat from getting into the conditioned space below and reducing HVAC load.)
  - b. Verified ducts in conditioned space.

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## 3.3 Compliance Options

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

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

When the Energy Commission approves a new compliance option, it is listed in the Special Cases section of the Energy Commission's website based on the adoption year of the Energy Standards: [http://www.energy.ca.gov/title24/2008standards/special\\_case\\_appliance/](http://www.energy.ca.gov/title24/2008standards/special_case_appliance/)

### 3.3.1 Mandatory Features and Devices

§150.0

Mandatory requirements are necessary to support the long-term goal of zero-net-energy buildings. When compliance is being demonstrated with either the prescriptive or performance compliance paths, there are *mandatory measures* that must be installed. Minimum mandatory measures must be met regardless of the method of compliance being used. For example, when using the performance modeling software, it may assume that an assembly meets compliance with a U-factor of U-0.065 in a wood-framed attic roof. However, it does not comply because the mandatory requirement of U-0.043 has not been met per §150.0.

### 3.3.2 Prescriptive Compliance Approach

Energy Standards Table 150.1-A

The *prescriptive approach* is the simplest way to comply with the building envelope requirements but generally offers limited flexibility; however, the 2016 revisions have added increased flexibility for prescriptive compliance. If every prescriptive requirement is met, the building envelope complies with the Energy Standards. The prescriptive envelope requirements are prescribed in §150.1, which includes Table 150.1-A.

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

1. Fenestration.
2. Roofs and ceilings, including exterior roofing products.
3. Exterior walls.
4. Floors.

### 3.3.3 Performance Compliance Approach

§150.1

The prescribed mandatory measures and prescriptive requirements affect the design and operation of the building. Mandatory measures, prescriptive requirements, and operational schedules establish a minimum performance level that can be exceeded by other design measures and construction practices, resulting in greater energy savings.

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

The performance approach allows for more energy tradeoffs between building features, such as increasing HVAC equipment efficiency to allow more fenestration area. See Section 3.8 and Chapter 8 for a more complete discussion of the performance approach.

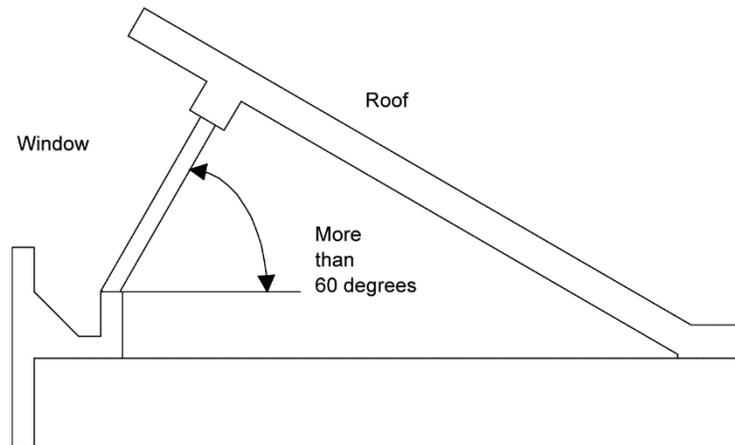
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## 3.4 Key Envelope Compliance Terms

Elements of the building envelope significantly contribute to the related energy efficiency. Several features are important to note when a method is chosen to demonstrate compliance. Components of the building envelope include walls, floors, the roof and/or ceiling, and fenestration. Details for compliance of fenestration are addressed in Section 3.5 below. Envelope and other building components are listed in §100.1 of the 2016 Energy Standards and the Reference Appendices (RA).

- A. **Envelope** requirements vary by envelope component and are a function of the type of construction, orientation and space conditions on either side of the envelope surface. Additional envelope component definitions are:
1. **Exterior partition or wall** is an envelope component (roof, wall, floor, window, and others) that separates conditioned space from ambient (outdoor) conditions.
  2. **Demising partition or wall** is an envelope component that separates conditioned space from an unconditioned space.

- B. **Conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1 for full definition.) An indirectly conditioned space has less thermal conductance to a directly conditioned space than to the outside. An *unconditioned space* is enclosed space within a building that is not directly conditioned, or indirectly conditioned.
- C. **Plenum** is a space below an insulated roof and above an uninsulated ceiling. It is an indirectly conditioned space as there is less thermal conductance to the directly conditioned space below than to the ambient air outside. By comparison, an attic is a space below an uninsulated roof that has insulation on the attic floor, and is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below. A plenum can also be the space between the underside of a raised floor and the slab or grade below and is sometimes used as an air supply for the building when the exterior foundation is sealed to the outside. A plenum can also be the space between the underside of an insulated ceiling and demising partitions or walls separating the attic from the conditioned space below.
- D. **Sloping surfaces** are considered either a wall or a roof, depending on the slope. (See Figure 3-1.) If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including windows in walls and any skylight types in roofs.
- E. Floors and roof/ceilings do not differentiate between demising and exterior. Thus an **exterior roof/ceiling** "is an exterior, or demising element, that has a slope less than 60 degrees from horizontal, and that has conditioned space below," ambient conditions or unconditioned space above.  
This definition does not include an exterior door or skylight.
- F. **Roof deck** is the surface of an exterior roof that is directly above the roof rafter and below exterior roofing materials.
- G. Similarly, an "exterior floor/soffit is a **horizontal exterior element**, or a horizontal demising element, under conditioned space" and above an unconditioned space or ambient (outdoor) conditions.
- H. **Vapor retarder** or barrier is a special covering over framing and insulation or covering the ground of a crawl space that protects the assembly components from possible damage due to moisture condensation. During cold weather, the inside of the house is warm and moist (from breathing, showers, and so forth), and the outside is cold and dry. Moisture moves from moist to drier conditions and from warm to cold. When the moisture (in vapor form) reaches a point in a wall or roof assembly that has a temperature below the dew point, it will condense into 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 effectiveness.
- I. **Fenestration (Windows)** are considered part of an exterior wall because the slope is typically over 60°. Where the slope of fenestration is less than 60°, the glazing indicated as a window is considered a **skylight**.

**Figure 3-1: Slope of a Wall or Window (Roof or skylight slope is less than 60°)**

Source: California Energy Commission

### J. Roofing Products (Cool Roof)

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

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

The Energy Standards specify radiative properties that represent minimum “cool roof performance” qualities for roofing products:

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

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

The Energy Standards prescribe cool roof radiative properties for low-sloped and steep-sloped roofs (§150.1(c)11). A *low-sloped roof* is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizon), while a *steep-sloped roof* is a surface with a pitch greater than 2:12. Low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is higher in the sky.

## Example 3-1

**Question:**

I am a salesperson and represent some roofing products, and many of them are on the U.S. Environmental Protection Agency's (EPA) ENERGY STAR® list for cool roofing materials. Is this sufficient to meet the Energy Standards?

**Answer:**

No. ENERGY STAR has different requirements for reflectance and *no* requirements for emittance. Per §10-113, the Cool Roof Rating Council ([www.coolroofs.org](http://www.coolroofs.org)) is the only entity recognized by the Energy Commission to determine what qualifies as a cool roof.

## Example 3-2

**Question:**

How does a product get CRRC cool roof certification?

**Answer:**

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

## Example 3-3

**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) and is given off – emitted – to the environment in varying amounts depending on the 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 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 the 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.

**K. Air Leakage**

Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It is a major component of heating and cooling loads. Infiltration can occur through holes and cracks in the building envelope and around doors and fenestration framing areas. Ventilation, on the other hand, is the

*intentional* replacement of conditioned air with unconditioned air through open windows and skylights or mechanical systems.

Reducing infiltration 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 occupant comfort, reduced moisture intrusion, and fewer air pollutants.

#### L. **Advanced Assemblies**

Common strategies for exceeding the minimum energy performance level set by the 2016 Energy Standards include the use of better components such as:

- Higher insulation levels
- More efficient fenestration
- Reducing building infiltration
- Use of roofing products
- Better framing techniques (such as the use of raised-heel trusses that accommodate more insulation)
- Reduced thermal bridging across framing members
- Greater use of nonframed assemblies or panelized systems (such as SIPs and ICFs)
- More efficient heating, cooling and water heating equipment

The Energy Commission encourages the use of energy-saving techniques for showing compliance with the Energy Standards. Innovative designs and practices are discussed in Section 3.6.3.4.

#### M. **Advanced Building Design**

The design of a building, floor plan, and site design layout all affect energy use. A passive solar building uses elements of the building to heat and cool itself, in contrast to relying on mechanical systems to provide the thermal energy needs of the building. Passive solar strategies encompass several advanced high performance envelope techniques, such as:

1. Carefully choosing the size, type and placement of fenestration and shading.
2. Providing and controlling fresh air ventilation during the day and night.
3. Having internal and external thermal mass components that help store useful heat and cooling energy.
4. Having highly insulated envelope assemblies.
5. Using high performing roofing materials (cool roofs) and radiant barriers.
6. Having very low air leakage.

Some measures designed as part of an advanced assembly system may require specific installation procedures or field verification and diagnostic testing to ensure proper performance. Field verification and diagnostic testing are ways to ensure that the energy efficiency features used in compliance calculations is realized as an energy benefit to the occupants.

## 3.5 Fenestration

Fenestration products such as windows, glazed doors, dynamic glazing, window films, and skylights have a significant impact on energy use and heating and cooling loads in a home. 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 energy use of a building, but can affect the operation of the HVAC system and the comfort of occupants.

### 3.5.1 Fenestration Types

When choosing a window (new or replacement), it is always best to look for a National Fenestration Rating Council (NFRC) label on the window. The *Energy Performance Ratings* label is designed to help consumers identify the thermal resistance (U-factor) and solar heat gain (SHGC), which are factors that affect the energy performance of a window. This will help the consumer or designer compare the energy efficiency of window and glazed door products of different brands and manufacturers.

The following NFRC label provides information about the energy performance rating by listing identifiers such as: U-factor, solar heat gain coefficient (SHGC), visible transmittance (VT), and air leakage (AL), which helps provide accurate information for the consumer or designer:

A. **U-factor** measures the rate of heat loss through a product. 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.

B. **The solar heat gain coefficient (SHGC)** measures the percentage of radiant heat that passes through a fenestration product. The lower the SHGC, the lower the amount of solar heat gain through a window. 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.

C. **Visible transmittance (VT)** measures the percentage of light that comes through a fenestration product. The higher the VT rating, the more light is allowed through a window or glazed door. Skylights allow significantly more lighting and can be as efficient as vertical windows.

D. **Air leakage (AL)** is a measurement of heat loss and gain by infiltration through cracks in the window assembly, which can affect occupant comfort. The lower the AL, the lower the amount of air that will pass through cracks in the window assembly.

		<b>World's Best Window Co.</b> Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Argon Fill • Low E Product Type: <b>Vertical Slider</b>	
ENERGY PERFORMANCE RATINGS			
U-Factor (U.S./I-P)		Solar Heat Gain Coefficient	
<b>0.30</b>		<b>0.30</b>	
ADDITIONAL PERFORMANCE RATINGS			
Visible Transmittance		Air Leakage (U.S./I-P)	
<b>0.51</b>		<b>0.2</b>	
<small>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information.  <a href="http://www.nfrc.org">www.nfrc.org</a></small>			

*There are three primary categories of fenestration:*

#### **A. WINDOWS**

A window is a vertical fenestration product that is an assembled unit consisting of a frame and sash component holding one or more pieces of glazing. New advances in framing material such as composites, fiberglass, and vinyl help improve the energy efficiency of fenestration products. New technology has advanced the glass industry to include reflective coatings such as silver, gold, bronze, low-e, low-e<sup>2</sup>, or low-e<sup>3</sup>, which can be applied to clear and tinted glass.

#### **B. GLAZED DOORS**

Glazed door is an exterior door having a glazed area of 50 percent or more of the area of the door. These doors are typically installed in exterior walls that separate conditioned space from exterior ambient or unconditioned space. When the door has less than 50 percent glazing material, it is no longer considered a glazed door but just a conventional door. But whatever the glazed area, it will still have to be counted toward the overall glazed area of the conditioned space in any calculations.

#### **C. SKYLIGHTS/TUBULAR DAYLIGHT DEVICES**

Skylights and tubular daylight devices (TDD) are an exceptional source of daylight and passive solar heating, illuminating rooms with direct and indirect sunlight. In addition, when used appropriately, daylighting can increase the quality of light in a room and reduce dependence upon electrical lighting. On the other hand, skylights and TDDs don't typically have the same thermal properties as vertical fenestration and can be prone to greater heat loss in winter and solar heat gain during the summer. When a building designer optimizes the whole envelope glazing arrangement for daylight and thermal control, significant heating and cooling energy savings can be realized, especially when skylights and TDDs are as efficient as any vertical windows used.

*The following is a list of subcategories of fenestration:*

- A. **Manufactured fenestration** is a fenestration product constructed of materials that are factory-cut or otherwise factory-formed with the specific intention of being used to fabricate a fenestration product. Knocked down or partially assembled products may be sold as a fenestration product when provided with temporary and permanent labels, as described in §10-111, or as a site-built fenestration product when not provided with temporary and permanent labels, as described in §10-111.
- B. **Field-fabricated** is when the windows are fabricated at the building site from elements that are not sold together as a fenestration product (that is, separate glazing, framing and weatherstripping elements). 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).
- C. **Site-built fenestration** is designed to be field-glazed or field-assembled units, using specific factory-cut or other factory-formed framing, and glazing units that are manufactured with the intention of being assembled at the construction site. These include storefront systems, curtain walls, or large-track sliding glass walls, and atrium roof systems.
- D. **Dynamic glazing** is a glazing system that can reversibly change the performance properties, specifically the SHGC, VT, and, rarely, the U-factor. These may include, but are not limited to, chromogenic glazing systems and integrated shading systems. Dynamic glazing systems may include internally mounted or externally mounted

shading devices that attach to the window framing/glazing and may be removable (but only if they are part of the original window, door, or skylight assembly, and the assembly is labeled as such).

- E. **Window films** were originally developed in the early 1950s and are made mostly of polyester substrate that is durable and highly flexible. It absorbs little moisture and has both high aridity and low temperature resistances. Polyester film offers high clarity and can be pretreated to accept different types of coatings for energy control and longterm performance. Window films are made with a special scratch resistant coating on one side and with a mounting adhesive layer on the other side. The adhesive is normally applied to the interior surface (room side) of the glass, unless it is a film specifically designed for the exterior window surface.

### 3.5.2 Relevant Sections in the Energy Standards for Fenestration

- 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, doors, and skylights whether they are used in residential or nonresidential buildings.
- C. §110.6(a)2 through 4 requires 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) field-fabricated fenestration that do not have an NFRC rating shall use the Energy Commission default U-factors, SHGC, and optional VT values.
- F. §110.7 requires that openings around windows, skylights 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 windows and skylights separating conditioned space from unconditioned space or the outdoors. An exception allows the greater of 10 ft<sup>2</sup> or 0.5 percent of the conditioned floor area to exceed 0.58 U-factor.
- H. §150.1(c)3 and 4 are 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, in addition to the basic fenestration allowance of 20 percent of conditioned floor area (CFA), Exception 1 allows each dwelling unit to have up to 3 ft<sup>2</sup> of glazing installed in doors and up to 3 ft<sup>2</sup> of tubular daylighting device with dual-pane diffusers to have an assumed U-factor and SHGC equivalent to the package requirements.
- J. §150.1(c)3A, in addition to the basic fenestration allowance of 20 percent of CFA, Exception 2 allows up to 16 ft<sup>2</sup> of the skylights 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 assume the lowest labeled U-factor and SHGC when connected to automatic controls that modulate the amount of heat flow into space in multiple steps in response to solar intensity. Chromogenic glazing shall be considered separately from other fenestration and must not be weight-averaged with other fenestration.

- L. §150.1(c)3A Exception 4 specifies that if a contains a combination of manufactured and site-built fenestration; only the site-built fenestration can be determined by using NA6; however, all fenestration, including site-built, can also default to Tables 110.6-A or B.
- M. §150.1(c)3B establishes a prescriptive limit in which the prescriptive maximum total fenestration area shall not exceed the percentage of CFA 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 prescriptive fenestration area requirements for residential additions, as well as other prescriptive requirements for new fenestration. Performance compliance options (existing plus addition) are also available.
- P. §150.2(b) establishes the prescriptive requirements for replacement fenestration in existing residential buildings. Performance compliance options (existing plus alteration) are also available.

### 3.5.3 Mandatory Measures, Features, and Devices

§110.6(a)1; §110.7

#### 3.5.3.1 Air Leakage

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<sup>2</sup> of the window area.

This mandatory measure applies to all manufactured windows that are installed in newly constructed residential (including high-rise) buildings or newly installed in existing buildings. To determine leakage, the standard test procedure requires manufacturers to use either NFRC 400 or ASTM E283 at a pressure differential of 75 Pascal (or 1.57 pounds/ft<sup>2</sup>).

- A. **Site-Built Products.** There are no specific air leakage requirements for site-built fenestration products, but the Energy Standards require limiting air leakage by weatherstripping and caulking.
- B. **Field-Fabricated Products.** No air leakage testing is required for field-fabricated fenestration products; however, the Energy Standards still require limiting air leakage by weatherstripping and caulking.
- C. **Exterior Doors.** Exterior doors, which includes pet doors, must meet the following requirements:
  - 1. Manufactured exterior doors must be certified as meeting an air leakage rate of 0.3 cfm/ft<sup>2</sup> of door area at a pressure differential of 75 Pascal, which is the same as windows.
  - 2. Field-fabricated exterior doors must comply with the requirements of §110.7, as described by “Other Openings”; for example, they must be caulked and weatherstripped.
  - 3. Any door with a surface area greater than 50 percent glass is considered a glazed door and must comply with the mandatory and applicable prescriptive and performance requirements of §150.0, §150.1, and §150.2.
  - 4. For any door with a surface area less than or equal to 50 percent glass, the area may be exempt in accordance with one of the exceptions of §150.0, §150.1, and §150.2.

### 3.5.3.2 U-Factor and SHGC Rating Mandatory Requirements

§110.6(a)2 and §110.6(a)3; Table 110.6-A and Table 110.6-B

Requiring that U-factor and SHGC be calculated using standardized procedures ensures that the thermal performance or efficiency data for fenestration products is accurate. Furthermore, the data provided by different manufacturers within each fenestration type (windows, doors, skylights, TDDs) can be easily compared to others within that type and can be independently verified.

For manufactured fenestration products, the mandatory requirements are that the U-factor and solar heat gain coefficient (SHGC) be rated by NFRC and be listed in NFRC's Certified Product Directory (CPD). The test procedure for U-factor is NFRC 100, and for SHGC and VT is NFRC 200 and NRC-202 or ASTM E972 for translucent panels, and NFRC-203 for tubular daylighting device skylights (TDDs) and for certain type of other skylights.

At the field inspection, the field inspector verifies that the fenestration U-factor and SHGC values meet the energy compliance values by checking the NFRC label sticker on the product.

When manufacturers do not rate the thermal efficiencies by NFRC procedures, the Energy Commission default values must be used and documented on a temporary default label (See Figure 3-2).

*Note:* If no labels are available on site for verification, the field inspector should not allow any further installation of fenestration until proof of efficiency (label) is produced. In cases when proof is not met, the field inspector should not allow construction until the designer or builder can produce such labels.

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

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

Energy Commission default values in Table 110.6-A and Table 110.6-B in the Energy Standards lists the worst performing values that can be assumed when fenestration is not rated by NFRC. For example, a single-pane, operable, metal-framed fenestration product has a U-factor of 1.28. To get credit for high-performance window features such as low-e (low-emissivity) coatings and thermal break frames, the window manufacturer must have the window tested, labeled, and certified according to NFRC procedures.

- A. **Site-Built Fenestration Products.** For special cases in low-rise residential construction in which site-built products are installed, the site-built products shall be treated the same as manufactured products: proof of U-factor and SHGC values must come from NFRC ratings or from the default Table 110.6-A and Table 110.6-B of the Energy Standards, or alternatively use of Reference Nonresidential Appendix NA-6 for nonrated site-built fenestration if the area of the site built is less than 250 ft<sup>2</sup>.

*Note:* When unrated site-built fenestration is used in a residential application, there is an alternative procedure to calculate the default U-factor and SHGC values. When using area-weighted averaging, the alternative may not result in meeting the prescriptive values as required by Table 150.1-A. The alternative calculation can be found in NA6, or it may be necessary to use the performance approach to meet energy compliance.

**B. Field-Fabricated Products §110.6(b).** Field-fabricated fenestration must always use the Energy Commission default U-factors from Table 110.6-A and SHGC values from Table 110.6-B of the energy standards. There is no minimum requirement for VT, as it is used for informational purposes.

Acceptable methods of determining U-factor and SHGC are shown in Table 3-1A and Table 3-1B, respectively.

**Table 3-1A: Methods for Determining U-Factor**

Fenestration Category					
U-factor Determination Method	Manufactured Windows	Manufactured Skylights	Site-Built Fenestration (Vertical & Skylight)	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA) <sup>1</sup>	✓	✓	✓	N/A	N/A
NFRC-100	✓	✓	✓	N/A	N/A
Standards Default Table 110.6-A	✓	✓	✓	✓	✓
NA6 <sup>2</sup>	N/A	N/A	✓	N/A	N/A
1. The NFRC Residential CMA method is an option that may be in the Energy Standards. 2. The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may be used only for site-built vertical and skylights having less than 1,000ft <sup>2</sup> .					

**Table 3-1B: Methods for Determining SHGC**

Fenestration Category					
SHGC Determination Method	Manufactured Windows	Manufactured Skylights	Site-Built Fenestration (Vertical & Skylight)	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA) <sup>1</sup>	✓	✓	✓	N/A	N/A
NFRC-200	✓	✓	✓	N/A	N/A
Standards Default Table 110.6-B	✓	✓	✓	✓	✓
NA6 <sup>2</sup>	N/A	N/A	✓	N/A	N/A
1. The NFRC Residential CMA method is an option that may be available in the Energy Standards. 2. The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may be used only for site-built vertical and skylights having less than 1,000ft <sup>2</sup> .					

3.5.3.3 Labeling Mandatory Requirements

§10-111(a); §110.6(a)5

**A. Default Temporary Label**

The manufacturer can choose to use Energy Commission default values from Table 110.6-A for U-factors and Table 110.6-B for SHGC of the Energy Standards. If default values are used, the manufacturer must attach a temporary label meeting the following specific requirements. (Permanent etching labels are not required.) The product shall meet the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, and SHGC criteria of §110.6(a)3 in the Energy Standards.

Although there is no exact format for the default temporary label, it must be clearly visible and large enough for the enforcement agency field inspectors to read easily; it must include all information required by the Energy Standards. The minimum suggested label size is 4 in. x 4 in., and the label must have the following words at the bottom of the label as noted in Figure 3-2:

*“Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2016 California Building Energy Efficiency Standards for Residential and Nonresidential Buildings.”*

The manufacturer ensures the U-factor and SHGC default values should be labeled large enough to be readable from four feet away. The manufacturer ensures the appropriate checkboxes are checked and indicated on default label.

**Figure 3-2: Sample of Default Temporary Label**

<b>2016 California Energy Commission Default Label</b>		
<b>XYZ Manufacturing Co.</b>		
<b>Key Features:</b>	<input type="checkbox"/> Doors	<input type="checkbox"/> Double-Pane
	<input type="checkbox"/> Skylight	<input type="checkbox"/> Glass Block
<b>Frame Type</b>	<b>Product Type:</b>	<b>Product Glazing Type:</b>
<input type="checkbox"/> Metal	<input type="checkbox"/> Operable	<input type="checkbox"/> Clear
<input type="checkbox"/> Non-Metal	<input type="checkbox"/> Fixed	<input type="checkbox"/> Tinted
<input type="checkbox"/> Metal, Thermal Break	<input type="checkbox"/> Greenhouse/Garden Window	<input type="checkbox"/> Single-Pane
<input type="checkbox"/> Air space 7/16 in. or greater <input type="checkbox"/> With built-in curb <input type="checkbox"/> Meets Thermal-Break Default Criteria	-----	To calculate VT see NA6
<b>California Energy Commission</b> Default U-factor =	<b>California Energy Commission</b> Default SHGC =	<b>California Energy Commission</b> Calculated VT =
Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.		

Source: California Energy Commission

## B. Certified Temporary and Permanent Labels

§10-111

### 1. Certified Manufactured Fenestration Products

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

2. The **permanent label** must, at a minimum, identify the certifying organization and have an ID number or code to allow tracking back to the original information on file with the certifying organization, NFRC. The permanent label can also be inscribed on the spacer, etched on the glass, engraved on the frame, or otherwise located so as not to affect aesthetics.
3. **Field-Fabricated Fenestration** A label is not required for field-fabricated fenestration products, but the default values in Table 110.6-A and Table 110.6-B of the Energy Standards must be used and documented on the Fenestration Certificate, NRCC-ENV-05-E form.

#### Example 3-4

##### Question:

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

##### Answer:

First, all windows must meet the mandatory requirements of §110.6 and §110.7, unless exempted.

