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3. Building Envelope

This chapter describes the requirements for efficiency measures used for the building envelope of nonresidential, high-rise residential, and hotel/motel occupancy buildings. Building energy use is affected by heating and cooling loads. Heating and cooling loads reflect the amount of energy needed, such as HVAC equipment size (capacity), to provide sufficient heating and cooling to meet inside temperature setpoints. The principal elements affecting heating loads are infiltration through the building and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors. Cooling loads, however, are dominated by solar gains through windows and skylights; from internal gains due to lighting, plug loads, and occupant use; and from additional ventilation loads needed for indoor air quality. For example, light entering the building through windows and skylights for daylighting can add to the internal gains incurred by indoor lighting specified for various occupancy uses if both are not properly controlled.

Outside air ventilation and lighting loads are addressed in Chapter 4, Mechanical Systems, and Chapter 5 and 6, Lighting Systems.

The design of the building envelope is usually the responsibility of the architect, but the design team may receive significant input from the contractor, engineer, or other design professionals. The designer is responsible for making sure that the building envelope complies with the Energy Standards. In addition, the building official is responsible for making sure that the building envelope shown on construction documents is designed and built in conformance with the Energy Standards. This chapter is written for the designer and the building official, as well as other specialists who participate in the design and construction of the building envelope.

3.1 Chapter Overview

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3.1.1 What's New for 2016

The *2016 Building Energy Efficiency Standards* (Energy Standards) include several important changes to the building envelope component requirements, as described below:

A. Revised the minimum mandatory requirements for insulation (§120.7) that apply to wall and roof/ceiling insulation:

a. Metal building.
b. Demising walls.
c. Placement of insulation in the roof/ceiling to limit heat loss and gain from conditioned to unconditioned spaces.

B. Revised prescriptive requirements of §140.3 that apply to:

a. Metal building roofs, and wood-framed and other roofs.
b. Metal-framed walls and wood-framed walls.

C. Requirements for additions, alterations, and repairs (§141.0) that apply to:

a. Mandatory insulation requirements for alterations.
b. Maximum U-factor and shading requirements for fenestration in alterations.
c. Roof/ceiling insulation tradeoff for aged solar reflectance of roofing being replaced, recovered, or recoated.
d. Window films.

D. Requirements for additions and alterations applying to covered processes, §141.1.

3.1.1.1 **Mandatory Measures**

§120.7

When compliance is being demonstrated with either the prescriptive or performance compliance paths, there are mandatory measures that must always be met. If the prescriptive compliance approach is used, the prescriptive efficiency levels are required; if the performance approach is used, the prescriptive requirements establish the baseline for comparison for the proposed building.

The minimum mandatory levels are sometimes superseded by more stringent prescriptive or performance approach requirements. For example, the mandatory measures specify a weighted average U-factor of a metal framed wall insulation to be U-0.151 but, if compliance is being demonstrated with the prescriptive approach for a nonresidential building, Table 140.3-B of the Energy Standards is used to establish the minimum wall thermal compliance level, which in some cases exceeds the mandatory insulation requirements.

3.1.1.2 Prescriptive Approach

Energy Standards Table 140.3-B, C, and D

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

The prescriptive compliance approach consists of specific requirements for each envelope component, in which minimum mandatory levels of insulation must be met. Prescriptive requirements apply to:

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

Envelope requirements vary by climate zone and occupancy type. The prescriptive requirements are located in §140.3 which includes Table 140.3-B for all nonresidential buildings; Table 140.3-C for high-rise residential buildings and hotel/motel buildings; and Table 140.3-D for relocatable public school buildings.

3.1.1.3 Performance Approach

§140.1

The performance approach is a more sophisticated compliance method that offers design flexibility. It may be used for:

- Envelope-only compliance
- Envelope and lighting compliance
- Envelope and partial lighting compliance (where some tenant spaces are not yet defined)
- Envelope and mechanical compliance
- Envelope, lighting, and mechanical compliance

The performance approach allows for energy tradeoffs between building features, such as increasing envelope insulation levels or improving window performance to allow more lighting power or a less efficient space-conditioning system. Under this method, energy use of the building is modeled by compliance software approved by the