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 of the Energy Standards). Windows that are not field-fabricated must be labeled with NFRC-certified or default efficiencies. If the U-factors or SHGC values do not comply with the prescriptive requirements, the performance method must be used. To simplify data entry into the compliance software, you may choose the U-factor from Table 110.6-A of the Energy Standards that is the highest of any of the windows planned to be installed, and use this for all windows for compliance. However, you must use the appropriate SHGC from Table 110.6-B for each window type being installed.

#### Example 3-5

##### Question:

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

##### Answer:

All windows must meet the mandatory requirements by §110.6 and §110.7, unless exempted.

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 (in other words, 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 one of 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).
3. Make a hole punch next to the appropriate values.

#### Example 3-6

**Question:**

Which U-factor do I use for an operable metal framed, glass block? Which SHGC do I use for clear glass block? Does it need a label?

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

**Answer:**

For glass block, use the U-factor and SHGC values from Table 110.6-A and Table 110.6-B of the Energy Standards 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.

Yes, the default tables for glass block do not include tinted glass.

#### Example 3-7

**Question:**

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

**Answer:**

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

#### Example 3-8

**Question:**

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

**Answer:**

All doors with glass area greater than 50 percent of the door area, which includes French doors, are defined as fenestration products and are covered by the NFRC Rating and Certification Program. The U-factor SHGC for doors with glass area greater than 50 percent may be determined in one of two ways:

1. Use the NFRC rated and labeled values.
2. Refer to Table 110.6-B of the Energy Standards. The values are based upon glazing and framing type.
3. In special cases where site-built fenestration is being installed in a residential application, the site-built windows can use an alternative method to calculate the U-factor and the SHGC by using the manufacturer's center-of-glass values (COG). The COG values are calculated in accordance with NA6. The maximum allowed of site-built fenestration is less than 1,000 ft<sup>2</sup>.

Doors with less than 50 percent 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 of the glass:

- The NFRC label if one is available
- The default values from Tables 110.6-A and 110.6-B of the Energy Standards

The opaque part of the door is ignored in the prescriptive approach. If the performance approach is used, a default SHGC value of 0.50 must be assumed for the opaque portion of the door. Alternatively, if NFRC values for U-factor and SHGC for the entire door are available, the door may be considered a fenestration product.

#### Example 3-9

**Question:**

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

**Answer:**

Each product line must be tested and certified for air infiltration rates. Features such as weather seal, frame design, operator type, and direction of operation 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 3-10

**Question:**

Is a custom window “field-fabricated” for 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 (such as 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 3-11

**Question:**

What constitutes a “double-pane” window?

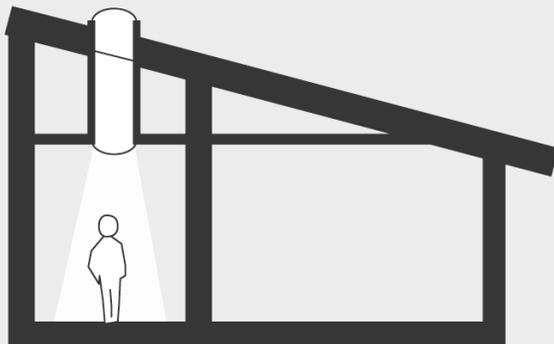
**Answer:**

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

## Example 3-12

**Question:**

To get daylight into a room in my new house, I plan on installing a tubular daylighting device and will be using the performance approach for compliance. 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 Energy Standards, if  $U_c$  is 1.20 and  $SHGC_c$  is 0.85?

**Answer:**

Tubular daylighting device (TDD) skylights are an effective means of bringing natural light indoors, as are traditional skylights.

There are three methods available for determining the thermal efficiencies for TDDs:

The first is to use the default U-factor from Table 110.6-A of the Energy Standards. This tubular product would be considered a metal frame, fixed, single-pane skylight resulting in a U-factor of 1.19, which must appear on a label preceded by the words “CEC Default U-factor.” (A tubular daylighting device 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 NA6, Equation NA6-1. The U-factor for this tubular daylighting device would be based on metal with no curb (Table NA6-5). The U-factor for this skylight, using Equation NA6-1, is 1.25, where  $U_t = (0.195 + (0.882 \times 1.20))$ . This must appear on a label stated as “CEC Default U-factor 1.25.”

The third and best method, applicable if the product 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 Table 110.6-B of the Energy Standards. This tubular daylight device would be considered a metal frame, fixed, clear, single-pane skylight 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 NA6, Equation NA6-2. The SHGC for this skylight using Equation NA6-2 is 0.81, where

$SHGC_t = (0.08 + (0.86 \times 0.85))$ . This must appear on a label stated as “CEC Default SHGC 0.81.”

The third method, applicable if the skylight has been tested and certified pursuant to NFRC procedures, requires a label that states, “Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures.”

**Example 3-13****Question:**

How would the U-factor and the SHGC be determined if the tubular daylighting device 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 the double-pane U-factor and SHGC values from Tables 110.6-A and 110.6-B of the Energy Standards would be used instead of single-pane values. Up to 3 ft<sup>2</sup> of tubular daylighting device is assumed to have the U-factor and SHGC required by Package A for prescriptive performance compliance (Exception 1 to §150.1(c)3A).

**Example 3-14: Through the wall pet doors****Question:**

How do I account for a pet door installed in an exterior wall in a newly constructed residential building design?

**Answer:**

Pet doors must meet all door requirements.

First a U-factor must be determined by an NFRC accredited testing lab using NFRC 100 U-factor requirements; otherwise, non-rated pet doors will assume no more than the maximum U-factor of 0.99 based on a nonmetal single pane door U-factor (See Table 110.6-A of the Energy Standards). Second, the rated pet door shall not exceed 0.3 cfm/ft<sup>2</sup> air leakage when tested using ASTM E283. Third, use the performance compliance approach to determine the weighted average U-factor of the wall assembly including the pet door. The proposed U-factor shall not exceed the mandatory minimum U-factor of 0.102 that results in installing R-13 cavity insulation in a 2x4 wood framed wall or a U-factor of 0.074 that results in installing R-19 cavity insulation in a 2x6 wood framed wall.

Note: Additional insulation may be added to the wall if unable to meet the mandatory minimum U-factor. See Reference Joint Appendix JA4, Table JA4.3.1 for other nominal wood framing size and Table JA4.3.4 for other nominal metal framing size.

**3.5.3.4 Fenestration U-factor**

§150.0(q)

For fenestration products, the mandatory maximum U-factor is 0.58. This is based on the worst case scenario for a double-pane, vinyl-framed fenestration product including skylights. Area-weighted averaging can be used to allow flexibility for the placement of a fenestration product with a U-factor greater than 0.58. Up to 10 ft<sup>2</sup> or 0.5 percent of conditioned floor area (whichever is greater) is exempt from the maximum U-factor requirement.

Figure 3-3: Package A, SHGC Criteria by Climate Zone



### 3.5.4 Prescriptive Requirements

§150.1(c)3

Prescriptive requirements described in this chapter typically refer to Package A or Table 150.1-A. The maximum U-factor required by prescriptive Package A for all climate zones is 0.32, and the maximum SHGC is 0.25 for residences in Climate Zones 2, 4, and 6-16. Homes constructed in Climate Zones 1, 3, and 5 have no SHGC requirements. The requirements apply to fenestration products without consideration of insect screens or interior shading devices. With some exceptions, some fenestration products may exceed the prescriptive requirement as long as the U-factor and SHGC of windows, glazed doors, and skylights can be area weight-averaged together to meet the prescriptive requirement using the WS-2R form in Appendix A of this manual.

Table 3-2: Maximum U-Factors, SHGC, and Fenestration Area by Climate Zone in Package A (from Table 150.1-A of the Energy Standards)

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%

### 3.5.5 Fenestration Prescriptive Exceptions

§150.1(c)3A through §150.1(c)3C

#### A. Doors and Tubular Daylighting Device

In each dwelling unit, up to 3 ft<sup>2</sup> of the glazing area installed in doors and up to 3 ft<sup>2</sup> of tubular daylighting devices area with dual-pane diffusers at the ceiling are exempt from the prescriptive U-factor and SHGC requirements, where glazed door and TDD area is included in the maximum of 20 percent fenestration area. However, the U-factor shall not exceed a maximum of 0.58. See §150.0(q) and Exception 1 of §150.1(c)3A.

#### B. Skylights

Each new dwelling unit may have up to 16 ft<sup>2</sup> of skylight area; the total area of skylights is included in the maximum of 20 percent fenestration area and meets a maximum 0.55 U-factor and a maximum SHGC of 0.30. See Exception 2 of §150.1(c)3A.

Aside from the specific exceptions to the fenestration prescriptive requirements, U-factors and SHGCs for skylights can be significantly higher than they are for windows so long as the area weight-averaged U-factor and SHGC do not exceed the 0.55 U-factor and is not greater than the 0.30 SHGC when large numbers of skylights are used for prescriptive compliance. Alternatively, the performance approach should be used for meeting energy compliance.

#### C. Dynamic Glazing

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

#### D. Site-Built Fenestration

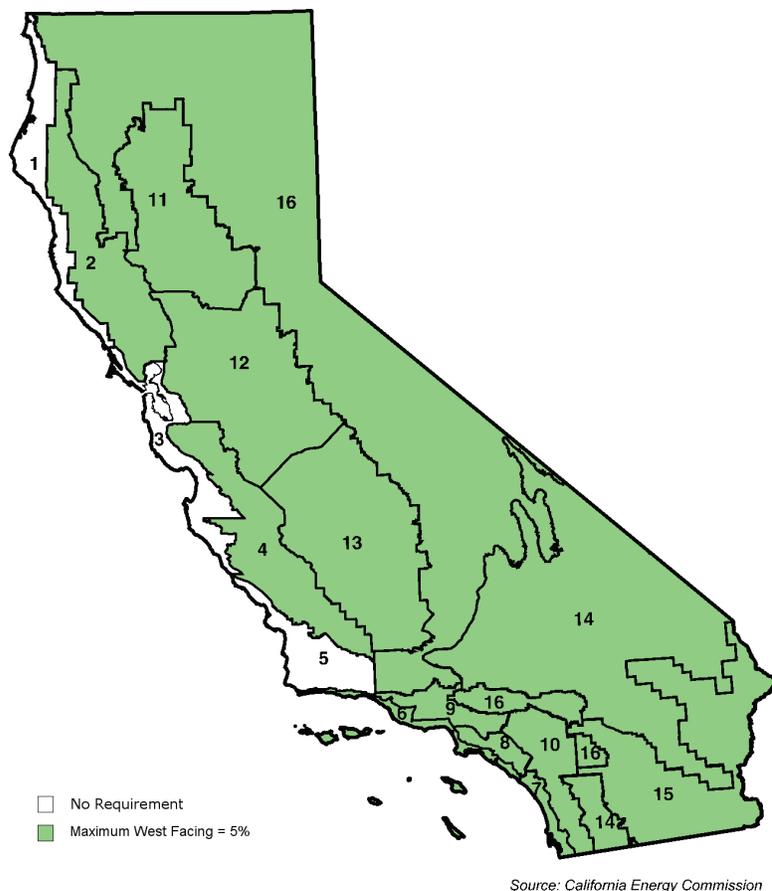
When a residential dwelling unit contains a combination of manufactured and site-built fenestration; only the site-built fenestration values can be determined by using NA6; however, all fenestration, including site-built, can default to Tables 110.6-A or B.

#### E. Maximum Area

The prescriptive requirements limit total glass area to a maximum of 20% of the conditioned floor area in all climate zones; however, there are exceptions to the prescriptive requirements for alterations in §150.2(b)1A which allow additional glass area beyond the 20% limitation, including west-facing glass.

#### F. Greenhouse Windows/Garden Windows

Compared to other fenestration products, the NFRC-rated U-factor for greenhouse windows are comparatively high. §150.0(q) includes an exception from the U-factor requirement for dual-glazed greenhouse or garden windows that total up to 30 ft<sup>2</sup> of fenestration area.

**Figure 3-4: Package A, Prescriptive West-Facing Window Area Limits by Climate Zone**

### 3.5.6 Fenestration Shading Types

#### A. Shading

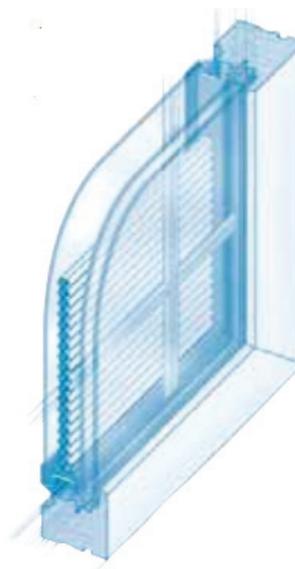
While a low emissivity (low-e) coating on the glass is one of the most common ways to reduce solar gain in combination with insulated window frame, there are other options to help increase shading:

1. Use of permanent installed exterior shade screens
2. Louvers on the outside of the window are typically used on windows facing south. See Table 3-3 for different types of exterior shades and SHGC's.
3. Properly sized overhang - Discussed later in Section 3.5.8.4.

#### B. Dynamic Glazing

Dynamic glazing products are either integrated shading systems or electro-chromatic-type devices and are considered a fenestration product. Integrated shading systems include blinds positioned between glass panes that can be opened and closed using automatic controls. The labels for integral shading systems will reflect the endpoints of the product's performance for U-factor and SHGC (See Figure 3-6).

Figure 3-5: Example of Dynamic Glazing Type - Integrated Shading System



Source: NFRC Dynamic Glazing Products Fact Sheet

The unique rating “variable arrow” identifier helps consumers understand the “dynamics” of the product and allows comparison with other similar dynamic fenestration products. The following is a label reference:

- A. The variable arrow – If the fenestration product can operate at intermediate states, a dual directional arrow ( $\leftrightarrow$ ) with the word “Variable” will appear on the label. Some dynamic glazing is able to adjust to intermediate states, allowing for a performance level between the endpoints. The low value rating is displayed to the left (in the closed or darker position), and the high value rating is displayed to the right (in the open or lighter position). This lets the consumer know at a glance the best and worst case performance of the product and the default or de-energized performance level.

Figure 3-6: Example of Dynamic Glazing Type - Integrated Shading System

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

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

Source: NFRC Dynamic Glazing Products Fact Sheet

### C. Chromatic Glazing

One type of dynamic glazing product uses a chromatic type of glass that has the ability to change the performance properties, allowing occupants to control their environment manually or automatically by tinting or darkening a glass with the flip of a switch. Some fenestration products can change performance automatically with the use of an automatic control or environmental signals. These high-performance 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. A view of chromatic glazing in the open (off) and closed (on) position is shown in Figure 3-7 below.

**Figure 3-7: Chromatic Glazing**



Source: Sage Electrochromics

## 3.5.7 Dynamic Glazing Device

### A. Integral Shading Device

To use the high-performance values, one of the following must be met:

1. Must have an NFRC Certified Label sticker.
2. When no NFRC is available, then the default values from Tables 110.6-A and 110.6-B must be used.

### B. Chromogenic Glazing

1. Must have an NFRC Certified Label sticker; and
2. Automatic controls must be installed to receive best rated performance value.
3. If there is no NFRC label but with automatic controls, then default to Table 150.1-A maximum U-factor of 0.32 and maximum SHGC of 0.25; or
4. If there is a NFRC label, but no automatic controls, then default to Table 150.1-A maximum U-factor of 0.32 and maximum SHGC of 0.25; or
5. If there is no NFRC and no automatic controls, then the default values from Tables 110.6-A and 110.6-B of the Energy Standards must be used.

### C. Window Films

Window films are polyester film that offer high-clarity and can be pretreated to accept different types of coatings. There are three basic categories of window films:

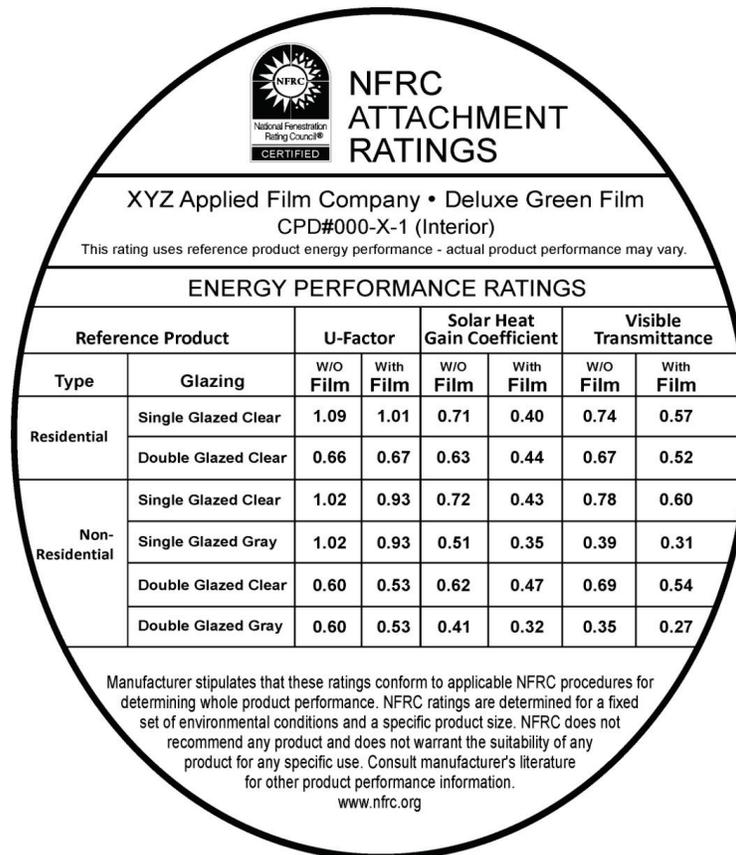
1. Clear (nonreflective) films are used as safety or security film to reduce ultraviolet (UV) light, which contributes greatly to fading; however, they are not normally used for solar control or energy savings.
2. Tinted or dyed (nonreflective) films reduce both heat and light transmission, mostly through increased absorbance, and can be used in applications where the desired primary benefit is glare control, with energy savings secondary.
3. Metalized (reflective) film, which can be metalized through vacuum coating, sputtering, or reactive deposition and may be clear or colored. These are the preferred film in most energy savings applications, since they reduce transmission primarily through reflectance and are manufactured to selectively reflect heat more than visible light through various combinations of metals.
4. Performance window film compliance:

To receive window film credit, the following must be met:

- The performance approach must be used to meet energy compliance.
- NFRC Window Film Energy Performance Label is required for each different film applied; otherwise, the default values from Tables 110.6-A and 110.6-B of the Energy Standards must be used.
- Window films must have at least a 10-year warranty.

See Figure 3-8 below. The NFRC Attachment Ratings Label helps identify the energy performance of window films.

**Figure 3-8: Window Film Energy Performance Label**



Source: NFRC Applied Film Products Fact Sheet

## D. Glazed Doors

### §110.6

Any door that is more than one-half glass is considered a glazed door and must comply with the mandatory measures and other requirements applicable to a fenestration product. Up to 3 ft<sup>2</sup> of glass in a door is exempt from the U-factor and SHGC requirements (or can be considered equivalent to the Package A values). The U-factor and SHGC 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 and Table 110.6-B for the SGHC of the Energy Standards. If the door has less than 50 percent glazing, the opaque part of the door is ignored in the prescriptive approach, but in the performance method it is assumed to have 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.

### 3.5.8 Compliance Alternatives

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

#### 3.5.8.1 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 20percent of the conditioned floor area (CFA).

Data shows 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 CFA.

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 2016 update. The Energy Commission recognizes that area and orientation can have a big effect on energy use, but because these are so variable in buildings, the Energy Commission does not want the energy efficiency of other building components to be eroded in buildings that have relatively small fenestration areas. While there is no credit for fenestration 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 fenestration area equal to the proposed design, up to 20 percent of CFA, 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.

#### 3.5.8.2 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.

### 3.5.8.3 Improved Fenestration Performance

With the 2016 update, the weighted average U-factor remains at 0.32 in all climate zones, as indicated in Package A. This means there is only a minor credit available for installing high-performance fenestration that could be traded off or be used to avoid other measures, such as duct sealing and verification. However, choosing high-performance fenestration that performs better than the prescriptive requirements level can still earn significant credit through the performance method. For example, 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 fenestration U-factor will be smaller than in cold, mountain climates. Several factors affect window performance. For fenestration with NFRC ratings, the following performance features are accounted for in the U-factor and SHGC ratings:

1. 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 having no such conductive thermal barriers.
2. Number of panes of glazing, coatings, and fill gases. Double-glazing with coatings or dynamic glazing with controls 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.

### 3.5.8.4 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.

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 Section 3.5.8.6 for details.

Shading is much more difficult on the east and west sides of the house. 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.

### 3.5.8.5 **Reserved**

### 3.5.8.6 **Exterior Shading Devices**

The prescriptive requirements 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 an SHGC greater than 0.25 may be used with the prescriptive requirements if a qualifying exterior shading device is used. Exterior shading devices and associated SHGC values are shown in Table 3-3. 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 overhangs are used, the SHGC requirements of prescriptive Package A may be met if the calculated combination of the overhang and fenestration SHGC efficiency is equal or lower than 0.25.

For compliance credit, exterior shading devices must be permanently attached as opposed to being attached using 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. Compliance form CF1R-ENV-03 is used to calculate the combined SHGC of windows and exterior shading devices. When exterior shades are required for compliance, they must also be listed on the CF1R form and documented on the plans.

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

*Equation 3-1:*

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

All operable windows and skylights 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 0.25 and an insect screen with an SHGC of 0.76. For this default case, the SHGC of the window is the  $\text{SHGC}_{\text{min}}$ , and the SHGC of the exterior sunscreen is  $\text{SHGC}_{\text{max}}$ . Working through the math on the CF1R-ENV-03 form,  $\text{SHGC}_{\text{combined}}$  is 0.25. This means that any combination of window SHGC and exterior SHGC that results in a  $\text{SHGC}_{\text{combined}}$  of 0.25 or less complies with the prescriptive requirements.

Most of the shading devices (other than the default insect screen) have an SHGC of 0.30 or lower. Combining this with the SHGC of any window may result in a combined SHGC that is equal to 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 form CF1R-ENV-03 is used to calculate the combined SHGC of windows and exterior sunscreen type shading devices. When exterior shades are required for compliance, they must be listed on the CF1R form and be documented on the plans.

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<sup>1</sup> The equation can be found in the *2016 Residential Compliance Manual*, and it is included in WS-3R in Appendix A.

**Table 3-3: Exterior Shades and Solar Heat Gain Coefficients**

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

**3.5.8.7 Interior Shading**

There is no credit for interior aftermarket shading devices, although they can be effective in reducing solar gains and should be considered by homeowners. The Energy Commission considers these added interior shades in the category of home furnishings and not a feature of the house that is provided by the builder or fenestration manufacturer. Draperies, interior blinds, interior shades, and other interior devices are not credited toward energy compliance; however, 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.

**3.5.8.8 Bay Windows**

Bay windows are a special compliance case. Bay windows may either have a unit NFRC rating (that is, 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. Nonrated 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 or area-weighted average, the project must show compliance using the performance approach.

Bay windows with no rating for the entire unit (where there are multiple windows that make up the bay) and with factory-installed or field-installed insulation must comply accounting for the performance characteristics of each component separately. Opaque portions of bay windows including roofs and floors must be insulated to meet the wall insulation requirements of Package A for prescriptive compliance. The opaque portion must either meet the minimum insulation requirements of Package A for the applicable climate zone or be included in a weighted average U-factor calculation of an overall opaque assembly that does meet the Package A requirements. For the windows, the U-factor and SHGC values may be determined either from an NFRC rating or by using default values in Tables 110.6-A and 110.6-B of the Energy Standards. 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.

### 3.5.8.9 Natural Ventilation Through Fenestration

Operable fenestration can be a source of ventilation air useful for improving indoor air quality by dilution of indoor air contaminants and moisture and by “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 fenestration 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.

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

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 3.6.1.17 and 3.6.1.18.

### 3.5.8.10 Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that the fenestration efficiency values, areas, orientation, and so forth be indicated on the CF1R form and also specified on the building plans. In addition, the area-weighted efficiency values of the actual installed fenestration products shall meet or exceed the efficiency values on the CF1R form. For more information, see Compliance and Enforcement on fenestration in Chapter 2 of this manual.

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## 3.6 Envelope Features

This section of the building envelope chapter addresses the requirements for the building shell, excluding fenestration. Components of the building shell include walls, floors, and roofs and/or ceilings. Fenestration, windows, and doors are addressed in Section 3.5.

### 3.6.1 Mandatory Measures

§110.7, §110.8, §150.0

#### 3.6.1.1 Joints and Other Openings

§110.7

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

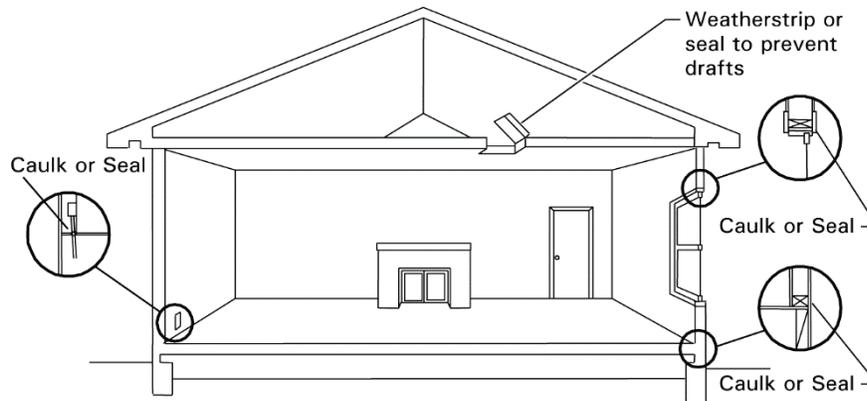
1. Exterior joints around window and door frames, including doors between the house and garage, between interior HVAC closets and conditioned space, between attic access and conditioned space, between wall sole plates and the floor, exterior panels and all siding materials
2. Openings for plumbing, electricity, and gas lines in exterior and interior walls, ceilings, and floors

3. Openings in the attic floor (such as where ceiling panels meet interior walls, 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))
6. All other such openings in the building envelope.

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

1. Stucco
2. Caulking and taping all joints between wall components (for example, between slats in wood slat walls)
3. Building wraps
4. Rigid wall insulation installed continuously on the exterior of the building

**Figure 3-9: Caulking and Weatherstripping**



Source: California Energy Commission

**Construction Practice/Compliance and Enforcement**

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

**3.6.1.2 Certification of Insulation Materials**

§110.8(a)

Manufacturers must certify that insulating materials comply with *California Quality Standards for Insulating Materials* (CCR, Title 24, Part 12, Chapters 12-13), which ensure that insulation sold or installed in the State performs according to stated R-values and meets minimum quality, health, and safety standards. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Material* to verify the certification of the insulating material. If an insulating product is not listed in the current 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](mailto:HomeProducts@dca.ca.gov).

### 3.6.1.3 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, a volatile and harmful organic chemical.

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 vapor retarder must be placed in the wall construction to isolate the insulation from the interior of the space. The vapor retarder must be 4-mil (0.1 mm) thick polyethylene or equivalent.

### 3.6.1.4 Flame Spread Rating of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* requires that exposed facings on insulation material be fire resistant and be tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings must be in contact with the finished assembly surface, or they are considered exposed applications and cannot be installed.

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

### 3.6.1.5 Insulation Requirements for Heated Slab Floors

§110.8(g)

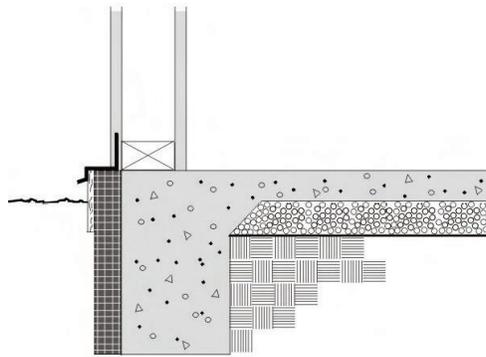
Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A and Table 3.4 below. The top of the insulation must be protected with a rigid material to prevent intrusion of insects into the building foundation.

A common location for the slab insulation is on the foundation perimeter. (See Figure 3-10.) Insulation that extends downward to the top of the footing is acceptable. Otherwise, the insulation must extend downward from the level of the top of the slab, down 16 inches (40 cm) or to the frost line, whichever is greater.

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

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

**Figure 3-10: Perimeter Slab Insulation**



Source: California Energy Commission

**Table 3-4: Slab Insulation Requirements for Heated Slab Floors**

Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Value
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop at the top of the footing where this is less than the required depth. For below grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.	1 – 15	5
			16	10
Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plan view.	1 – 15	5
			16	10 vertical and 7 horizontal

**3.6.1.6 Wet Insulation Systems**

§110.8(h)

Wet insulation systems are roofing systems where the insulation is installed above the waterproof membrane of the roof. Water can penetrate this insulation material and affect the energy performance of the roofing assembly in wet and cool climates. In Climate Zones 1 and 16, the insulating R-value of continuous insulation materials installed above the waterproof membrane of the roof must be multiplied by 0.8 and using the result value in choosing the table column in Reference Joint Appendix JA4, for determining assembly U-factor (when using the Joint Appendix JA4 table to comply). See the footnotes for Tables 4.2.1 through 4.2.7 in the Reference Joint Appendix JA4.

### 3.6.1.7 Roofing Products Solar Reflectance and Thermal Emittance

§110.8(i)

Roofing products shall be rated by the Cool Roof Rating Council (CRRC) and labeled appropriately by the roofing manufacturer for both solar reflectance and thermal emittance. The CRRC certification includes solar reflectance and thermal emittance. There are three kinds of solar reflectance:

1. Initial solar reflectance.
2. Three-year aged solar reflectance.
3. Accelerated aged solar reflectance.

All requirements of the Energy Standards are based on the three-year aged reflectance. However, if the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the aged value shall be derived from the CRRC aged value equation (using the initial value for solar reflectance) or an accelerated process. Until the appropriate aged rated value for the reflectance is posted in the directory, the equation below can be used to calculate the aged rated solar reflectance or a new method of testing is used to find the accelerated solar reflectance.

*Equation 3-2:*

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

Where:

$\rho_{\text{initial}}$  = Initial Reflectance listed in the CRRC Rated Product Directory

$\beta$  = soiling resistance which is listed in Table 3-5

**Table 3-5: Values of Soiling Resistance  $\beta$  by Product Type**

PRODUCT TYPE	$\beta$
Field-applied coating	0.65
Other	0.70

The Energy Standards do not distinguish between initial and aged thermal emittance, meaning that either value can be used to demonstrate compliance with the Energy Standards. If a manufacturer fails to obtain CRRC certificate for its roofing products, the following default aged solar reflectance and thermal emittance values must be used for compliance:

1. For asphalt shingles, 0.08/0.75
2. For all other roofing products, 0.10/0.75



coatings shall be manufactured to contain no less than 20 percent Portland cement and meet the requirements of ASTM D822, ASTM C1583, and ASTM D5870.

*c. Other Field-Applied Liquid Coatings*

Other field-applied liquid coatings include elastomeric and acrylic-based coatings. These coatings must be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. The field-applied liquid coatings must be tested to meet several performance and durability requirements as specified in Table 110.8-C of the Energy Standards or the minimum performance requirements of ASTM C836, D3468, or D6694, whichever are appropriate to the coating material.

### 3.6.1.8 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 are installed below the roof deck in the attic and reduce radiant heat to air distribution ducts and insulation located below the radiant barrier. To qualify, a radiant barrier must have an emittance of 0.05 or less. The product must be tested according to ASTM C-1371-10 or ASTM E408-13(2013) and must be certified by the California Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation and listed in its Consumer Guide and Directory of Certified Insulation material, at <http://www.bhfti.ca.gov/industry/tinsulation.shtml>.

### 3.6.1.9 Ceiling and Attic Roof Insulation

§110.8(d), §150.0(a).

Wood-framed roof/ceiling construction assemblies must have at least R-22 insulation or a maximum U-factor of 0.043 based on 16 inch on center wood-framed rafter roofs, as determined from JA4. Some areas of the roof/ceiling can be greater than the maximum U-factor as long as other areas have a U-factor lower than the requirement and the weighted average U-factor for the overall ceiling/roof is 0.043 or less.

Metal-framed and roof/ceiling constructions other than wood-framed must have a U-factor of 0.043 or less to comply with the mandatory measures. If the insulation is not penetrated by framing, such as rigid insulation laid over a structural deck, then the rigid insulation can actually have a rated R-value of less than R-22 so long as the total roof/ceiling assembly U-factor is not greater than U-0.043.

### 3.6.1.10 Loose Fill Insulation

§150.0(b)

Loose fill insulation must be blown in evenly, and insulation levels must be documented on the certificate of installation (CF2R). 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 ft<sup>2</sup> for the corresponding R-value. When installing loose fill insulation, the following guidelines should be followed:

1. For wood trusses that provide a flat ceiling and a sloped roof, the slope of the roof should be 4:12 or greater 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.

2. 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.
3. At the apex of the truss, a clearance of at least 30 inch should be provided to simplify installation and inspection.

#### 3.6.1.11 Wall Insulation

§150.0(c)

The mandatory measures have two requirements depending on frame size:

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

There are several cases where the mandatory measures for wall insulation do not apply or apply in a special way. For best practice, the following should be implemented:

1. The mandatory measures apply to framed foundation walls of heated basements or heated crawl spaces that are located above grade, but not to the portion that is located below grade.
2. For additions to existing buildings, existing wood-framed walls that are already insulated with R-11 insulation need not comply with the mandatory R-13 wall insulation.
3. Rim joists between floors of a multistory building are deemed to comply with these mandatory measures if they have R-13 insulation installed on the inside of the rim joist and are properly installed between intersecting joist members.

Demising partitions and knee walls are not required to meet the prescriptive requirements of §150.1(c)1B. Demising partitions and knee walls are required to meet the mandatory minimum insulation requirement as set in §150.0(c)1 and §150.0(c)1, requiring that insulation not less than R-13 be installed between 2x4 framing, or a U-factor that shall not exceed U-0.102. §150.0(c)2 requires insulation not less than R-19 be installed in framing of 2x6 inch or greater, or a U-factor equal to or less than 0.074.

#### 3.6.1.12 Raised-Floor Insulation

§150.0(d)

Wood-framed floors must have at least R-19 insulation installed between framing members, or the construction must have a U-factor of 0.049 or less. The equivalent U-factor is based on R-19 insulation in a 2x6, 16 inch on center wood-framed floor without a crawl space. The R-19 insulation value and U-factor of U-0.049 are for the floor assembly alone and do not assume the effects of a crawlspace or buffer zone beneath the floor. If comparing to a crawlspace assembly, the equivalent U-factor is 0.037, which includes the effect of the crawlspace.

Other types of raised floors, except for concrete raised floors (concrete raised floors do not have a mandatory requirement, but do have a prescriptive requirement) must also meet the maximum U-factor. In all cases, some areas of the floor can have a U-factor greater than the requirement as long as other areas have a U-factor that is lower than the requirement and the area-weighted average U-factor is less than that described above.

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

When a controlled ventilated or an unvented crawlspace is used, raised-floor insulation is not required, although vapor retarder is required over the ground, and the foundation walls must be insulated.

### 3.6.1.13 Fireplaces, Decorative Gas Appliances, and Gas Logs

§150.0(e)

The Energy 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. Reduced infiltration is also a benefit when the fireplace is not operating (the majority of the time for most homes).

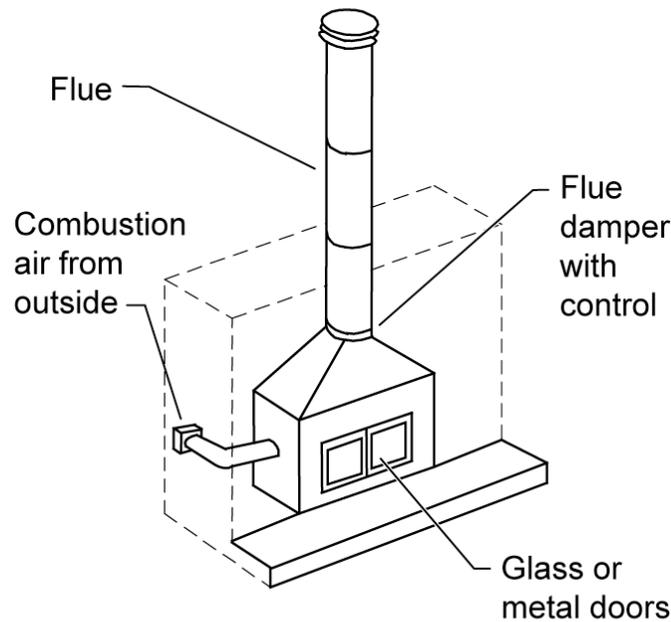
Installation of factory-built or masonry fireplaces (see Figure 3-12) must include:

1. Closable metal or glass doors covering the entire opening of the firebox that can be closed when the fire is burning.
2. A combustion air intake that is at least 6 square inches to draw air from outdoors and 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 a concrete slab and the fireplace is not located on an exterior wall.*)
3. 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.*)

Continuously 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.

Equipment certified to the Energy Commission as a gas space heater may have a continuously burning pilot light.

**Figure 3-12: Fireplace Installation**

Source: California Energy Commission

**Example 3-15****Question:**

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

**Answer:**

The Energy Standards disallow standing pilot lights. The flue damper may be blocked open if required by either the manufacturer's installation instructions or the California Mechanical Code.

**Example 3-16****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 3-17

**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 3-18

**Question:**

Do decorative gas appliances need glass or metal doors?

**Answer:**

Yes, 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.

**3.6.1.14 Slab Insulation**

*§150.0(f) §118(g)*

The mandatory requirements state 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.

**3.6.1.15 Vapor Retarder**

*§150.0(g) and RA4.5.1*

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

1. Class I: 0.1 perm or less
2. Class II:  $0.1 < \text{perm} \leq 1.0$  perm
3. Class III:  $1.0 < \text{perm} \leq 10$  perm

In Climate Zones 14 and 16, a continuous Class I or Class II vapor retarder, lapped or joint sealed, must be installed on the conditioned space side of all insulation in all exterior walls, on the roof decks of vented attics with above-or below-deck air-permeable insulation, and in unvented attics with air-permeable insulation.

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

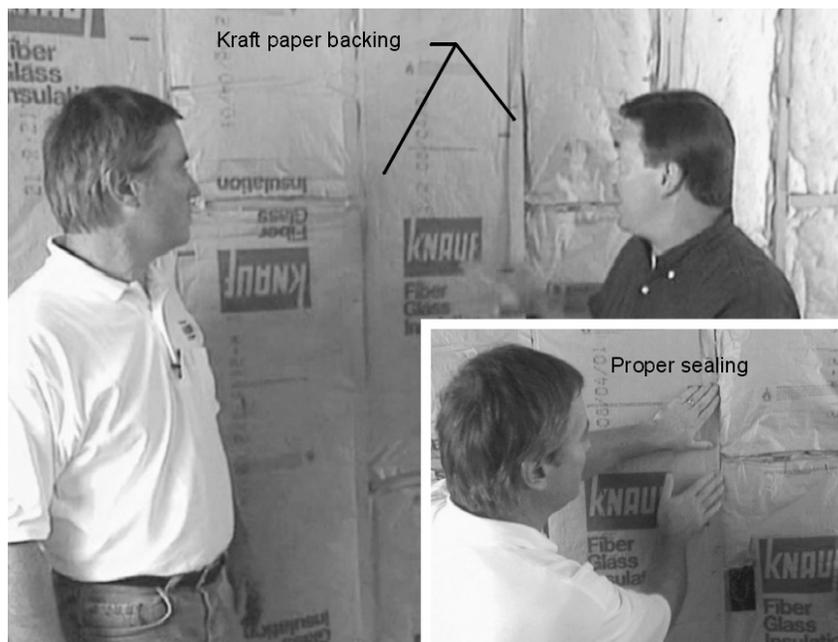
If a building has a controlled-ventilation crawl space, a Class I or Class II vapor retarder must be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with RA4.5.1.

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

1. Foil and other facings on gypsum board can provide moisture resistance, and product literature should always be checked to ensure conformance to ASTM E96.
2. The kraft paper used as facing on thermal batt insulation material is typically a Class II vapor retarder. Faced batts may have flanges for fastening to assembly framing. Fastening flanges may be face- or inset-stapled or not stapled at all, as the flanges provide no moisture control. Face stapling of flanged thermal batts helps ensure the insulation material is installed fully and properly within the framed cavity. Flangeless batts are also common and require no fastening as these materials maintain installation integrity through friction-fitting within the cavity of framed assemblies. In all cases, the insulation must be installed properly.
3. Many interior painted surfaces may also qualify for meeting the vapor retarder requirement if the paint product has been tested to show compliance as a vapor retarder. The effectiveness of vapor retarder paint depends upon the installed thickness (in mils). These products often require more than one layer to achieve the tested perm rating, and care must be shown by the installer of the paint and for inspection by the building official.
4. Closed-cell spray polyurethane foam (ccSPF) products can provide Class I or Class II vapor retarder performance, depending on thickness.

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

**Figure 3-13: Typical Kraft Faced Vapor Retarder Facing**



Source: California Energy Commission

### 3.6.1.16 Recessed Luminaires in Ceilings

§150.0(k)1C

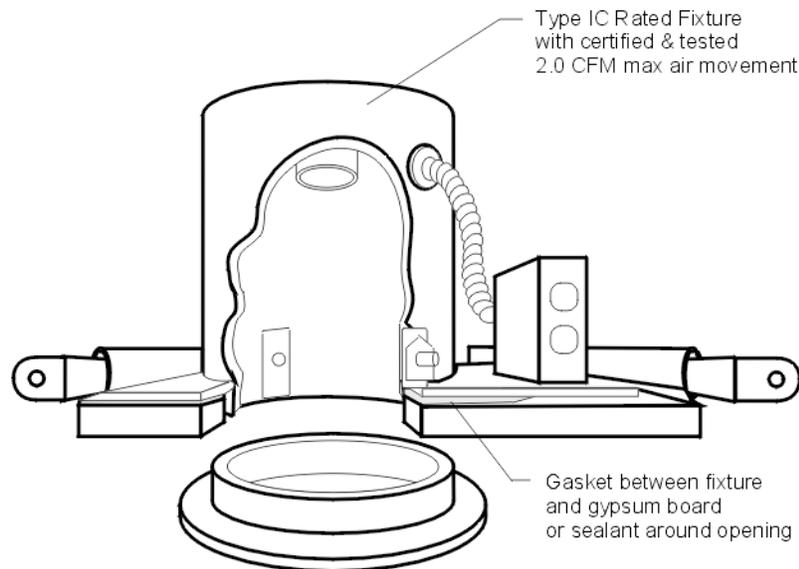
Luminaires recessed in insulated ceilings can create thermal bridging through the insulation. Not only does this degrade the performance of the ceiling assembly, but it can permit condensation on a cold surface of the luminaire if exposed to moist air, as in a bathroom.

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

1. They must be listed as defined in the Article 100 of the California Electric Code for zero clearance insulation contact (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Code Council (ICC). This enables insulation to be in direct contact with the luminaire.
2. The luminaire must have a label certified as per §150.0(k)1Cii for airtight (AT) construction. Airtight 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.
3. The luminaire must be sealed with a gasket or caulk between the housing and ceiling.

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

**Figure 3-14: IC-Rated Luminaire (Light Fixture)**



Source: California Energy Commission

**3.6.1.17 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*. The whole-building ventilation airflow shall be provided to meet the requirements of ASHRAE 62.2. Window operations are not a permissible method for providing whole-house ventilation. 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.

**3.6.1.18 Ventilation Openings**

ASHRAE Standard 62.2 requires ventilation openings in habitable spaces, toilets, and utility rooms. Spaces that meet the exhaust requirements are exempted from meeting the whole-building ventilation air flow requirement; therefore, an exhaust system can be substituted for a ventilation opening. (See Section 4.6.6.6.)

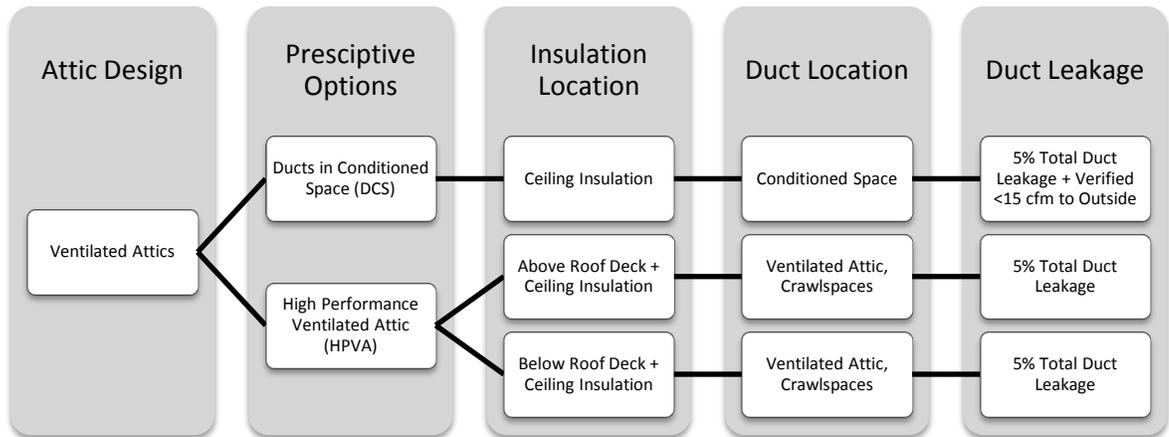
Field verification and diagnostic testing is required to confirm proper ventilation airflow, following the procedures specified in the RA3.7.

**3.6.2 Prescriptive Approach**

**3.6.2.1 Roof/Attic**

The 2016 Energy Standards are designed to offer flexibility to the builders and designers of residential new construction in terms of achieving the intended energy efficiency targets. As such, the Energy Standards offer several options for achieving one of two design objectives related to improving energy performance of homes built with ventilated attics in Climate Zones 4, 8-16 as shown in Figure 3-15.

**Figure 3-15: Ventiladed Attic Prescriptive Compliance Choices**



High-Performance Ventiladed Attic (HPVA) implements measures that minimize temperature difference between the attic space and the conditioned air being transported through ductwork in the attic. The package consists of insulation either below the roof deck or insulation above the roof deck in addition to insulation at the ceiling, R-8 ducts, and 5 percent total duct leakage of the nominal air handler airflow.

Ducts in Conditioned Space (DCS) locates ducts and air handlers in the thermal and air barrier envelope of the building. The Ducts in Conditioned Space option requires field verification to meet the prescriptive requirement.

*Note:* All the prescriptive requirements for HPVA or DCS are based on the assumption that the home is built with the following construction practices:

1. The attic is ventilated with appropriate free vent area as described in Section 3.6.2.1(E).
2. The roof is constructed with standard wood rafters and trusses.
3. The outermost layer of the roof construction is either tiles or shingles.
4. The air handler and ducts are in the ventilated attic for HPVA and are in conditioned space for DCS.
5. The air barrier is located at the ceiling (excludes “cathedral” roof/ceiling systems).

If a building design does not meet all of these specifications, it must comply through the performance approach.

#### Example 3-19

**Question:**

If 5 percent of a roof will be a cathedral ceiling, can it still comply under the prescriptive requirements?

**Answer:**

No. The entire attic must be a ventilated space with the building air barrier located at the ceiling with standard wood rafter trusses to comply with the prescriptive requirements. This project must comply through the performance approach.

#### Example 3-20

**Question:**

Does a sealed (unventilated) attic with insulation at the roof deck comply under the prescriptive requirements?

**Answer:**

No. The entire attic must be a ventilated space with the building air barrier located at the ceiling with standard wood rafter trusses to comply with the prescriptive requirements. This project must comply through the performance approach.

### A. Roof/Ceiling Insulation

This section describes the requirements and approaches necessary to meet the requirements for the HPVA as they relate to roof/ceiling insulation. HVAC aspects of the HPVA including duct insulation and duct leakage are described in Section 4. Requirements and approaches to meet the Ducts in Conditioned Space (DCS) are also described in Section 4 of this manual.

§150.1(c).1 requires different values of roof/ceiling insulation, depending on whether the HPVA (option A or B) or DCS (option C) is chosen as described in Figure 3-16.

The standard design in the performance approach is based on Option B, as detailed in <sup>1</sup> of Figure 3-17, installed with a tile roof.

**Figure 3-16: Prescriptive Requirements for Roof/Ceiling Insulation (§150.1(c).1)**

Strategy		How to Comply
<b>High-Performance Ventilated Attics</b>		
Option A	Vented attic with continuous insulation applied above the roof deck. (Figure 3-18).  Ceiling insulation required separately above finished attic ceiling.	Table 150.1-A of the Energy Standards Roof Assembly Option A
Option B	Vented attic with batt, spray in cellulose/fiberglass secured with netting, or SPF. (Figure 3-18).  Ceiling insulation required separately above finished attic ceiling.	Table 150.1-A of the Energy Standards Roof Assembly Option B
<b>Ducts in Conditioned Space</b>		
Option C	Vented attic with no insulation at roof deck. Ceiling insulation required separately above finished attic ceiling.  Ducts and air handler equipment in conditioned space that is NOT a sealed attic.	Table 150.1-A of the Energy Standards Roof Assembly Option C  Form: CF2R-MCH-20b

**Figure 3-17: Checklists for Prescriptive Requirements for HPVA/DCS for the related climate zones**

Option A (CZ 4, 8-16)	Option B <sup>1</sup> (CZ 4, 8-16)	Option C (CZ 4, 8-16)
<input type="checkbox"/> Vented attic <input type="checkbox"/> R6 (air space) or R8 (no air space) continuous above deck rigid foam board insulation <input type="checkbox"/> R38 ceiling insulation <input type="checkbox"/> Radiant Barrier <input type="checkbox"/> R8 duct insulation <input type="checkbox"/> 5% total duct leakage	<input type="checkbox"/> Vented attic <input type="checkbox"/> R13 (air space) or R15 (no air space) batt, spray in cellulose/fiberglass below roof deck secured with netting, or SPF <input type="checkbox"/> R38 ceiling insulation <input type="checkbox"/> R8 duct insulation <input type="checkbox"/> 5% total duct leakage	<input type="checkbox"/> Vented attic <input type="checkbox"/> R30 or R38 ceiling insulation (climate zone specific) <input type="checkbox"/> R6 or R8 ducts (climate zone specific) <input type="checkbox"/> Radiant Barrier <input type="checkbox"/> Verified ducts in conditioned space
<sup>1</sup> Standard Design used to set the energy budget for the Performance Approach.		

Figure 3-18: Option A (left) and Option B (right)

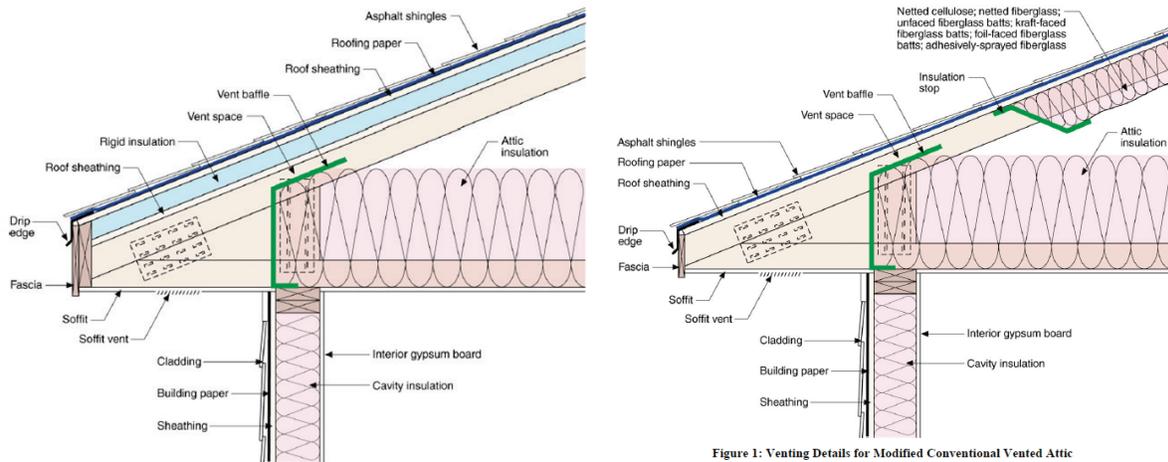


Figure 1: Venting Details for Modified Conventional Vented Attic

Source: Building Science Corporation

Option A requires insulation above the roof rafters, directly in contact with the roof deck, while Option B requires insulation installed between the roof rafters. The insulation values are different depending on whether there is an air gap present between the roofing materials and the roof deck. For roof constructions with an air gap present, which is standard for concrete or clay tile, R6 insulation is required above the roof rafters or R13 below the roof deck placed between the rafters. If there is no air gap present between the roofing and roof deck, R8 insulation is required above the roof rafter or R18 below the roof deck placed between the rafters.

The R-values for insulation installed above the roof rafters are lower than the R-values for insulation installed below the roof deck due to the added benefit of reduced thermal bridging when continuous insulation is applied to the roof deck. Further, when an air space is present between the roofing and the roof deck, the effect of insulation is greater than when there is no air space.

Standard residential roof construction practice in California for concrete/clay tiles is to have an air gap between the tiles and roof deck. For asphalt shingles, the practice is to place the roofing material directly on top of the roof deck without an air gap. It is, however, possible for builders to construct different construction assemblies than these standard assemblies such as providing air gaps between the asphalt shingles and roof deck through construction techniques explained later in this document.

The prescriptive requirement for roof deck insulation can also be met by placing ducts in conditioned space and getting HERS verification (Option C). The requirements to comply with Option C are explained in Chapter 4 of this manual.

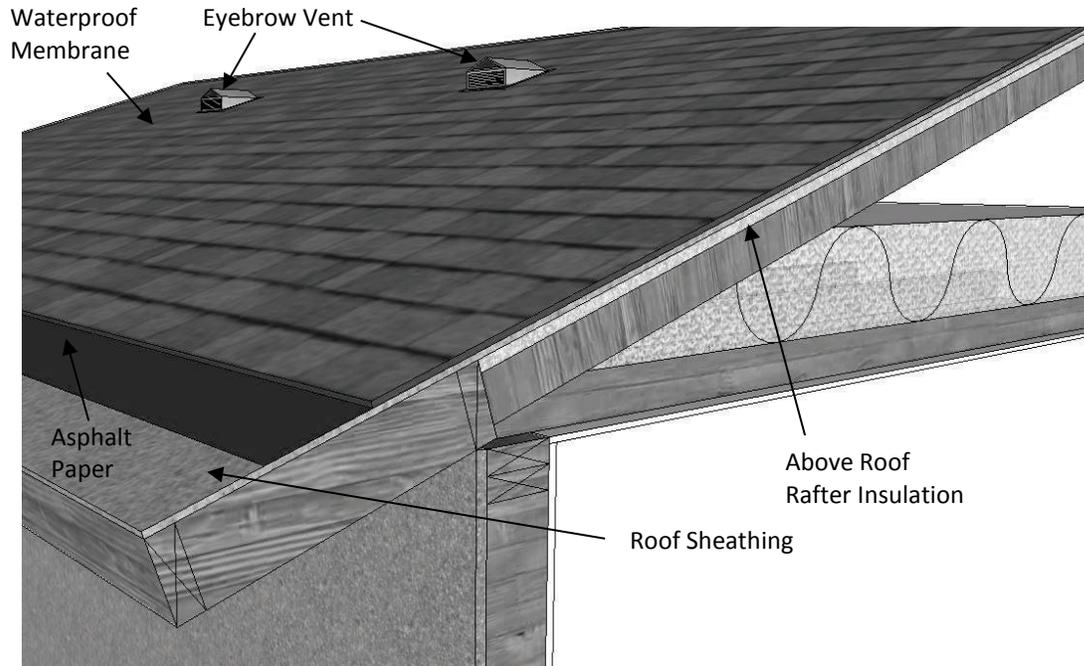
*Construction Practice/Compliance and Enforcement***Is this strategy new for you?**

## Design Considerations and Best Practices:

- Commit to a compliance strategy early in the building design process.
- Have a kick-off meeting with builder, subcontractor, designer, energy consultant, and HERS Rater to set expectations and express the value of the design.
- Communicate strategy and schedule to subcontractors and other team members early.
- May require coordinating an additional building inspection for above-deck insulation prior to installation of final roofing materials.
- Include insulation specifications according to the CF1R on the building plans.
- Roofer will install above-roof deck insulation, whereas insulation contractor will install insulation below roof deck (ideally at the same time as ceiling insulation).
- All relevant subcontractors must be aware of where air barrier is located and be conscious of where they make penetrations, especially if designing for verified ducts in conditioned space.

**1. Above-Roof Rafter Insulation (Option A):**

In a vented attic, rigid board insulation can be installed above the roof rafters to add value to the thermal integrity of the roof system. As described above, the prescriptive insulation value depends on whether an air gap is present above the rigid insulation. Above-rafter insulation can be implemented with either asphalt shingles or clay/concrete tiles. Check manufacturer's specifications for proper nail schedules (fastening patterns); this will change depending on the roof pitch, truss spacing, and roofing material. When above-rafter insulation is installed, a radiant barrier must also be installed in the required climate zones.

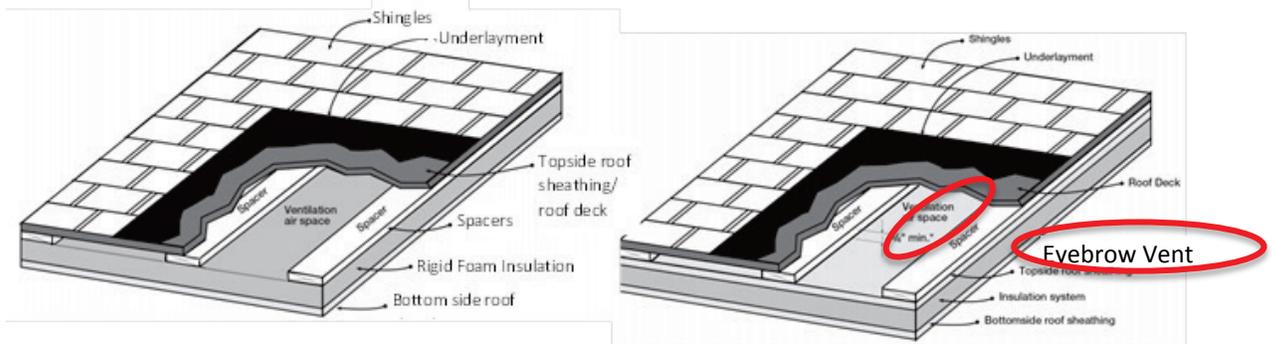
**Figure 3-19: Above-Roof Rafter Insulation**

Source: California Energy Commission

**Roofing With Asphalt Shingles – Best Practices:**

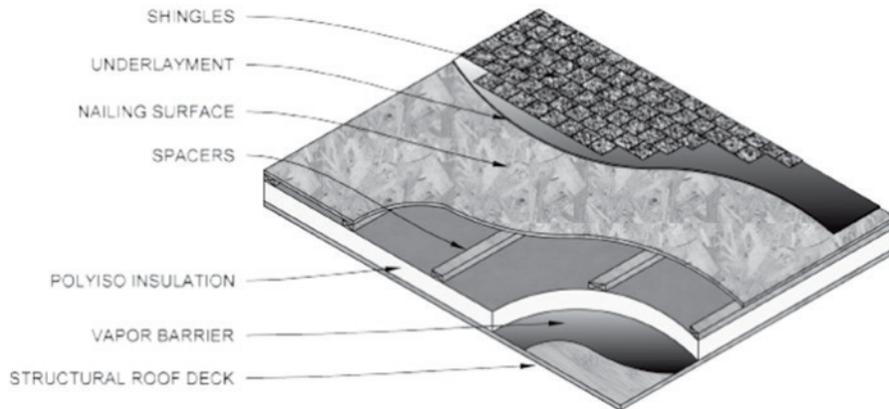
When installing asphalt shingles with roof deck insulation, it is best to implement a ventilation method between the roofing product and the top sheathing or insulation, as shown in Figure 3-20, to prevent the roofing material from experiencing high temperatures and reducing effective product life. Spacers can be inserted either above or below a second roof sheathing to provide both roof deck ventilation and a nailable base for asphalt shingles, as seen in Figure 3-21. Manufacturers offer prefabricated insulation products with spacers and top sheathing. Check manufacturers' and trade association websites for a list of products available that provide an air space and nailable base.

**Figure 3-20: Above Deck Insulation With Spacers Installed With and Without Top Sheathing**



Source: ARMA technical bulletin No. 211-RR-94

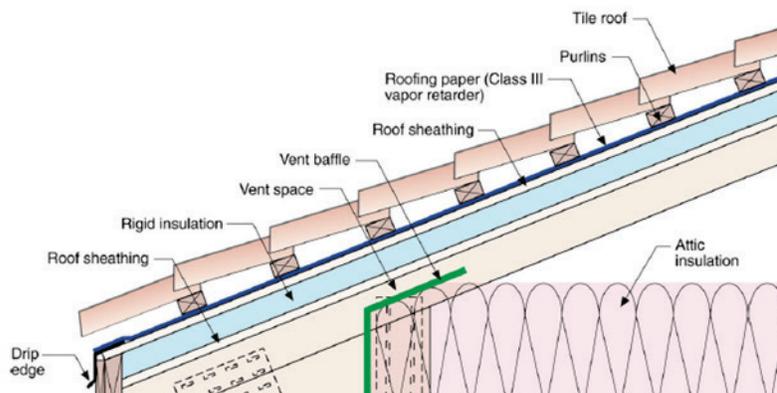
**Figure 3-21: Asphalt Shingles and Spacers Installed With Above-Deck Insulation**



Source: PIMA Tech Bulletin #106

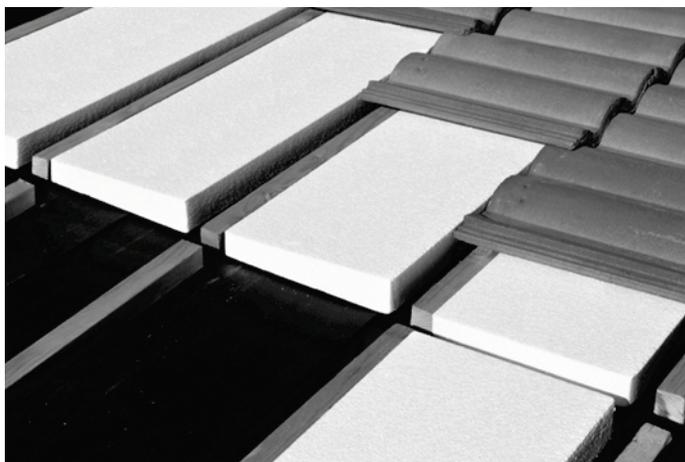
**Roofing With Concrete/Clay Tiles – Best Practices:**

With tile roofs, there is traditionally an air gap between the tile and the roof deck due to the shape of the tiles and the way tiles are installed over battens. When adding insulation above roof deck, there are two options to addressing the air gap. If the air gap is desired, one option is to install rigid insulation over the roof deck and a second roof sheathing layer added above the rigid insulation, along with a vapor retarder above that to host the purlins above with the tiles rest. This is shown in Figure 3-22.

**Figure 3-22: Battens (Purlins) Installed With Above-Deck Insulation**

Source: Building Science Corporation

If the air gap is not desired, there are insulation products available that can fit directly under concrete/clay or steel tile, as shown in the figure below.

**Figure 3-23: Wedged Insulation Formed to Be Placed Directly Below Tile Without an Air Gap**

Source: Wedge-It

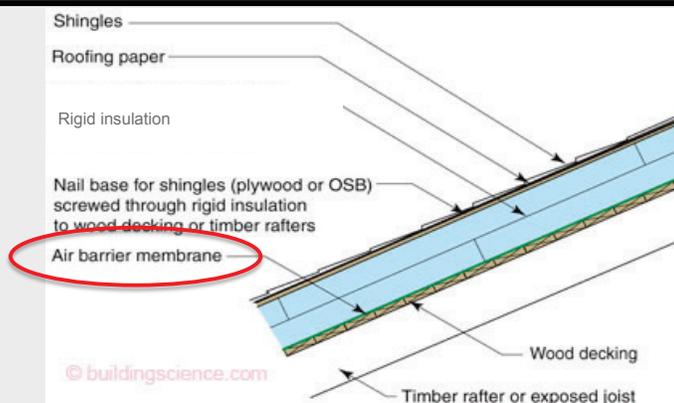
#### Example 3-21

##### Question:

A project plans to install R8 rigid foam insulation above the roof deck using two R4 foam boards. Can this method be used to meet the prescriptive requirements? If so, are there best practices for installing the two layers of insulation?

##### Answer:

Yes, installing two R4 rigid foam board layers meets the R8 prescriptive requirement. (Remember that R8 is required when there is no air gap between insulation and roofing materials, but R6 is required if there is air gap.) To prevent water infiltration, it is best to stagger the horizontal and vertical joints of the two layers and take care to seal each joint properly.



Source: Building Science Corporation

#### Example 3-22

##### Question:

A project plans to install R6 rigid foam insulation above the roof deck with roofing material placed *directly* over the insulation; does this meet the prescriptive requirements? Are there best practices for installing the insulation?

##### Answer:

No, this construction does not comply with the prescriptive requirements. R6 insulation can be used only above the roof deck when there is an air gap between the insulation and the finishing roofing material. Using spacers or battens (purlins) are two strategies to create this air gap. Products exist that combine insulation, spacers, and an additional sheathing for nailing asphalt shingles, check with insulation manufacturers for available products. Refer to the best practices above in the Above Roof Deck Insulation section. Alternatively, R8 insulation can be installed if no air gap is desired.

### Addressing Attic Ventilation With Above-Deck Insulation

Proper attic ventilation occurs at two points at the roof: the soffit (or eave) vents and the ridge (or eyebrow) vents. Ridge or eyebrow venting must be maintained when installing above-deck insulation, as shown in Figure 3-26.

#### Example 3-23

##### Question:

Does a roof assembly using above deck insulation meet Class A/B/C fire rating specifications, as determined by California Building Code, Chapter 15?

##### Answer:

Application of above-deck insulation affects the fire rating classification of roof covering products. Roof covering products are currently rated to class A/B/C based on the ASTM E108 (NFPA 256, UL790) test. Class A/B/C ratings are done with specific roof assemblies, and ratings are valid only when the installation is the same as the assembly as rated. Under current building code requirement, tile roof products installed directly over the roof deck or over purlins are automatically rated Class A. Chapter 15 in the California Building Code (and International Building Code section 1505 for Fire Classification) specify that certain roofing materials are Class A without having to test to ASTM E108. These materials include slate, clay, concrete roof tile, an exposed concrete roof deck, and ferrous and copper shingles; however, asphalt shingles are not covered under this category.

Insulation products, on the other hand, are subject to a different fire test from roof-covering products. California Building Code and International Building Code (Section 2603 for Foam Plastic Insulation) require foam plastic insulation to be tested to demonstrate a flame-spread index of not more than 75 and a smoke-developed index of not more than 450 according to ASTM E84 [UL723]. The requirements are applicable to roof insulation products, including XPS/polyiso/polyurethane above-deck insulation and SPF below-deck insulation products.

To ensure that roof assemblies with insulation meet the proper fire rating classification, roof product manufacturers and insulation manufacturers must test and develop assemblies that meet the CBC testing specifications.

## 2. Below-Deck Insulation (Option B):

In a vented attic, air-permeable or air-impermeable insulation (that is, batt, spray foam, loose-fill cellulose, or fiberglass) should be placed **directly** below the roof deck between the truss members and secured in place to provide a thermal barrier for the attic space. This is especially useful when ducts and equipment are present. Insulation must be in direct contact with the roof deck and secured by the insulation adhesion, facing, mechanical fasteners, wire systems, a membrane material, or netting.

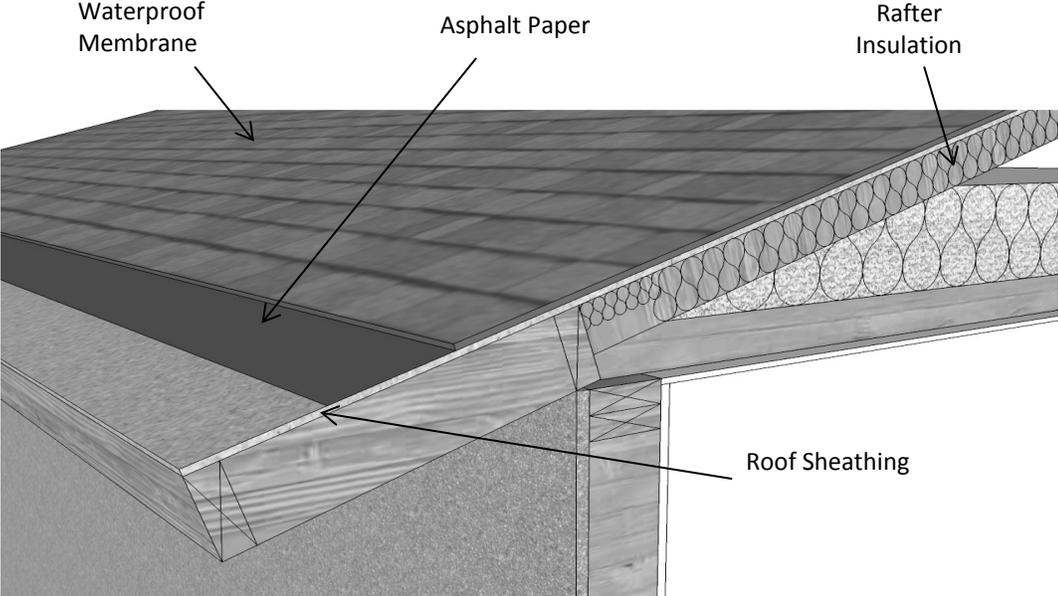
Proper attic ventilation must always be maintained to prevent the potential for moisture to condense. In Climate Zones 14 and 16, a Class I or Class II vapor retarder must also be used to manage moisture<sup>2</sup>, as stated in California Residential Code Section R806.2. See Figure 3-24 through Figure 3-27 for depictions of insulation options and maintaining proper ventilation. More information on best practices to maintain proper attic ventilation is discussed below.

### Best Practice:

Attic vapor retarders are not required in most climates when using spray foam, blown-in insulation or unfaced batts when sufficient attic ventilation is maintained. Even when not required, the use of vapor retarders can provide additional security against possible moisture buildup in attic and framed assemblies.

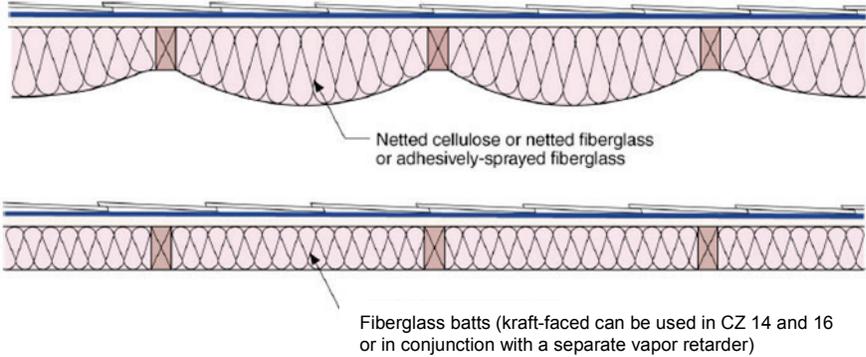
<sup>2</sup> Insulation Contractors Association of America. (2004). Technical Bulletin No. 6 Use of Vapor Retarders.

**Figure 3-24: Below-Roof Deck Insulation**



Source: California Energy Commission

**Figure 3-25: Placement of Insulation Below the Roof Deck**



Source: Building Science Corporation

When insulation is installed below the roof deck to meet the prescriptive requirements, a radiant barrier is not required. However, a draped radiant barrier may be installed to receive performance credit.

### Addressing Attic Ventilation With Below-Deck Insulation

When installing insulation below the roof deck, vent baffles and insulation stoppers can be used to maintain proper ventilation space, as shown in Figure 3-27. Proper flow of air through the space helps remove moisture and prevents any associated issues.

Figure 3-26: Insulation Air Baffles

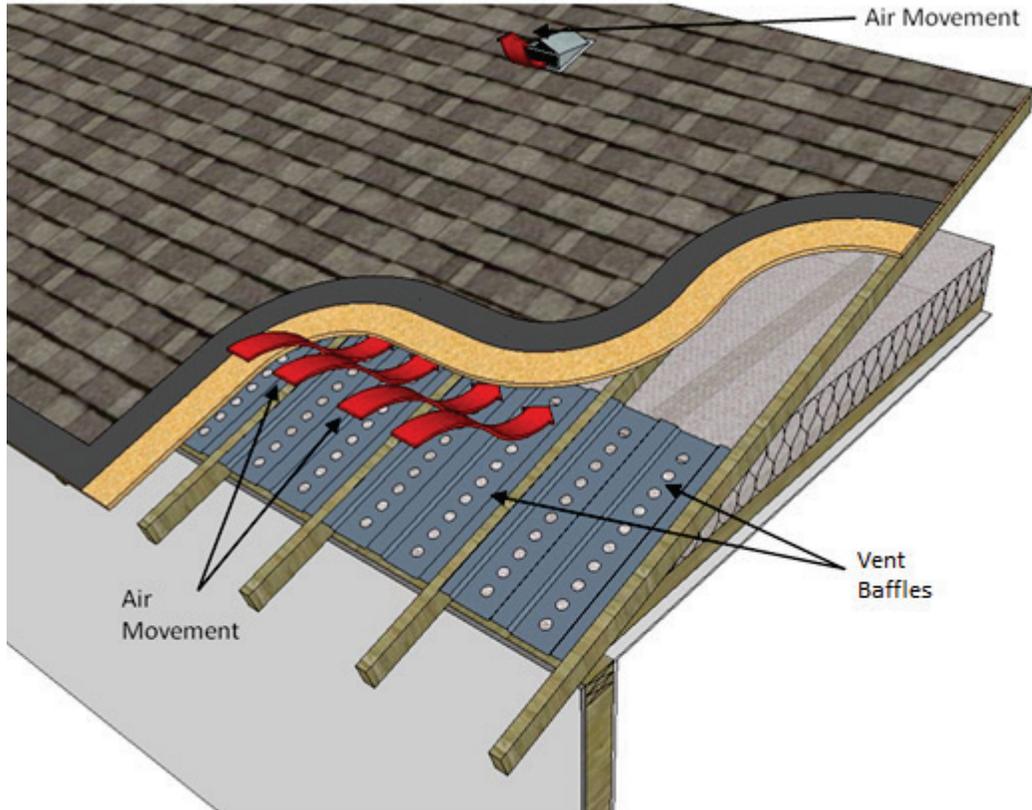


Figure 3-27: Vented Attic – Below-Deck Insulation With Insulation Stopper

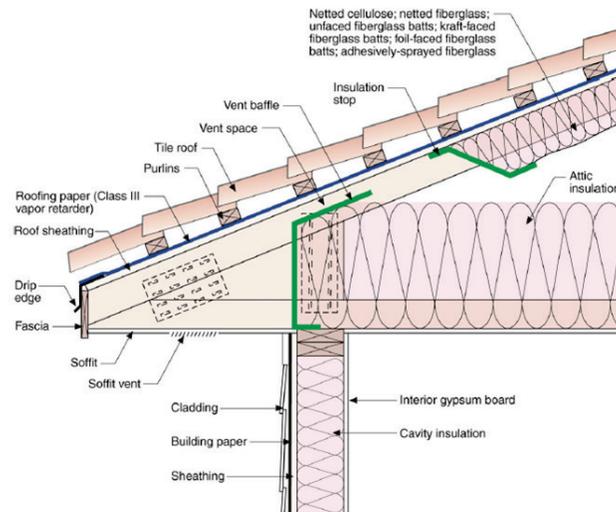


Figure 31: Vented Attic – Tile Roof – Air Permeable Insulation On Underside of Roof Deck - Can be

Source: Building Science Corporation

**Example 3-24****Question:**

A new construction project in Climate Zone 12 with HVAC ducts in the attic was designed to meet the prescriptive requirements for roof deck and ceiling insulation. Due to miscommunication amongst the team, however, the roof deck insulation was not installed, and R-49 ceiling insulation was installed instead. Does this project still comply?

**Answer:**

This project no longer meets the prescriptive requirements and must follow the performance approach. For future projects, clearly communicating the project expectations to all team members early in the construction process is key to succeeding at this design strategy. Having a project initiation meeting with all subcontractors and team members is a best practice, at least for the first few projects, until the entire team is aware of the design needs.

*Note: If the design was changed so that the roof deck has a radiant barrier and the HVAC equipment and ducts are verified to be in conditioned space, the altered design will meet the prescriptive requirements under Option C.*

**3. Duct and Air Handlers Located in Conditioned Space (Option C):**

Option C allows a project to place and verify that ducts are located in conditioned space instead of installing insulation at the roof deck. If complying with this path, ceiling and duct insulation must be installed at the values specified in Table 150.1-A for Option C, and a radiant barrier is also required in some climate zones. Simply locating ducts in conditioned space does not qualify for this requirement; a HERS Rater must test and verify the system and that the ducts are insulated to a level required in Table 150.1-A of the Energy Standards.

Design strategies that can be used to prescriptively comply with Option C include dropped ceilings (dropped soffit), plenum or scissor truss to create a conditioned plenum box, and open-web floor truss. The key is that the ducts and equipment are placed within the air barrier of the building. See Section 4.4.2 for detailed information on DCS strategies.

**B. Ceiling Insulation**

Insulation coverage should extend far enough to the outside walls to cover the bottom chord of the truss. However, insulation should not block eave vents in attics because the flow of air through the attic space helps remove moisture that can build up in the attic and condense on the underside of the roof. (See Figure 3-27.) This can cause structural damage and reduce the effectiveness of the insulation.

Based on area-weighted averaging, ceiling 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 Section 3.6.3.1(C) for details.

**C. Radiant Barriers**

§150.1(c)2

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

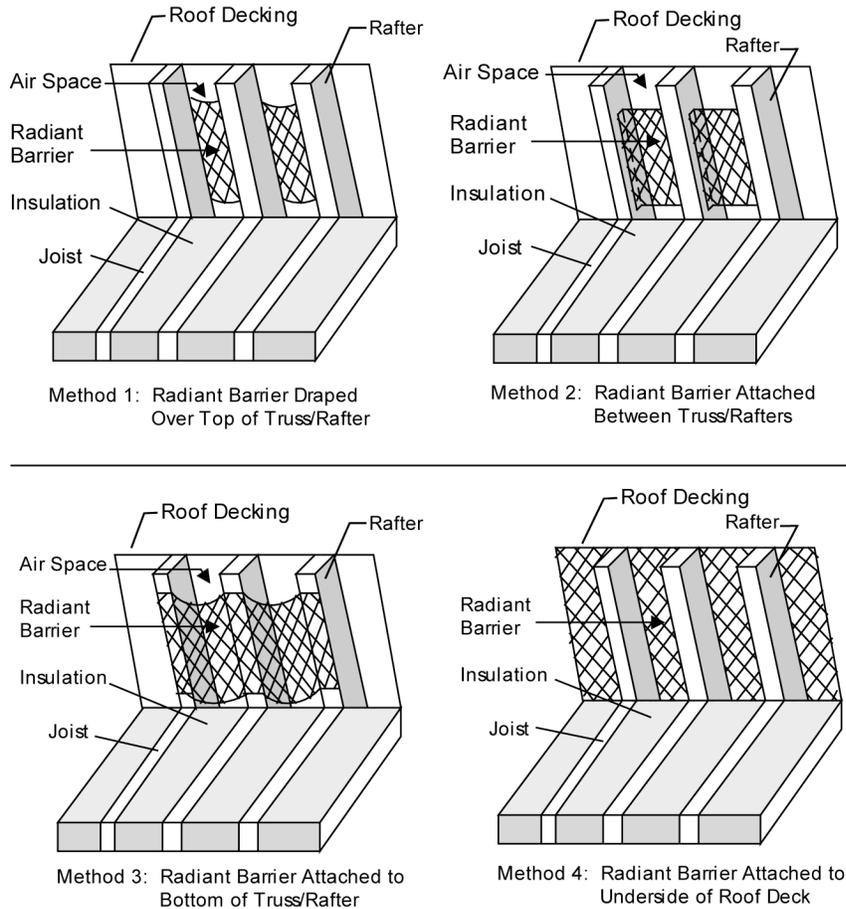
efficiency is also affected by the presence of a radiant barrier when using the performance approach.

#### *Construction Practice*

A radiant barrier must have a tested emissivity of 0.05 or less. The most common way of meeting the radiant barrier requirement is to use roof sheathing that has a radiant barrier bonded to it by the manufacturer. Some oriented strand board (OSB) products have a factory-applied radiant barrier. The sheathing is installed with the radiant barrier (shiny side) facing down toward the attic space. Alternatively, a radiant barrier material that meets the same ASTM test and moisture perforation requirements that apply to factory-laminated foil can be field-laminated. Field lamination must use a secure mechanical means of holding the foil type material to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material. Roofs with gable ends must have a radiant barrier installed on them to meet the radiant barrier requirement.

Other acceptable methods are to drape a foil type radiant barrier over the top of the top chords before the sheathing is installed, stapling the radiant barrier between the top chords after the sheathing is installed, and stapling the radiant barrier to the underside of the truss/rafters (top chord). For these installation methods, the foil must be installed with spacing requirements as described in Residential Reference Appendices RA4.2.1. Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces, particularly when roof sheathing is installed that does not include a laminated foil type radiant barrier. Radiant barrier foil material may be field-laminated after the sheathing has been installed by “laminating” the foil as described above to the roof sheathing between framing members. This construction type is described in the Residential Reference Appendices RA4.2.1.1. See below for drawings of radiant barrier installation methods.

**Figure 3-28: Methods of Installation for Radiant Barriers**



Source: California Energy Commission

**D. Roofing Products (Cool Roof)**

§150.1(c)11

Cool roofs of steep and low-sloped roofs are required in some climate zones. 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 requirement is based on an aged solar reflectance and thermal emittance tested value from the Cool Roof Rating Council (CRRC).

For projects using the prescriptive compliance path, an alternative to the aged solar reflectance and thermal emittance is to use the Solar Reflectance Index (SRI) to show compliance. A calculator has been produced to calculate the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The calculator can be found at <http://www.energy.ca.gov/title24/2016standards>. To calculate the SRI, the 3-year aged value of the roofing product must be used. By using the SRI calculator a cool roof may comply with an emittance lower than 0.85, as long as the aged reflectance is higher and vice versa.

The residential roofing product requirement in the prescriptive package is as follows:

1. For steep-sloped applications in Climate Zones 10-15, the three year aged solar reflectance minimum is 0.20 and the (three-year aged or initial) thermal emittance minimum is 0.75, or a minimum solar reflectance index (SRI) of 16.
2. For low-sloped roofing applications in Climate Zones 13 and 15, there is a minimum aged solar reflectance of 0.63 and thermal emittance of 0.75, or a minimum SRI of 75.

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

1. 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.
2. Roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft<sup>2</sup> are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI under Exception 2 to §150.1(c)11B.

#### *Construction Practice/Compliance and Enforcement*

The compliance and enforcement process should ensure that the cool roof efficiency values (solar reflectance and thermal emittance values) modeled on the CF1R 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 CF1R form. For more information on compliance and enforcement for cool roofs, see Chapter 2 of this manual.

---

#### Example 3-25

**Question:**

A computer method analysis shows that a new house requires R-19 ceiling insulation to comply using the performance approach, but the minimum mandatory insulation level for ceiling insulation is R-22. Which insulation level should be used?

**Answer:**

The mandatory insulation requirement is an area-weighted average. Therefore, some areas can have lower insulation, such as R-19, but other areas will need to have higher levels of insulation so that the area-weighted average is at least R-22.

#### Example 3-26

**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:**

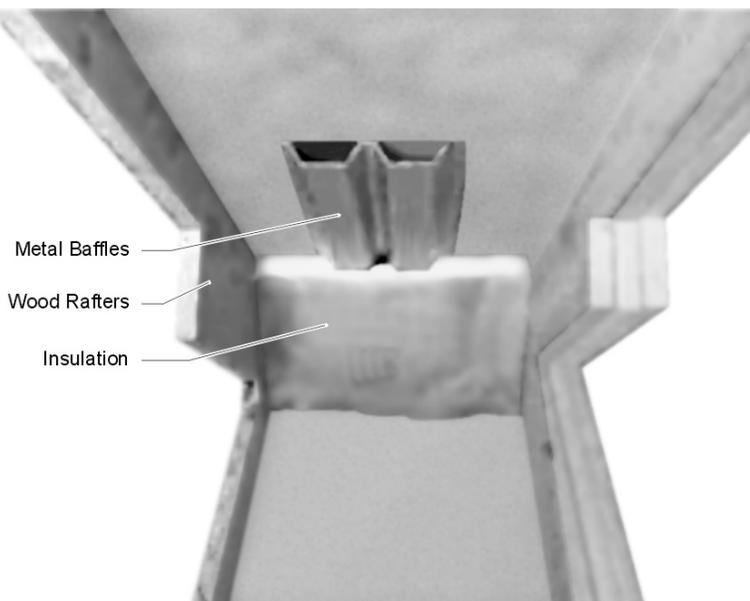
No. R-15 would not be sufficient because the required minimum ceiling insulation level established by the mandatory measures is R-22. However, R-15 could be used in limited areas, as follows:

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.
-

## E. Attic Ventilation

Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation. (See Figure 3-29.) 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 several acceptable methods for maintaining ventilation air, including preformed baffles made of either cardboard or plastic. In some cases, plywood baffles are used.

**Figure 3-29: Baffles at the Eave in Attics**



Source: California Energy Commission

Source: California Energy Commission

The California Building Code (CBC) requires a minimum vent area to be provided in roofs with attics, including enclosed rafter roofs creating cathedral or vaulted ceilings. Check with the local building jurisdiction to determine which of the two CBC ventilation requirements are to be followed:

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

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

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

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

### 3.6.2.2 Walls

#### A. Wall Insulation

##### 1. Framed Walls

§150.1(c)1B

The Package A prescriptive requirements (Table 150.1-A) call for a U-factor of 0.051 in Climate Zones 1-5 and 8-16, and a U-factor of 0.065 in Climate Zones 6 and 7.

The designer may choose any wall construction from Reference Joint Appendix JA4 (Tables 4.3.1 and 4.3.4) that has a U-factor equal to or less than 0.051 or 0.065, depending on the climate zone. U-factors can also be calculated by building the construction assembly in Commission-approved compliance software, including the inside finish, sheathing, cavity insulation, and exterior finish. JA4 Table 4.3.4 shows that a 2x6 wood-framed wall at 16" on center can achieve a U-factor of 0.051 with R-19 batt insulation in the cavity and R-5 exterior insulation. Some examples of various wood-framed wall assemblies, associated construction, and U-values are provided in Figure 3-30.

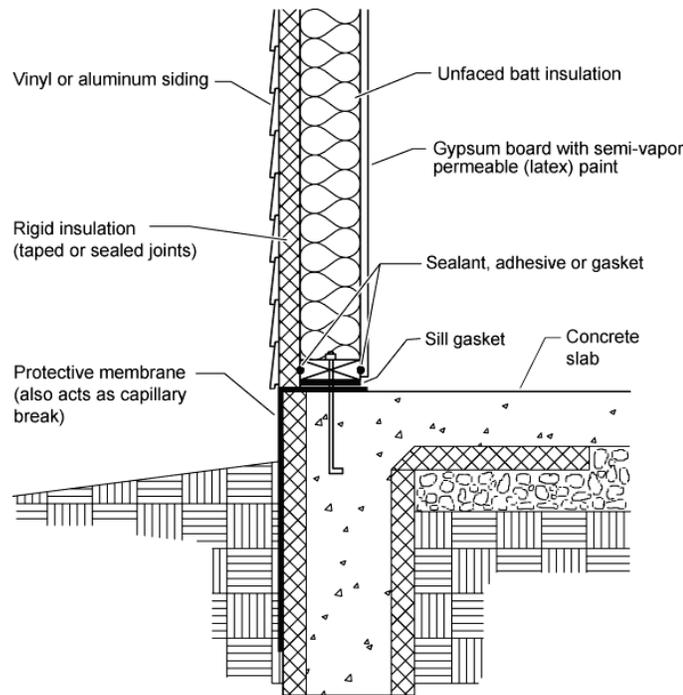
**Figure 3-30: Examples of Wood-Framed Wall Assemblies and U-Factors, Assuming Gypsum Board Interior**

Stud	Cavity Insulation	Cavity Insulation Type	Exterior Insulation	U-Factor
2x4	R15	High density batt	R4	0.065
2x6	R21	Loose-fill cellulose or high density batt	R4	0.051
2x6	R19	Low density batt	R5	0.051
2x4	R15	High density batt	R8	0.050
2x6	R31	Closed-cell spray foam (ccSPF)	R2	0.050
2x6	R23	High density batt or mineral wool	R4	0.049

Metal-framed assemblies will also require rigid insulation to meet the maximum U-factor criteria. U-factors for metal-framed walls are given in Reference Joint Appendix JA4 Table 4.3.4 and can also be calculated in compliance software.

Demising partitions and knee walls are not required to meet the prescriptive Package A requirements. Demising partitions and knee walls shall meet the mandatory minimum wall insulation requirements from §150.0(c)1 and §150.0(c)1 requires a minimum of R-13 cavity insulation in 2x4 wood framing, or a U-factor less than or equal to U-0.102. §150.0(c)2 requires a minimum of R-19 cavity insulation for 2x6 inch or greater wood framing, or a U-factor less than or equal to 0.074.

**Figure 3-31: Example of Wood-Framed Wall With Protective Membrane on Slab-Edge Insulation Detail**



Source: California Energy Commission

## 2. Mass Walls

§150.1(c) These sections are also shown in Appendix B of this document.

The prescriptive requirements have separate criteria for mass walls with interior insulation and mass walls with exterior insulation. “Interior” denotes that insulation is installed on the interior surface of the mass wall, and “exterior” denotes insulation is installed on the exterior surface of the mass wall. Placement of insulation on mass walls does affect the thermal mass properties of a building. The effect of thermal mass helps temper the fluctuation of heating and cooling loads throughout the year in the building.

### a. 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 compliance approach is used, the insulation must be installed integral with or on the exterior or interior of the mass wall.

**Figure 3-32: Masonry Wall With Furring Details**

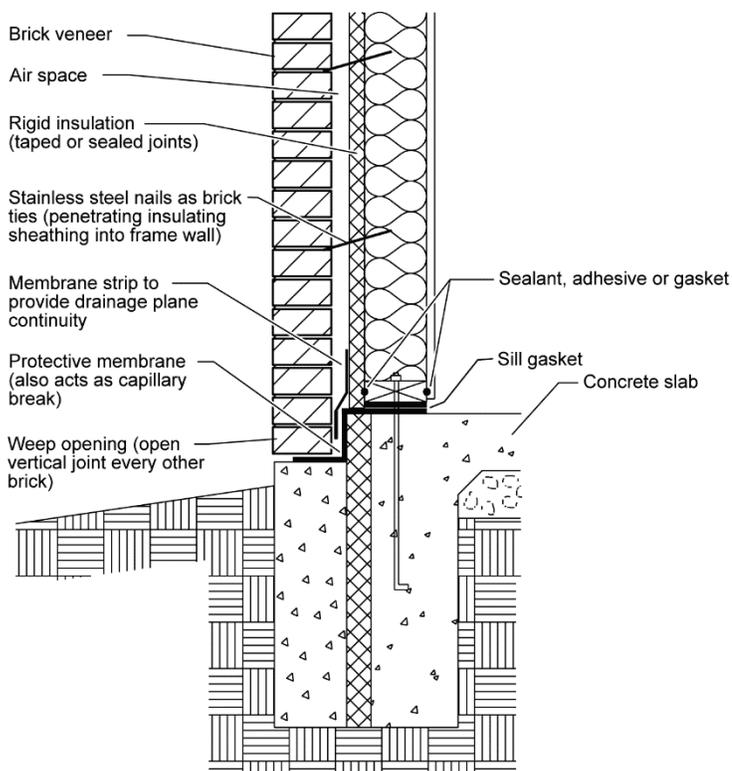
Source: California Energy Commission

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 CF1R, CF1R-ADD and CF1R-ALT can calculate complex wall systems to include furred walls.

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

1. Select one of the concrete or masonry walls tables and select a U-factor.
2. Select the appropriate effective R-value for interior or exterior insulation layers in Table 4.3.14.
3. Fill out the CF1R 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 completed.
4. Calculate the final assembly R-value and carry the value 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 of the Energy Standards.

The U-factor of furred concrete or masonry walls could also be determined by building the construction assembly in Commission-approved compliance software.

**Figure 3-33: Wood-Framed Wall With Brick Veneer**

Source: California Energy Commission

### *Construction Practice/Compliance and Enforcement*

The compliance and enforcement process should ensure that the insulation R-value for walls (cavity and/or continuous) on the CF1R 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 CF1R form. For more information on compliance and enforcement on wall insulation, see Chapter 2 of this manual.

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

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

Wall insulation should extend into the perimeter floor joist (rim joist) cavities along the same plane as the wall. If a vapor retarder is required, it must be installed on the conditioned space side of the framing.

#### **Example 3-27**

##### **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:**

Block walls are considered opaque nonframed assemblies and according to §150.0(c)3, the wall has to have a U-factor not exceeding U-0.102, which is equivalent to R-13 insulation in a wood framed wall.

## Example 3-28

**Question:**

For a new wall, if 2-inches of medium–density, closed-cell spray polyurethane foam (ccSPF) is used in combination with R-13 batt insulation in the cavity of a 2x6 wood framed wall with 16” on center spacing, without continuous insulation added, what is the total U-factor for the wall assembly? Does this assembly meet prescriptive compliance Package A requirements in Climate Zones 6 and 7? How about other climate zones?

**Answer:**

The assembly does meet Package A requirements in Climate Zones 6 and 7. Medium-density ccSPF is given a default value of R-5.8 per inch, as per JA Table 4.1.7. When 2 inches of ccSPF is added to R-13 batt insulation, the total cavity insulation is rounded to R-25. The assembly U-factor was calculated to be 0.065 using Commission-approved compliance software:

Construction Data		
Currently Active Construction:	Exterior Wall Cons	
Construction Name:	Exterior Wall Cons	
Can Assign To:	Exterior Walls	
Construction Type:	Wood Framed Wall	
Construction Layers (inside to outside)		
	Cavity Path	Frame Path
Inside Finish:	Gypsum Board	Gypsum Board
Sheathing / Insulation:	- no sheathing/insul. -	- no sheathing/insul. -
Cavity / Frame:	R 25	2x6 @ 16 in. O.C.
Sheathing / Insulation:	- no sheathing/insul. -	- no sheathing/insul. -
Exterior Finish:	- select finish -	- select finish -
<input type="checkbox"/> Non-Standard Spray Foam in Cavity		
<input type="checkbox"/> Specify Non-std Framing Factor		
Winter Design U-value:	0.065 Btu/h-ft <sup>2</sup> -°F (meets max code 0.065 U-value (0.065))	

*CBECC-Res Software Wall Assembly Construction showing U-0.065 Assembly*

The assembly does meet the minimum mandatory wall insulation U-factor requirement of 0.074, as well as the prescriptive Package A U-factor requirement of 0.065 in Climate Zones 6 and 7.

However, the assembly does not meet the prescriptive compliance Package A U-factor requirement of 0.051 in Climate Zones 1-5 and 8-16. To meet the Package A requirement for those climate zones, other wall assemblies may be used, such as those in Figure 3-30, and/or advanced wall system (AWS) techniques may be used to reduce the framing factor. Alternatively, the project could be shown to comply with Title 24 using the performance approach, which allows energy efficiency trade-offs with other building components.

Example 3-29

**Question:**

A new single-family house will have six inches of framed walls with R-19 cavity insulation and R-5 continuous rigid insulation on the outside. Can this building comply with Title 24 using either the prescriptive or performance approach?

**Answer:**

If the house has wood framing, the assembly U-factor would be U-0.051 as per JA4 Table 4.3.1. This U-factor prescriptively complies with the Package A U-factor requirements in all climate zones, and the building would not need to use the performance approach. If the house has metal framing, the assembly U-factor would be U-0.084 as per JA4 Table 4.3.4. This U-factor exceeds the maximum U-factor allowed in the prescriptive Package A and exceeds the mandatory maximum (U-0.074). Thus, the building would not be able to comply even by using the performance method.

**3.6.2.3 Floor/Slab**

**A. Floor Insulation**

**1. Raised-Floor**

§150.1(c)1C

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

The requirement may be satisfied by installing the specified amount of insulation in a wood-framed floor or by meeting an equivalent U-factor. U-factors for raised floors are listed in Reference Joint Appendix JA4. Concrete floors separating multifamily habitable space from a parking garage are also considered a raised floor. 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 with a concrete raised floor.

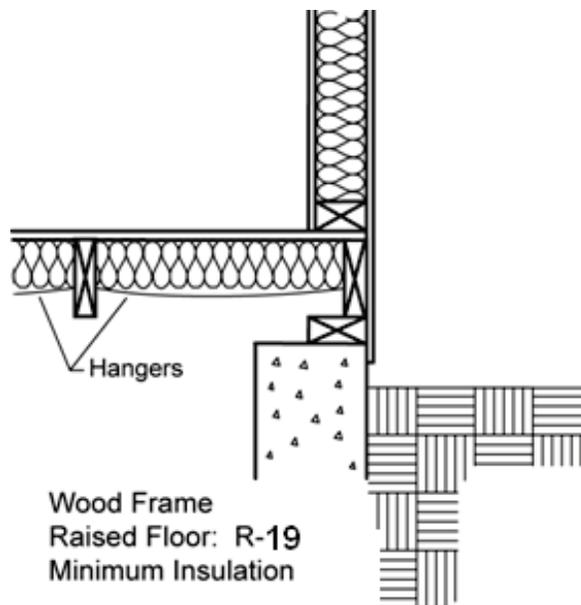
**Table 3-6: Raised Floor Constructions Used as Basis for Equivalent U-Factor Compliance**

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

*Construction Practice/Compliance and Enforcement*

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

Options for support include netting stapled to the underside of floor joists, insulation hangers running perpendicular to the joists, or other suitable means. Insulation hangers should be spaced at 18 inch or less before rolling out the insulation. (See Figure 3-34.) 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 3-34: Raised Floor Insulation**

Source: California Energy Commission

## B. Slab Insulation

§150.1(c)1D

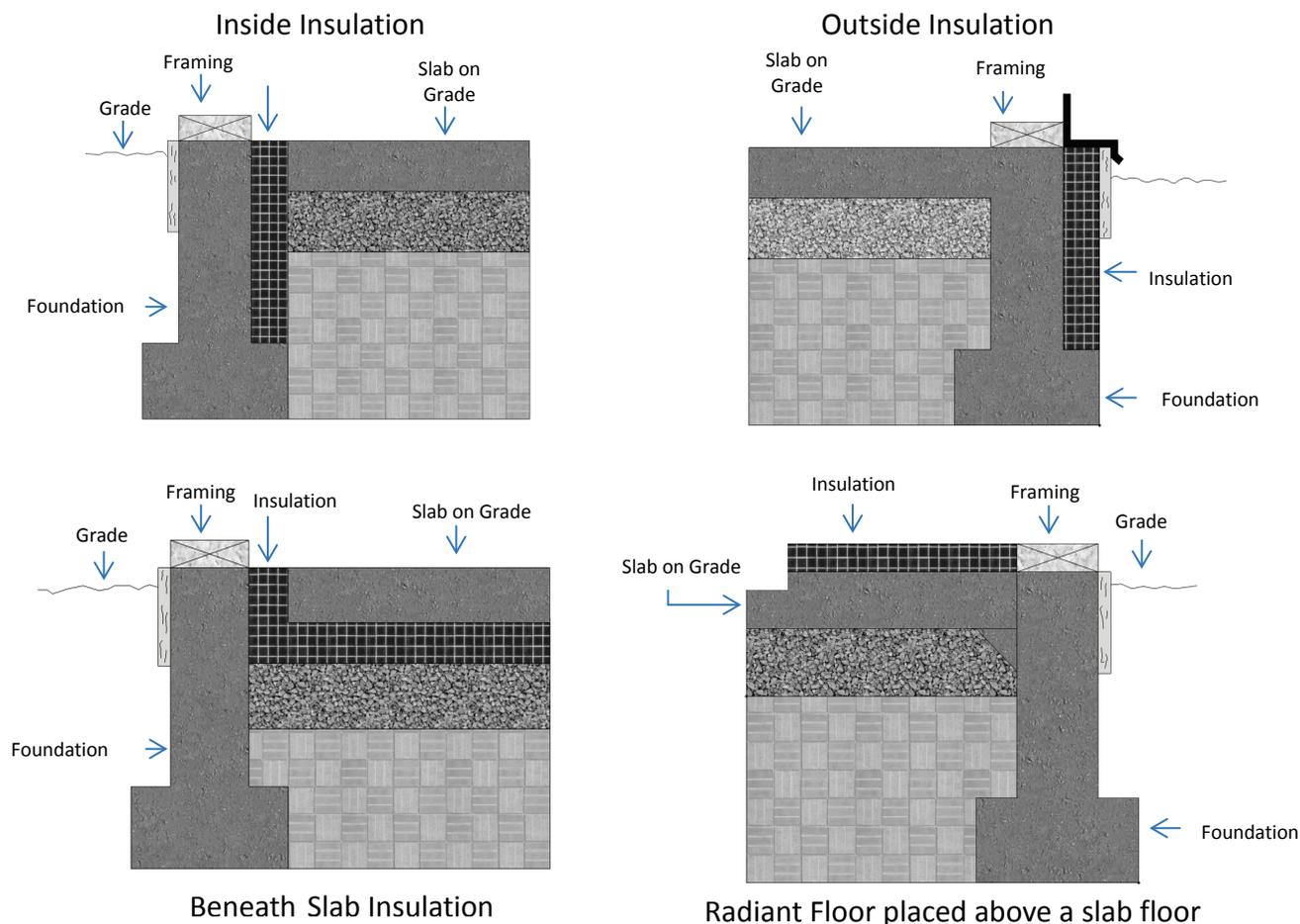
§150.1-A of the Energy Standards, Package A, requires slab insulation only in Climate Zone 16. In this case, a minimum of R-7 must be installed. The insulation must be installed to a minimum depth of 16 in. or to the bottom of the footing, whichever is less. The depth is measured from the top of the insulation, as near the top of slab as practical, to the bottom edge of the insulation. (See Figure 3-35.)

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 close to ground level as possible and extended down at least 16 inches. In situations where the slab is above grade and slab edge insulation is being applied, the top of the slab edge insulation should be placed at the top of the slab.

### *Construction Practice/Compliance and Enforcement*

Slab-edge insulation should be protected from physical damage and ultraviolet light exposure because deterioration from moisture, pest infestation, ultraviolet light, and other factors can significantly reduce the effectiveness of the insulation. (See Figure 3-31.)

**Figure 3-35: Allowed Slab Edge Insulation Placement**

Source: California Energy Commission

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

#### Example 3-30

##### 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 Energy 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 Energy Standards
- Protection from physical damage and ultraviolet light deterioration
- Water absorption rate no greater than 0.3 percent (ASTM-C272)
- Water vapor permeance no greater than 2.0 perm/inch (ASTM-E96)

### 3.6.3 Performance Approach

Some residential designs may not wish to use or do not meet the requirements for prescriptive options A, B, and C described above in Section 3.6.2. The performance approach offers increased flexibility as well as compliance credits for certain assemblies, usually requiring HERS verification. The designs described below are examples of residential envelope strategies that can be implemented under the performance approach. The proposed design used under the performance approach is compared to the standard design, which is determined by the prescriptive requirements.

#### 3.6.3.1 Roof Assembly

The construction techniques described below are assemblies that can be used in residential construction to help meet or perform better than minimum prescriptive requirements when using the performance compliance approach. This section describes typical constructions for unvented attics, attic ventilation, insulated tiles, and raised heel trusses (also called “energy trusses”).

##### A. Unvented Attics

Attic ventilation is the traditional way of controlling temperature and moisture in an attic. In an unvented attic assembly, insulation is applied directly at the roofline of the building, either above or below the structural roof rafter. The roof system becomes part of the insulated building enclosure. For this case, the thermal boundary of the building results in an unvented attic space between the ceiling gypboard and the insulated roof above (See Figure 3-36).

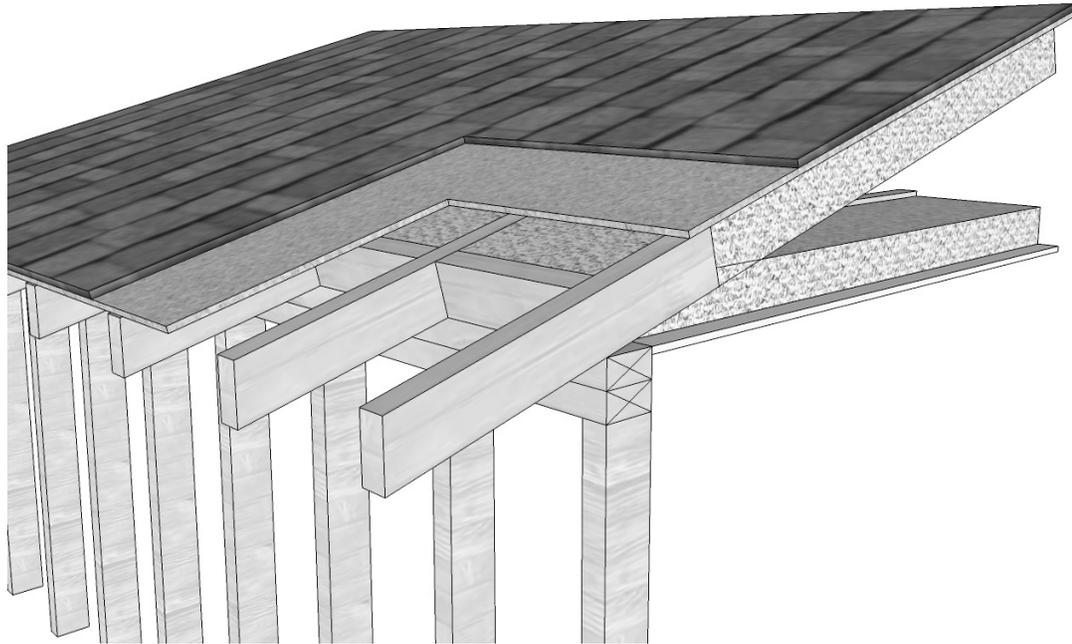
The provisions of CBC, Title 24, Part 2, Vol. 2.5, Section R806.4 describes conditions for insulation placed at the roof of the building as opposed to on top of the horizontal ceiling. Unvented attic assemblies are allowed provided that:

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

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

Combining this strategy with the additional design improvement of low air leakage for the rest of the building would achieve energy savings and compliance energy credit. Furthermore, this design eliminates the need to seal or limit penetrations at the ceiling level, such as recessed cans, because the air and thermal boundary is now located at the roof deck.

**Figure 3-36: Unvented Attic Assembly With Insulation at the Ceiling and Between the Roof Rafters**

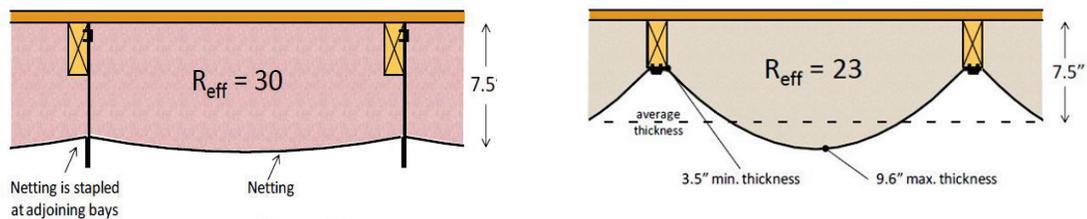


Source: California Energy Commission

**B. Below-Deck Netted Insulation**

Alternative types of insulation can provide high R-value insulation below the roof deck in an unvented attic. One approach is a boxed netted system that is suspended from the top member of the truss, or top chord, to provide a fill depth that completely encloses the top chord, creating a uniform insulation layer of loose-fill fiberglass across the entire underside of the roof deck. This method can be done with common loose-fill insulation tools and equipment. See Figure 3-37A for details of this type of below-deck netted insulation. Draped netted insulation, another approach to below deck insulation, results in a non-uniform insulation layer, created by leaving the truss chords exposed and leading to increased thermal bridging (see Figure 3-37B).

**Figure 3-37A (left): Box Netted Insulation and Figure 3-37B (right): Draped Netted Insulation**



Source: Owens Corning

### C. Insulated Roof Tiles

Insulating roof tile (IRT) is another option for improving the thermal performance of the roof assembly and lowering attic temperatures. IRT combines concrete/clay tiles with insulation as a packaged product. Most of the increase in R-value is due to the integration of insulation into the roofing product itself; however, additional thermal performance can be gained by combining IRT with rigid foam insulation inserts (Figure 3-39). These tiles are lighter than typical roof tiles and have better thermal performance than traditional tiles due to the insulation core.

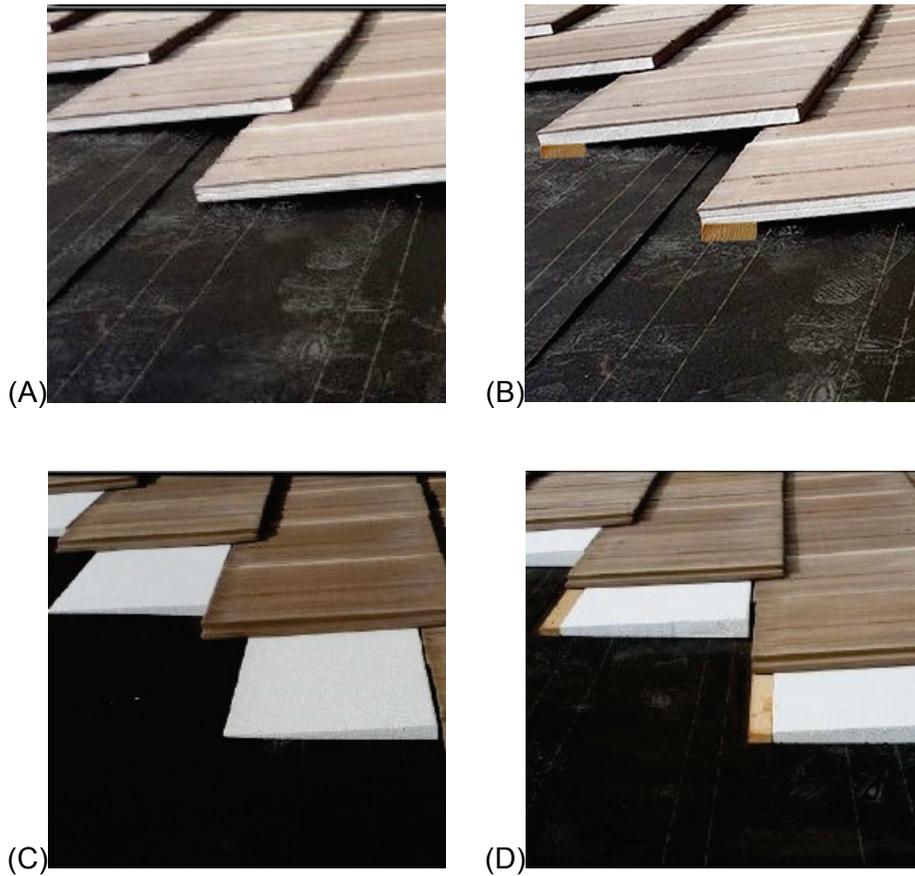
Furthermore, IRT can reduce radiant losses and maintain warmer roof deck temperatures, thereby reducing the potential for condensation. Using one of the options below provides additional R-value when conventional (ceiling) insulation is also installed. All four configurations (A-D) can be installed without any significant changes to conventional roof or attic design (such as changes to fascia dimensions, and so forth), and IRT can be used in both vented and unvented attic configurations.

**Figure 3-38: Insulated Concrete Tile**



*Source: Green Hybrid Roofing*

**Figure 3-39: Insulated Roof Tile (IRT) (A) attached directly to roof deck, (B) attached to batten, (C) attached directly to roof deck with wedged foam filling air space, and (D) attached to battens with wedged foam filling air space**



Source: Green Hybrid Roofing

Some IRTs are ASTM rated for Class A fire rating (ASTM E108) and have CRRC certification for cool roof tiles in several colors. Depending on the configuration selected from the four options (A-D) in Figure 3-39, a U-factor between 0.18 and 0.10 can be achieved, with option D performing the best. It is best practice to check with manufacturers about the ratings and certifications for each tile. Product manufacturers cite several advantages of the product due to its lightweight construction and increased insulation properties – ease of installation, ability to install similar to traditional roof tiles but at a much faster pace, less weight on the roof structure, increased thermal resistance, and improved thermal performance.

**D. Raised Heel or Extension Truss (Energy Truss)**

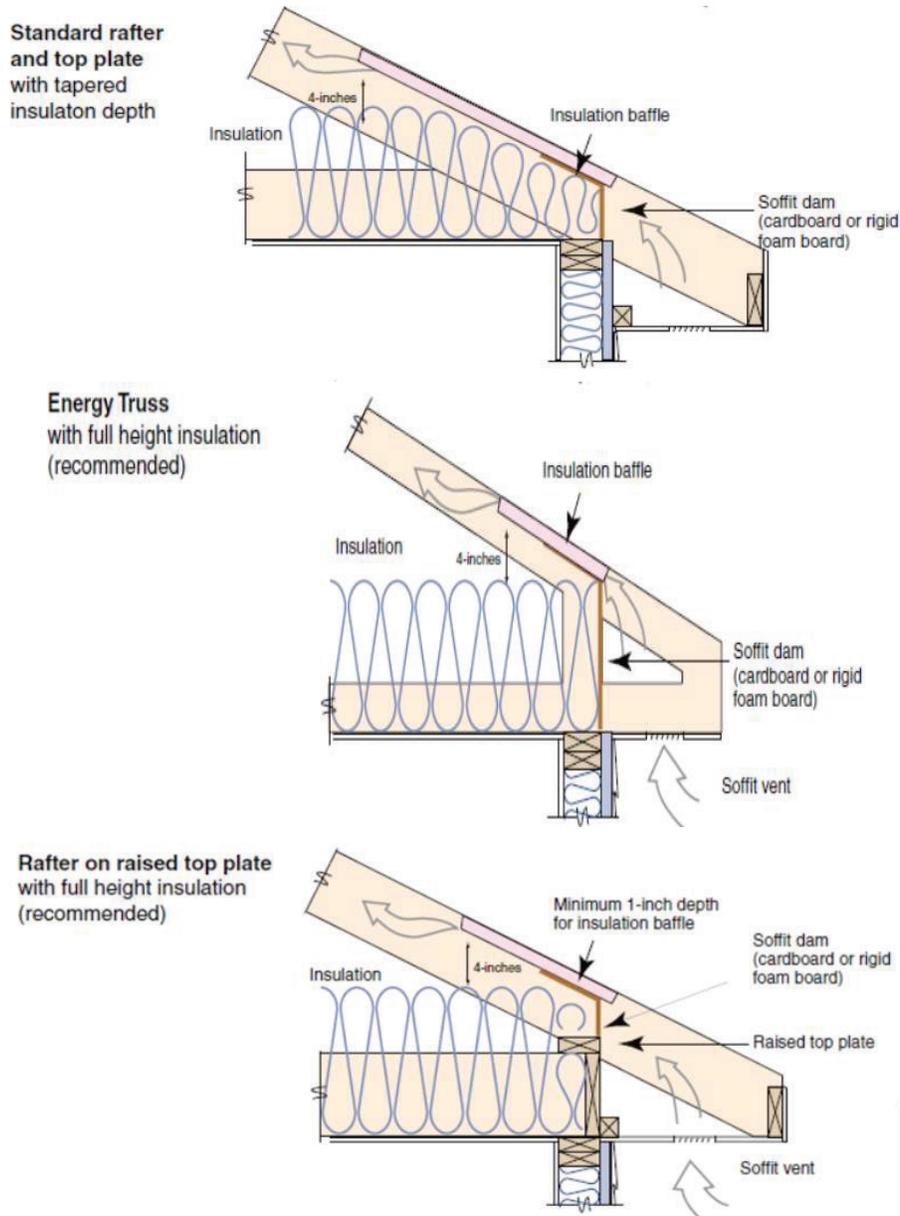
The use of an energy truss, usually referred to as a raised heel or extension truss, allows full depth, uncompressed insulation at the ceiling to continue to the ceiling edge where the roof and ceiling meet. For this strategy, the roof truss is assembled with an additional vertical wood framed section at the point where the top and bottom truss chords meet. The vertical section raises the top chord and provides increased space that can be filled with insulation. See Figure 3-40 for details of a raised heel truss. Benefits of this strategy include:

- Realizing the full benefit of ceiling insulation.
- Providing more space for air handler and duct systems if located in the attic.

The 2016 CBECC-Res compliance software allows for the modeling of raised heel trusses and provides credit for the additional insulation at the edges.

Other methods to achieve the similar outcome include framing with a rafter on raised top plate or using spray foam or rigid foam at the edge.

**Figure 3-40: Raised Heel Truss (Energy Truss)**

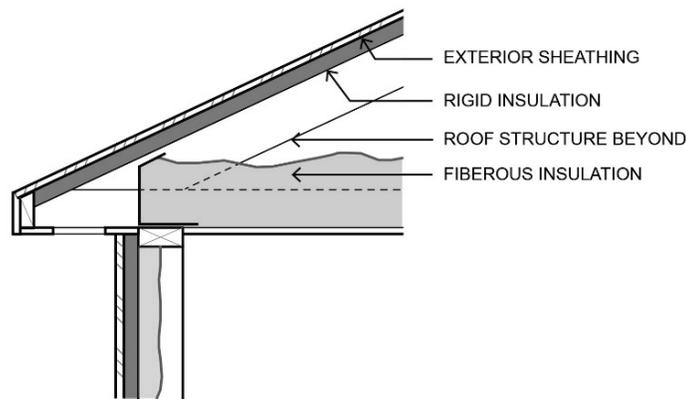


Source: Georgia Department of Community Affairs

**E. Nail Base Insulation Panel**

The nail base insulation panel is an above-roof rafter insulation strategy that consists of exterior-facing OSB or other structural sheathing laminated to continuous rigid insulation, which is fastened directly to roof framing (See Figure 3-40A). This saves the time and expense of installing a structural sheathing layer above and below the rigid insulation. The nail base insulation panel creates a nailing surface for the attachment of roof cladding. Suitable for both vented and unvented attic assemblies, the exposed underside of the rigid insulation has a facer that provides a radiant barrier as well as ignition/thermal barrier protection as required by code.

**Figure 3-40A: Nail base insulation panel with radiant barrier (one-sided SIP) affixed to trusses in a prescriptive, vented attic configuration**



**3.6.3.2 Wall Assembly**

See Energy Commission videos

**A. Advanced Wall System (AWS)**

*Advanced wall systems (AWS)*, also known as *optimum value engineering (OVE)*, refers to a set of framing techniques and practices that minimize the amount of wood and labor necessary to build a structurally sound, safe, durable, and energy-efficient building. AWS improves energy and resource efficiency while reducing first costs.

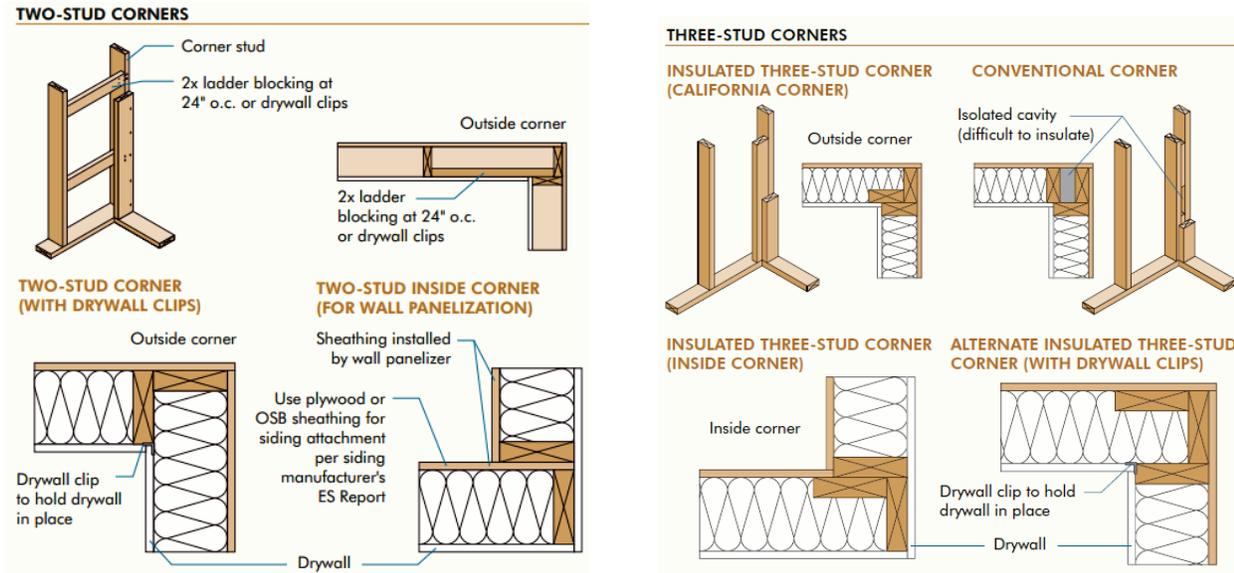
Reducing the amount of wood in wood-framed exterior walls improves energy efficiency, allowing more insulation to be installed, and has greater resource efficiency for the materials being used. In addition, using fewer framing studs reduces the effects of “thermal bridging” and increases the amount of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

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

1. Use a minimum 2x6 at 24" on-center wall framing.
  2. Use precise engineering of headers on load-bearing walls.
  3. Install 2x4, 2x6, or I-joist headers on exterior nonload-bearing walls.
  4. Eliminate cripple studs at window and door openings less than 4 feet wide.
  5. Align window/door openings with standard stud spacing.
  6. The king stud, on at least one side of the window/door opening, must take the place of an on-layout AWS stud.
  7. Use an insulated corner, either a two-stud corner or a California (3-stud) corners, as in the examples provided in Figure 3-41.
  8. 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.
  9. Use ladder block where interior partitions intersect exterior walls, instead of 3-stud channels.
  10. Eliminate unnecessary double-floor joists underneath nonbearing walls.
  11. Use metal let-in T-bracing or other methods on non-shear walls to allow full insulation.
  12. Include detailed framing plans and elevations on the construction permit plan set.
  13. Optimize house design for efficient material use (for example, reducing header spans, designing exterior surfaces in two-foot modules, designing clear spans to eliminate interior bearing walls).
  14. Build with "insulated headers" (a "sandwich" of two solid or engineered lumber components with a layer of foam insulation in the middle or on one or both sides of the header). An example of a single-ply insulated header is provided in Figure 3-42. Insulated headers may also earn QII compliance credits by installing R-2 insulation in one of three ways:
    - a. Two-member header with insulation in between. The header and insulation must fill the wall cavity. There are prefabricated products available that meet this assembly. Example: a 2x4 wall with two 2x nominal headers, or a 2x6 wall with a 4x nominal header and a 2x nominal header. Insulation is required to fill the wall cavity and must be installed between the headers.
    - b. Single-member header, less than the wall width, with insulation on the interior face. The header and insulation must fill the wall cavity. Example: a 2x4 wall with a 3-1/8-inch-wide header, or 2x6 wall with a 4x nominal header. Insulation is required to fill the wall cavity and must be installed to the interior face of the wall.
    - c. Single-member header, same width as wall. The header must fill the wall cavity. Example: a 2x4 wall with a 4x nominal header or a 2x6 wall with a 6x nominal header. No additional insulation is required because the header fills the cavity.
- Wood structural panel box headers may also be used as load-bearing headers in exterior wall construction, when built in accordance with 2015 CRC Figure R602.7.3 and Table R602.7.3.
15. 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).

16. Eliminate trimmers at window and door opening headers less than 4 ft wide, only when rated hangers are used and noted on the plans.
17. Use 2x4 or 2x3 interior nonload-bearing walls.
18. Integrate framing design with HVAC system.
19. Use “inset” shear wall panels.

**Figure 3-41: Advanced Framing Corners**



Source: APA Advanced Framing Guide

**Figure 3-42: Headers Designs with Cavity Insulation Space**

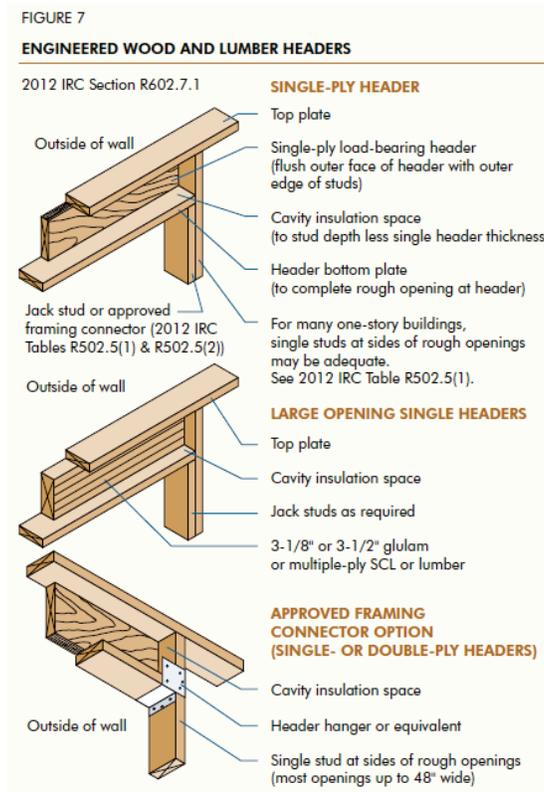
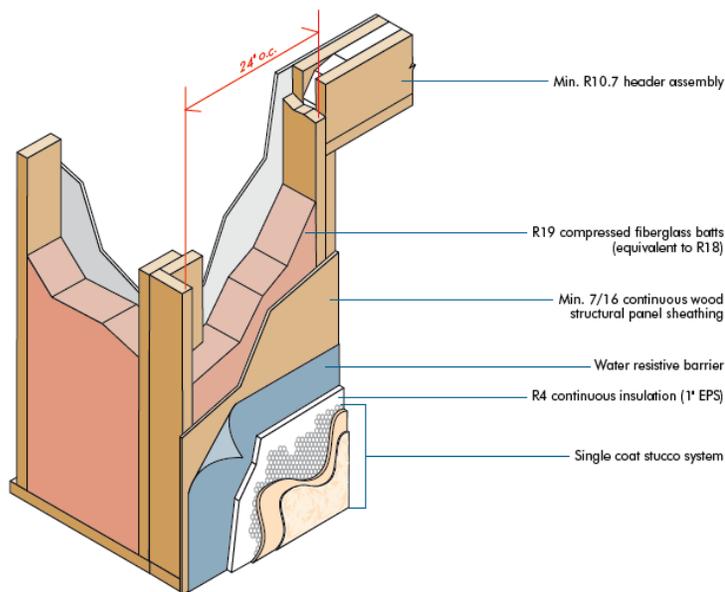


Figure 3-43 below is a description of one AWS and the assembly characteristics that are used in the prescriptive and performance compliance approaches. This assembly meets a U-factor of 0.051 with an exterior insulation of R-4, due to 24” stud spacing and R-7 header assemblies. The building official must ensure during planning, to check the accuracy of the parallel heat flow calculation and, during framing, inspect that all elements of AWS have been met.

**Figure 3-43: Wood-Framed Wall, 2x6 @ 24” oc, AWF with 3-stud corners**



Source: APA, The Engineered Wood Association

**Table 3-7: Assumptions**

Layer	<b>Assembly Type: Wall 2x6 @ 24” oc AWS</b>	<b>R-Value</b>		
	Framing Material: Wood			
	<b>Assembly Components</b>	<b>Cavity (R<sub>c</sub>)</b>	<b>Frame (R<sub>f</sub>)</b>	<b>Header (R<sub>h</sub>)</b>
0	Frame Factor	78%	18%	4%
1	Outside air film	0.17	0.17	0.17
2	Building paper	0.06	0.06	0.06
3	3/8 inch single coat stucco	0.08	0.08	0.08
4	R4 continuous insulation (1” EPS)	4	4	4
5	7/16 inch continuous oriented strand board sheathing (OSB)	0.44	0.44	0.44
6	R-18 compressed fiberglass batts	18.0	--	--
7	Header assembly – 3.5” wood			3.46
8	Header assembly – 1 inch of R4 foam			4
9	2x6 douglass fir framing @ R-1.086/inch	--	5.973	--
10	½ inch gypboard	0.45	0.45	0.45

11	Inside air film	0.68	0.68	0.68
	Subtotal R-Values	23.875	11.848	13.335
	U-Factors (Frame % x 1/R)	0.0327	0.0152	0.0030
	[Assembly U-factor	<b>Assembly U-factor</b>	<b>0.051</b>	

**Assumptions:** Values in Table 3-7 were calculated using the parallel heat flow calculation method, documented in the *2009 ASHRAE Handbook of Fundamentals* and outlined in Joint Appendices JA4.1.2 and JA4.6. The construction assembly in Table 4.6.1 in JA4.6 assumes an exterior air film of R-0.17, a 3/8-inch layer of stucco of R-0.08 (SC01), building paper of R-0.06 (BP01), sheathing or continuous insulation layer, if present, the cavity insulation/framing layer, 1/2-inch gypsum board of R-0.45 (GP01), and an interior air film 0.68. The framing factor is assumed to be 25 percent for 16-inch stud spacing, 22 percent for 24-inch spacing, and 17 percent for advanced wall system (AWS). Actual cavity depth is 3.5 inch for 2x4, 5.5 inch for 2x6.

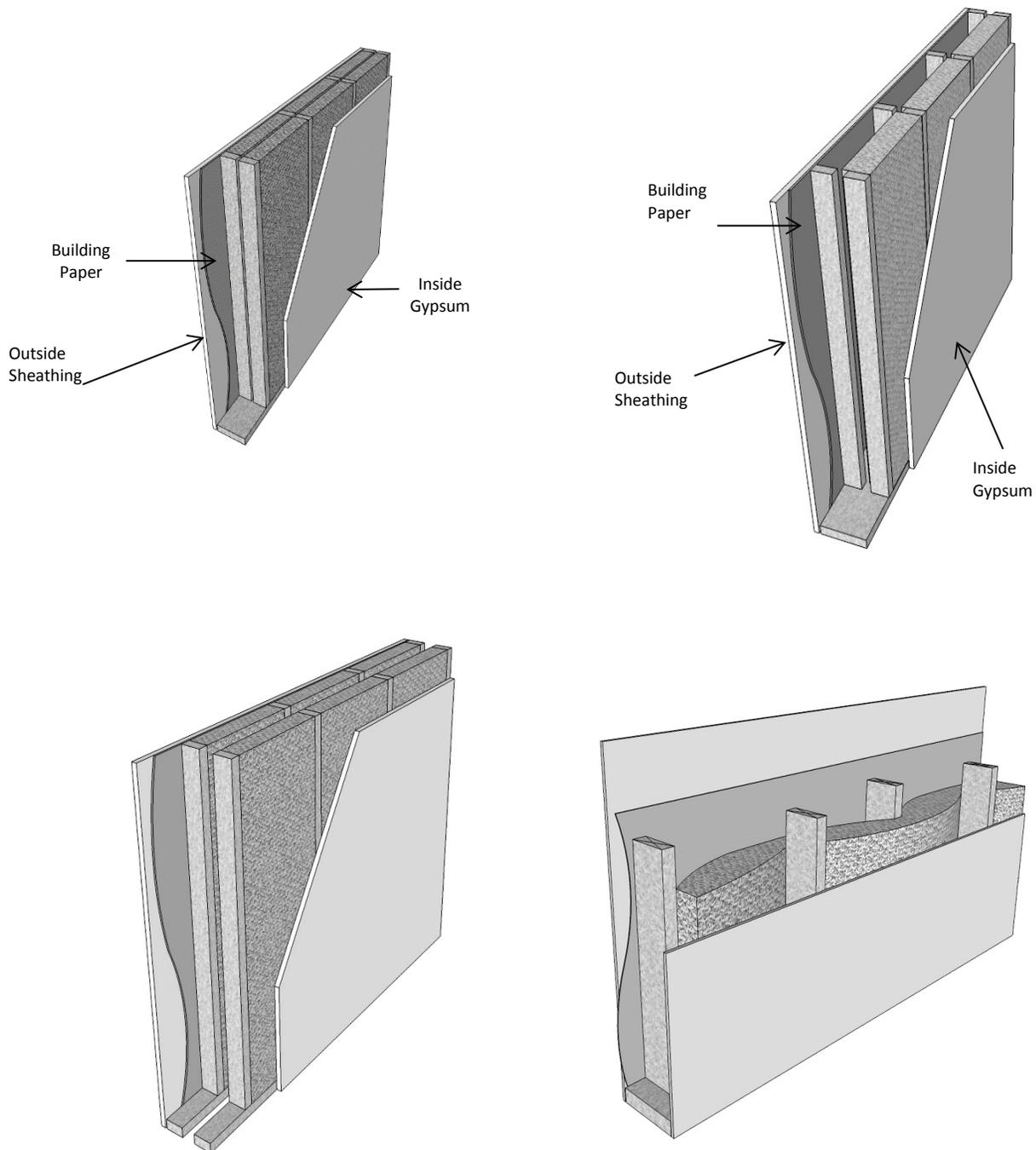
**B. Double and Staggered Wall Assemblies**

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

1. Smaller dimensional lumber can be used.
2. It is easier to install installation properly.
3. It eliminates thermal bridging through the framing.
4. It reduces sound transmission through the wall.

With double walls, insulation may be on one side of the wall or on both (higher R-values). It is not uncommon to find double walls with insulation installed within the outside wall cavities, leaving the inside wall sections open for wiring and plumbing. (See Figure 3-44.)

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

**Figure 3-44: Typical Double and Staggered Wall Systems**

Source: California Energy Commission

### C. Metal Framing

A change from wood framing to metal framing can significantly affect compliance. Metal-framed assemblies are often chosen where greater structural integrity is necessary, or in climate conditions where greater durability is desired from the effects of excessive moisture exposure. Metal-framed wall construction generally requires a continuous layer of rigid insulation to meet the mandatory minimum wall insulation levels and/or the

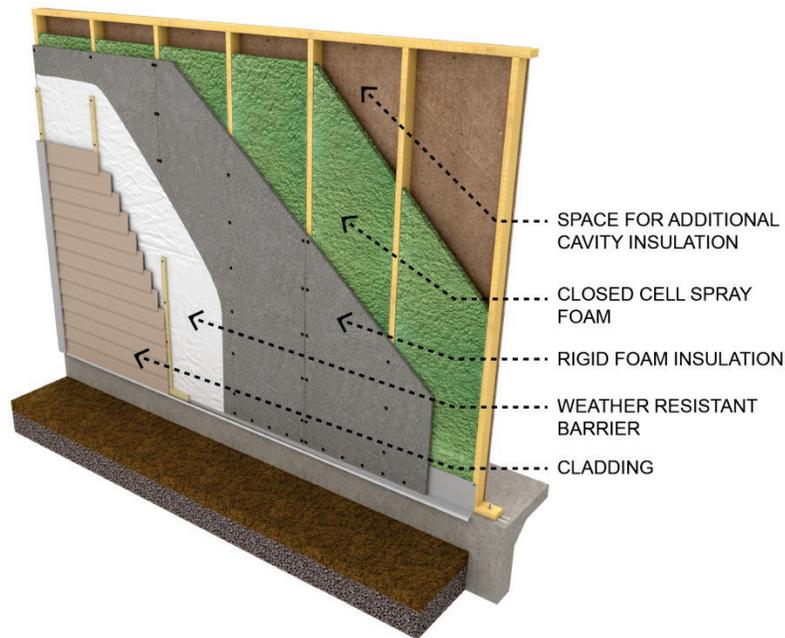
prescriptive requirements since metal is more conductive than wood. In JA4, Tables 4.2.4 and 4.2.5 have U-factors for metal-framed ceiling/roof constructions. Table 4.3.4 has U-factors for metal-framed walls. Tables 4.4.4 and 4.4.5 have U-factors for metal-framed floors.

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

**D. High-Performance Structural Foam Wall System**

The high-performance structural foam wall assembly is an Advanced Assembly System that consists of ccSPF placed in the cavity bonded to wood framing and continuous rigid board insulation on the exterior of the frame. The bond that occurs between the ccSPF, the framing, and the continuous rigid insulation can provide code-compliant wind and seismic structural load resistance without the use of OSB sheathing (See Figure 3-44A).

**Figure 3-44A: High Performance Structural Foam Wall Systems use ccSPF to insulate, air seal, and structurally bond together exterior foam sheathing with wall framing to allow builders to construct 2x4 at 24” O.C. while improving structural and thermal performance.**



Source: BASF Corporation

A builder can configure the thicknesses of the cavity ccSPF, rigid insulation, and alternative cavity insulation to attain U-factors of 0.050 or better in 2x4 at 24” OC assembly. The structural foam wall assembly can be combined with advanced framing or OVE techniques to increase energy and resource efficiency while reducing both material cost and labor.

### 3.6.3.3 Floor Assembly

#### A. Controlled Ventilation Crawl Space (CVC)

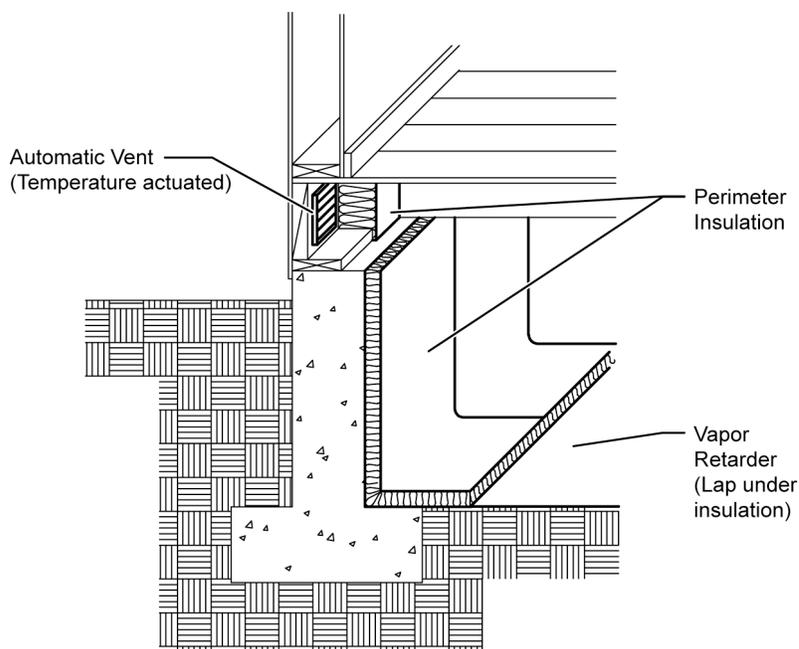
CVC Eligibility Criteria in 2016 RA4.5.1

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

1. Reducing heat transfer into the unconditioned crawl space.
2. Reducing moisture buildup in the crawl space.
3. Minimizing insulation exposure to adverse weather prior to enclosure of the building shell.

An energy credit can be taken in compliance software for controlled ventilation crawl space (CVC). This credit requires insulating the foundation stem wall, using automatically controlled crawl space vents, and vapor retarder covering the entire ground soil area for moisture control on the crawl space floor.

**Figure 3-45: Controlled Ventilation Crawl Space**



Source: California Energy Commission

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:

1. **Drainage:** Crawl space buildings in particular are susceptible to moisture ponding when good drainage and/or moisture removal designs are not employed.
2. **Ground water and soils:** Local groundwater 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 enforcement agency's discretion. The building permit applicant should be prepared to provide supporting information that site drainage strategies (for example, perimeter drainage techniques) will prevent potential moisture concerns.

The following eligibility criteria in RA4.5.1 are required in order to use the CVC energy credit:

1. **Ventilation:** All crawl space 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 about 40°F and fully open at about 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 crawl space floor for a distance of 2 ft (24 inches).
3. **Direct Earth Contact:** Foam plastic insulation used for crawl space insulation having direct earth contact shall be a closed-cell, water-resistant material and meet the slab edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory requirements (§110.8(g)1).

A Class I or Class II vapor retarder rated as 1.0 perm or less must be placed over the earthen floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with RA4.5.1. This requires essentially a polyethylene-type ground cover having a minimum 6 mil thickness (0.006 inch) or approved equal. The vapor retarder must be overlapped a minimum of 6 inches at joints and shall extend over the top of footings and piers. All overlapping of joints shall be sealed with tape, caulk, or mastic.

- Penetrations, tears, and holes in the vapor barrier shall be sealed with tape, caulk, or mastic.
- Edges of the vapor retarder shall be turned up a minimum of 4 inches at the stem wall and securely fastened and before insulation is installed.
- In sloping crawl space ground soil areas, the vapor retarder shall be securely held in place, such as spiked with 5-inch gutter nails, then have proper sealing of penetration holes.
- The vapor retarder shall be shown on the plans.

#### 3.6.3.4 Quality Insulation Installation (QII)

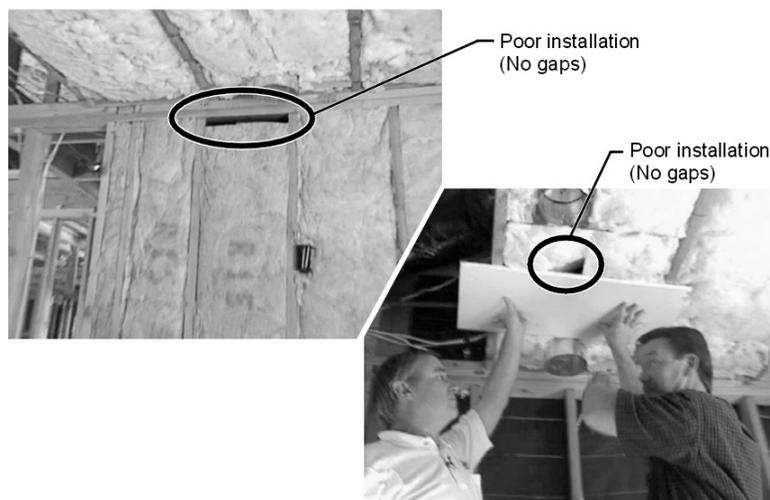
*Energy Commission videos  
RA3.5*

All insulation shall be installed properly throughout the building. When compliance credit is taken for QII, 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 is installed to meet specified R-values and assembly U-factors.

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

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

**Figure 3-46: Examples of Poor Quality Insulation Installation**



Source: California Energy Commission

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

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

1. Compliance credit is not allowed for walls alone, or credit is allowed 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 (that is, 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).
7. Compliance credit is not allowed when using the PV trade-off package.

Approved computer compliance modeling software automatically reduces the effectiveness of insulation for compliance. This reduction is accounted for in developing the Energy Standards and prescribing the required prescriptive measures for each climate zone to establish the standard design energy budget in performance compliance calculations. The effect of a poorly installed air barrier system and envelope insulation results in 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.

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

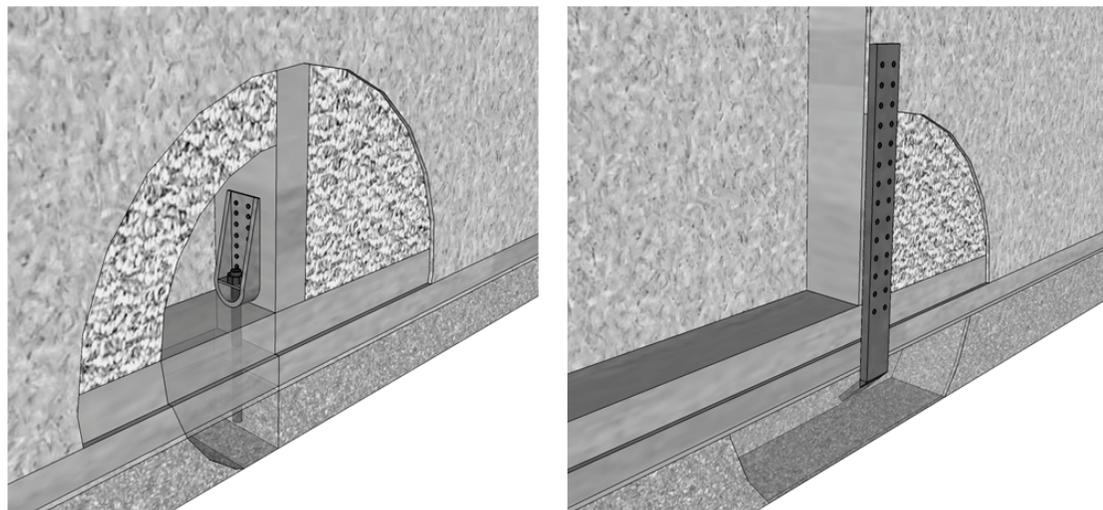
**A. Structural Bracing, Tie-Downs, Steel Structural Framing**

RA3.5.5.2.8

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

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

**Figure 3-47: Structural Bracing, Tie-downs**



Source: California Energy Commission

**B. Air Barrier**

RA3.5.2

An air barrier shall be installed enclosing the entire building. 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 nonframed envelope assemblies. The installer shall provide evidence with compliance documentation that the air barrier system meets one or more of the air barrier specifications shown in Table 3-8 below. More detailed explanation is provided in RA3.5. Documentation for the air barrier includes product data sheets and manufacturer specifications and installation guidelines. The third-party HERS Rater shall verify that the air barrier has been installed properly and is integral with the insulation being used throughout the building.

**Table 3-8: Continuous Air Barrier**

<p>Continuous Air Barrier</p>	<p>A combination of interconnected materials and assemblies are joined and sealed together to provide a continuous barrier to air leakage through the building envelope separating conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses. An air barrier is required in all thermal envelope assemblies to limit air movement between unconditioned/outside spaces and conditioned/inside spaces and must meet one of the following:</p> <ol style="list-style-type: none"> <li>1. Using materials that have an air permeance not exceeding 0.004cfm/ft<sup>2</sup> under a pressure differential of 0.3in. w.g. (1.57psf) (0.02 L/s.m<sup>2</sup> at 75 pa) when tested in accordance with ASTM E2178.</li> <li>2. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft<sup>2</sup> under a pressure differential of 0.3 in. w.g (1.57psf) (0.2 L/s.m<sup>2</sup> at 75 pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680 or ASTM E283.</li> <li>3. Testing the completed building and demonstrating that the air leakage rate of the building envelope does not exceed 0.40 cfm/ft<sup>2</sup> at a pressure differential of 0.3 in w.g. (1.57 psf) (2.0 L/s.m<sup>2</sup> at 75 pa) in accordance with ASTM E779 or an equivalent approved method.</li> </ol> <p>Materials and assemblies of materials that can demonstrate compliance with the air barrier testing requirements must be installed according to the manufacturer's instructions, and a HERS Rater shall verify the integrity of the installation. Below are example materials meeting the air permeance testing performance levels of 1 above. Manufacturers of these and other product types must provide a specification or product data sheet showing compliance to the ASTM testing requirements to be considered as an air barrier.</p> <ul style="list-style-type: none"> <li>• Plywood – minimum 3/8 inch</li> <li>• Oriented strand board – minimum. 3/8 inches</li> <li>• Extruded polystyrene insulation board – minimum. ½ inch</li> <li>• Foil-back polyisocyanurate insulation board – minimum. ½ inch</li> <li>• Foil backed urethane foam insulation (1 inch)</li> </ul> <p>-- Closed-cell spray polyurethane foam (ccSPF) with a minimum density of 2.0 pcf and a minimum thickness of 2.0 inches. Alternatively, ccSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m<sup>2</sup> at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.</p> <p>-- Open cell spray polyurethane (ocSPF) foam with a minimum density of 0.4 to1.5 pcf and a minimum thickness of 5½ inches. Alternatively, ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m<sup>2</sup> at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.</p> <ul style="list-style-type: none"> <li>• Exterior or interior gypsum board - minimum 1/2 inch</li> <li>• Cement board - minimum 1/2 inch</li> <li>• Built-up roofing membrane</li> <li>• Modified bituminous roof membrane</li> <li>• Particleboard-minimum 1/2 inch</li> <li>• Fully adhered single-ply roof membrane</li> <li>• Portland cement/sand parge ,or gypsum plaster minimum 5/8 inch</li> <li>• Cast-in-place and precast concrete.</li> <li>• Fully grouted uninsulated and insulated concrete block masonry</li> <li>• Sheet steel or aluminum</li> </ul>
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### C. Reduced Building Air Leakage

RA3.8

An energy credit is allowed through the performance approach when the rate of envelope air leakage of the building 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 air leakage of the building.

The air leakage testing (blower door) involves closing all the windows and doors; pressurizing the house with a special fan, usually positioned in a doorway (see Figure 3-48); 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 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 be used only 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 air leakage rate of the building's, such as for an exterior air retarding wrap, or for an air barrier material or assembly meeting the requirements describe in Table 3-8 above.

**Figure 3-48: Blower Door Testing**

Source: California Energy Commission

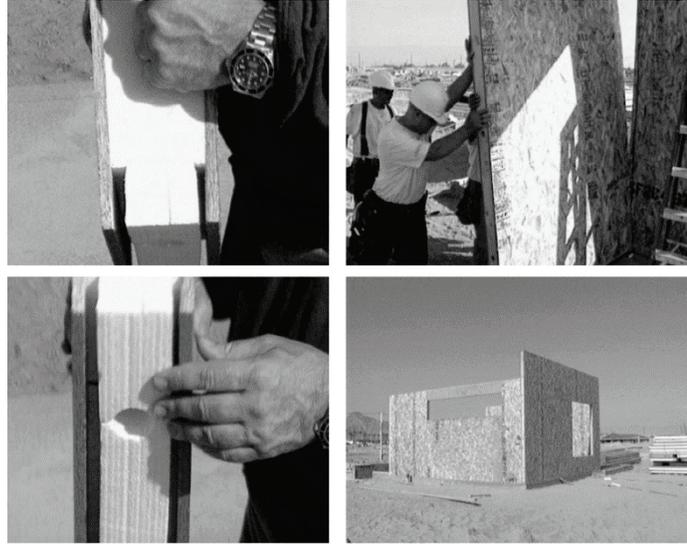
**D. Structural Insulated Panels (SIPS)**

RA3.5.7

Structural insulated panels (SIPS) are a nonframed advanced construction system that consists of rigid foam insulation sandwiched between two sheets of board. The board can be sheet metal, plywood, cement, or oriented strand board (OSB), and the foam can be expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane, or polyisocyanurate (polyiso) foam. SIPS combine several components of conventional building, such as studs and joists, insulation, vapor barrier, and air barrier. They can be used for many different applications, such as exterior walls, roofs, floors, and foundation systems. Little or no structural framing penetrates the insulation layer. Panels are typically manufactured at a factory and shipped to the job site in assemblies that can be as large as 8 ft by 24 ft.

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

**Figure 3-49: Methods of Joining SIPS Panels**



Source: California Energy Commission

**E. Insulating Concrete Forms (ICF)**

RA3.5.8

*Insulating concrete forms* (ICFs) is a system of formwork for concrete that stays in place as permanent building insulation is used for cast-in-place, reinforced above- and below-grade concrete walls, floors, and roofs. ICFs are interlocking modular units that can be dry-stacked (without mortar) and filled with concrete as a single concrete masonry unit (CMU). ICFs lock together externally and have internal metal or plastic ties to hold the outer layer(s) of insulation to create a concrete form for the structural walls, roof/ceilings, or floors of a building. ICFs are manufactured from several materials, including expanded and extruded polystyrene foam, polyurethane foam, cement-bonded wood fiber, and cement-bonded polystyrene beads.

Three factors contribute to the energy efficiency of buildings using an ICF wall:

1. Continuous rigid insulation on both sides of a high-mass core,
2. Elimination of thermal bridging from wood framing components, and
3. A high degree of air-tightness inherent to this method of construction.

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

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

composites of cement and shredded wood fiber, although these tend to be proprietary materials developed by the ICF manufacturer.

Plastic or metal cross-ties, consisting of two flanges and a web, separate the insulating panels and provide structural integrity during the pouring of concrete, 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 finished materials to the interior and exterior of the wall. ICFs can be used to construct load-bearing and nonload-bearing walls and 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 preassembled blocks or as planks that require the flanges and web to be assembled during construction. The forms vary in height from 12" - 24" and are either 4' or 8' long. Vertical panels come in similar modules but are stacked vertically. ICF panels are typically available with core thickness ranging from 4" to 12".

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

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### 3.7 More Information on Insulation and Assemblies

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

#### 3.7.1 Insulation Installation in Framed Assemblies

Insulation is one of the least expensive measures to improve building energy efficiency. Insulation requires no maintenance, helps improve indoor comfort, and provides excellent sound control. Adding extra insulation at a later time is much more expensive than maximizing insulation levels at the beginning of construction. General insulation types are discussed below.

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 JA4 or from results of approved performance compliance computer software. The third-party HERS Rater shall verify that all insulation has been installed properly and is integral with the air barrier being used throughout the building.

There are four basic types of insulation, or insulation "systems," installed in residential buildings and the 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. They offer ease of installation with R-values set by the manufacturer based on size and thickness. They

are available with facings, some as vapor retarders, and have flanges to aid in installation to framed assemblies. They also are available as unfaced material and can be easily friction-fitted into framed cavities.

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

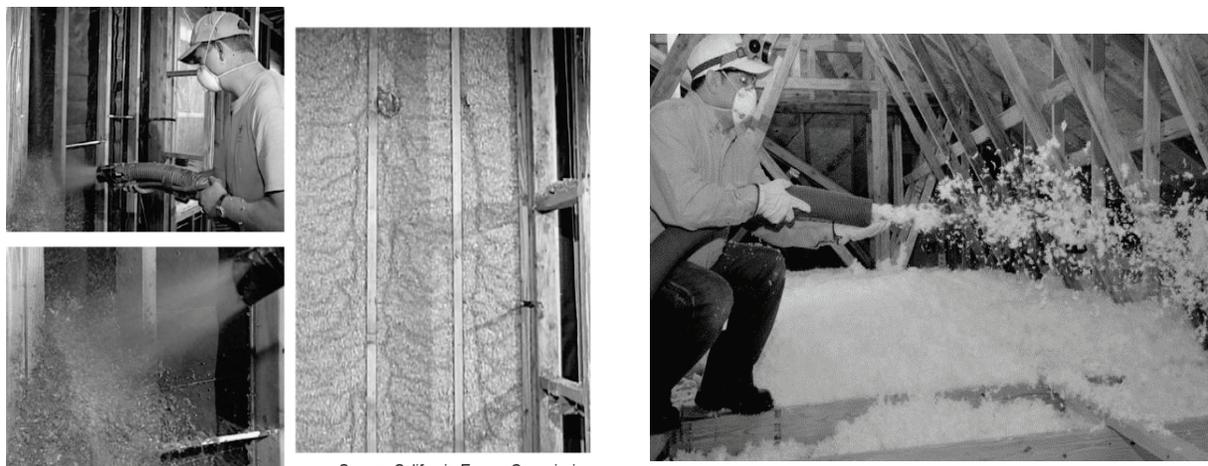
2. **Loose-Fill Insulation:** There are several commonly used types of insulation that have a pneumatic or blown installation process, including cellulose, fiberglass, and natural wool (animal- or cotton-based products). Blown wall insulation can be an effective way to deal with the irregularities of wall cavities, especially the spaces around pipes, electric cables, junction boxes, and other equipment that is embedded in cavities. (See Figure 3-50A.) The R-value of blown wall insulation material installed in closed cavities is determined by the installed thickness. This differs from manufactured products such as fiberglass or mineral wool batts for which the R-value has been tested and arrives at the construction site in preformed lengths and thicknesses with set R-value thicknesses.

When installed in floors, walls, and other vertical assemblies, these fibrous insulations are held in place in one of three ways:

1. Pre-installed netting or fabric
2. Use of existing cavity walls
3. Use of integral adhesives

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

When installed in open surfaces, such as an attic floor or open wall, no netting or preexisting wall cladding is needed. (See Figure 3-50B.) In open horizontal applications, such as attic floors, no adhesives are used, and the R-value is verified by thickness and rated coverage. In open vertical applications, integral adhesives are used to hold the fibers in place. Water-activated adhesives are used for moist-spray cellulose, and polymer adhesives are used for fiberglass loose-fill applications. The adhesive causes the insulation to adhere to itself and stick to surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off and recycled. R-value depends on the installed density of the material at the building site, and the building official should ensure that the installed density meets manufacturer specifications.

**Figure 3-50A (left): Cellulose-Insulated Wall and Figure 3-50B (right): Attic Floor**

Source: California Energy Commission

3. **Spray Polyurethane Foam (SPF):** SPF is a two-part, liquid-foamed thermoset plastic (such as polyurethane). Polyurethane is formed by the reaction of an isocyanate and a polyol. Blowing agents, catalysts, and surfactants are added to develop a cellular structure before the polyurethane mixtures cures. When this mixture is applied to substrate materials, the SPF material forms in place to provide insulation, an air seal, and, in the case of closed-cell SPF, an integral vapor retarder and water barrier.

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 the wall, roof/ceiling, and floor cavities. SPF insulation can be formulated to have specific physical properties (such as density, compressive strength, fire resistance, and R-value).

SPF insulation is spray-applied to adhere fully to the joist and other framing faces to form a complete air seal within the construction cavities. SPF must be separated from the interior of the building, even attic spaces, by an approved thermal barrier consisting of ½-inch (12.7 mm) gypsum wallboard or equivalent thermal barrier material (Section 316.4, CBC).

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), ocSPF has been assigned a default R-value of 3.6 per inch for compliance purposes, but some products can achieve higher R-values. The ocSPF insulation is sprayed then expands to fill the framed cavity. (See Figure 3-51.) Excess insulation is removed with a special tool. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the foam insulation surface shall not be greater than 1 inch of the required thickness, provided these depressions do not exceed 10 percent of the surface area being insulated. The ocSPF must fill the cavity of 2x4 framing to achieve R-13.

**Figure 3-51: Open-Cell SPF Installed in Wall Cavity (may be trimmed to facilitate interior cladding installation)**



Source: SPFA

**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), ccSPF has been assigned a default R-value of 5.8 per inch for compliance, but some products can achieve higher R-values. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the surface of the foam insulation shall not be greater than ½-inch of the required thickness at any given point of the surface area being insulated. CcSPF is not required to fill the cavity. (See Figure 3-52.)

SPF R-value depends on the installed thickness, and the building official should ensure the thickness and uniformity of the SPF material within each cavity of framed assemblies meets manufacturer specifications. Default R-values assigned to SPF are shown in Table 3-9.

**Table 3-9: Required Thickness of SPF Insulation to Achieve Default R-values**

Thickness of SPF Insulation	R11	R13	R15	R19	R21	R22	R25	R30	R38
Required thickness of ccSPF Insulation (inches)	2.00	2.25	2.75	3.50	3.75	4.00	4.50	5.25	6.75
Required thickness of ocSPF Insulation (inches)	3.00	3.50	4.20	5.30	5.80	6.10	6.90	8.30	10.6

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

**Figure 3-52: Closed-Cell SPF Installation in a Wall Cavity (full-fill not needed; thickness installed to achieve R-value only)**



Source: SPFA

4. **Rigid Insulation:** Rigid board insulation sheathing is made from fiberglass, expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate (ISO), or polyurethane. It varies in thickness, and some products can provide up to R-6 per inch of thickness.

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. Properly sealed rigid insulation can be used continuously across an envelope surface to reduce air infiltration and exfiltration, and thermal bridging at framing.

The Department of Energy Building America website contains regularly updated information on proper continuous rigid insulation installation, including recommendations for button cap nails, furring strips, flashing, and design of the drainage plane. An image showing proper rigid insulation installation is shown in Figure 3-53.

**Figure 3-53: Properly Installed Rigid Insulation With Sealant Tape**



Source: U.S. Environmental Protection Agency

The 2015 California Residential Code (CRC) provides guidance on fastener penetration depth, diameter, and spacing for exterior foam sheathing in Section R703.11.2. CRC Table 703.15.1, reproduced below in Figure 3-54, shows the fastener spacing for cladding attachment over foam sheathing to wood framing.

**Figure 3-54: Fastening Requirements Over Foam Sheathing**

TABLE R703.15.1  
CLADDING MINIMUM FASTENING REQUIREMENTS FOR DIRECT ATTACHMENT  
OVER FOAM PLASTIC SHEATHING TO SUPPORT CLADDING WEIGHT<sup>a</sup>

CLADDING FASTENER THROUGH FOAM SHEATHING	CLADDING FASTENER TYPE AND MINIMUM SIZE <sup>b</sup>	CLADDING FASTENER VERTICAL SPACING (inches)	MAXIMUM THICKNESS OF FOAM SHEATHING <sup>c</sup> (inches)					
			16" o.c. Fastener Horizontal Spacing			24" o.c. Fastener Horizontal Spacing		
			Cladding Weight:			Cladding Weight:		
			3 psf	11 psf	25 psf	3 psf	11 psf	25 psf
Wood Framing (minimum 1 1/4-inch penetration)	0.113" diameter nail	6	2	1	DR	2	0.75	DR
		8	2	1	DR	2	0.5	DR
		12	2	0.5	DR	2	DR	DR
	0.120" diameter nail	6	3	1.5	0.5	3	0.75	DR
		8	3	1	DR	3	0.5	DR
		12	3	0.5	DR	2	DR	DR
	0.131" diameter nail	6	4	2	0.75	4	1	DR
		8	4	1.5	0.5	4	0.75	DR
		12	4	0.75	DR	2	0.5	DR
	0.162" diameter nail	6	4	4	1.5	4	2	1
		8	4	3	1	4	1.5	0.75
		12	4	2	0.75	4	1	DR

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa, 1 pound per square inch = 6.895 kPa.

DR = Design required.

o.c. = On center.

a. Wood framing shall be Spruce-pine-fir or any wood species with a specific gravity of 0.42 or greater in accordance with AWC NDS.

b. Nail fasteners shall comply with ASTM F 1667, except nail length shall be permitted to exceed ASTM F 1667 standard lengths.

c. Foam sheathing shall have a minimum compressive strength of 15 psi in accordance with ASTM C 578 or ASTM C 1289.

Source: 2015 International Residential Code

### 3.7.2 Thermal Mass

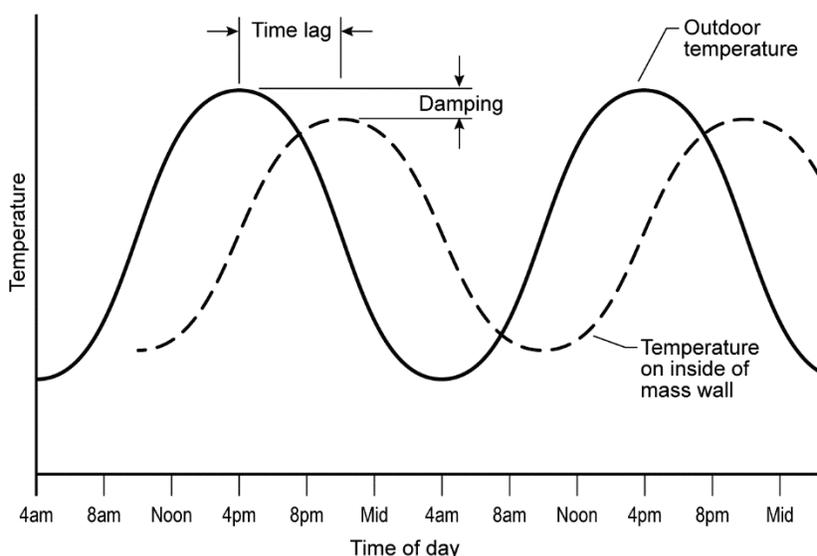
Mass walls typically fall into two categories:

1. Masonry types include clay and concrete units, which may be solid or hollow, and glazed or unglazed. Other masonry unit types include cast stone and calcium silicate units. Concrete masonry units (CMU) are made from a mixture of Portland cement and aggregates under controlled conditions. Concrete masonry units can be manufactured in different sizes and with a variety of face textures.
2. Concrete and concrete sandwich panels typically use a precast form by casting concrete in a reusable mold or "form" that is then cured in a controlled environment, transported to the construction site, and lifted into place. Precast stone is distinguished from precast concrete by using a fine aggregate in the mixture, giving the appearance of naturally occurring rock or stone.

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 stabilizes indoor temperatures. Thermal mass helps temper interior temperature, storing heat or cooling for later use. 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 stabilizes 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 between 6 to 10 hours. Second, there is a dampening effect whereby the temperature range on the inside of the house is less than the temperature range on the outside of the house. These effects are illustrated in the following figure.

**Figure 3-55: Thermal Mass Performance**



Source: California Energy Commission

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

thick concrete. This procedure is automated in Energy Commission-approved computer compliance software.

### 3.7.3 Alternative Construction Assemblies

#### A. Log Homes

Log walls are typically made from trees that have been cut into logs that have not been milled into conventional lumber. Logs used for walls, roofs, and/or floor systems may be milled and/ or laminated by the manufacturer or supplier to meet specific dimensions and fitting and finishing conditions.

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 the reference appendices (RA). 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<sup>2</sup> is equivalent to a heavy mass wall (40 lb/ft<sup>3</sup>). 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 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 JA4) would have to be approved by the Energy Commission through the exceptional methods process.

Log walls have a heat capacity that exceeds conventional construction. 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 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.

#### B. Straw Bale

Straw bale construction is a building method that uses bales of straw (commonly wheat, rice, rye, and oat straw) as structural and insulating elements of the building. Straw bale construction is regulated within the CBC, and specific guidelines are established for moisture content, bale density, seismic bracing, weather protection, and other structural requirements.

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

Straw bales that are 22 inch by 16 inch are assumed to have a thermal resistance of R-30, whether stacked so the walls are 23 inch wide or 16 inch wide. The minimum density of load bearing walls is 7.0 lb/ft<sup>3</sup>, 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<sup>3</sup>, for example, the volumetric heat capacity is 2.24 Btu/ft<sup>3</sup>-°F.

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

The nature of straw bale construction provides an effective air barrier. For compliance, infiltration is assumed to be equivalent to framed walls.

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## 3.8 Compliance and Enforcement

For buildings in which the certificate of compliance (CF1R) requires HERS field verification for compliance with the Energy 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 (CF3R).

The following measures require field verification and diagnostic testing if they are used in the proposed design for compliance, and are listed on the CF1R as special features requiring HERS Rater verification:

1. Building Envelope Sealing
2. 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 CF3R is required. The HERS Rater must submit the CF3R information to the HERS provider data registry as described in Chapter 2. For additional detail describing HERS verification and the registration procedure, refer to RA2.

### 3.8.1 Design

The initial compliance documentation consists of the certificate of compliance (CF1R). MF1R is no longer a checklist, but a statement of the mandatory features that must be included with the CF1R forms. The mandatory features are also included in the CF2R forms. The CF1R must be filed on the plans and specifications. Included on the CF1R 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:

1. Interzone ventilation
2. Radiant barriers
3. Multiple orientation
4. Controlled ventilation crawlspace

5. Nonstandard ventilation height differences
6. Standard-free ventilation area greater than 10 percent of the window area
7. Metal-framed walls
8. Sunspace with interzone surfaces
9. Roofing products (Cool roof)
10. Air-retarding wrap

Plan checkers should verify that insulation levels, fenestration U-factors, and SHGCs listed on the CF1R are consistent with the plans and specifications.

If registration of the CF1R is required (see Chapter 2 for requirements), the building owner or the person responsible for the design must submit the CF1R to the HERS Provider data registry for retention following the procedures described in Chapter 2 and in RA2.

### **3.8.2 Construction**

During construction, the contractor and/or the subcontractors shall complete the necessary sections of the certificate of installation (CF2R):

1. 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. The installer should ensure that the dynamic glazing controls are functional with energy management systems or similar.
2. Building Envelope Leakage Diagnostics. This is applicable only if the builder/contractor does blower door testing to reduce building envelope leakage.
3. Insulation Installation Quality Certificate. The insulation contractor documents the insulation installation quality features that have been followed as shown on the CF2R checklist.
4. 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 construction. These visits verify that the equipment and materials installed are consistent with the plans and specifications.

If registration of the CF2R is required, the licensed person responsible for the installation must submit the portion of the CF2R information that applies to the installation to a HERS Provider data registry using procedures described in Chapter 2 and in RA2.

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## **3.9 References**

JA1 contains a glossary of terms. The following terms either expands on those listed in the reference appendices or are provided here to better clarify compliance issues for the building envelope.

### **3.9.1 Building Orientation**

Orientation of the building, particularly walls and fenestration, can affect energy use. Orientation is also critical for sizing and installing renewable energy sources, such as solar thermal collectors for domestic water heating and solar electric collectors to help offset electrical demand.

- A. **East-Facing** – "East-facing is oriented to within 45 degrees of true east, including 45°0'0" south of east (SE), but excluding 45°0'0" north of east (NE)." [§100.1] The designation "east-facing" is also used in production buildings using orientation restrictions (for example, shaded areas: east-facing).
- B. **North-Facing** "North-facing is oriented to within 45 degrees of true north, including 45°0'0" east of north (NE), but excluding 45°0'0" west of north (NW)." [§100.1]
- C. **South-Facing** – "South-facing is oriented to within 45 degrees of true south, including 45°0'0" west of south (SW), but excluding 45°0'0" east of south (SE)." [§100.1] The designation "South-Facing" is also used in production buildings using orientation restrictions (e.g., Shaded Areas: East-Facing).
- D. **West-Facing** - "West-facing is oriented to within 45 degrees of true west, including 45°0'0" due north of west (NW) but excluding 45°0'0" south of west (SW)." [§100.1]. The designation "West-Facing" is also used in production buildings using orientation restrictions (for example, shaded areas: west-facing).

### 3.9.2 Fenestration Terminology

The following terms are used in describing fenestration products:

- A. **Center of Glass.** U-factor, SHGC, and VT are measured only through glass at least 2.5 inches from the edge of the glass or dividers.
- B. **Clear glass** has little if any observable tint with an IG unit with an SHGC of 0.5 or greater.
- C. **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.
- D. **Dynamic Glazing.** 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.  
  
Includes active materials (for example, electrochromic) and passive materials (for example, photochromic and thermochromic) permanently integrated into the glazing assembly. Electro-chromatic glass darkens by demand or lightens up when more free daylight or solar heat is desired. Improved glazing decreases the SHGC in the summer and reduces heat loss in the winter and have the ability to reversibly change their performance properties, including U-factor, SHGC, and/or VT between well-defined end points.  
  
Integrated shading systems is a class of fenestration products including an active layer: for example, shades, louvers, blinds, or other materials permanently integrated between two or more glazing layers and that has the ability to reversibly change performance properties, including U-factor, SHGC, and/or VT between well-defined end points.
- E. **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.
- F. **Fixed glass.** The fenestration product cannot be opened.
- G. **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.

H. **Grille.** See Divider.

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

J. **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.

K. **Light or Lite.** A layer of glazing material, especially in a multi-layered IG unit. Referred to as panes in §110.6 when the lites are separated by a spacer from inside to outside of the fenestration.

L. **Low-e Coatings.** Low-emissivity coatings are special coatings applied to the second, third or fourth 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:

1. 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.
2. High solar gain low-e coatings, by contrast, are formulated to maximize solar gains. Such coatings would be preferable in passive solar applications or where 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.

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

N. **Muntin.** See Dividers.

O. **National Fenestration Rating Council** is the entity recognized by the Energy Commission to supervise the rating and labeling of fenestration products. NFRC lists the Certified Product Directory, containing NFRC certified U-factors, SHGC and VT 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, SHGC and VT in accordance with §10-111 procedures.

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.

- P. **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.
- Q. **Operable.** The fenestration product can be opened for ventilation.
- R. **R-value.** A measure of a material's thermal resistance, expressed in  $\text{ft}^2(\text{hr})^\circ\text{F}/\text{Btu}$ . 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.

- S. **Soft Coat.** A low-e coating applied through a sputter process. See separate glossary term for low-e coating.
- T. **Solar Heat Gain Coefficient (SHGC).** 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 or SHGCt is the SHGC for the total fenestration product and is the value used for compliance with the Standards.

- 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 a VT less than 0.5.
- X. **U-factor.** A measure of how much heat can pass 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  $\text{ft}^2$  of window area per degree  $^\circ\text{F}$  of temperature difference ( $\text{Btu}/\text{hr}\text{-ft}^2\text{-}^\circ\text{F}$ ). 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 fenestration products, the frame losses can be significant.

- Y. **Visible Transmittance (VT)** is the ratio of visible light transmitted through the fenestration. The higher the VT rating, the more light is allowed through a window.
- Z. **Window Films** 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.

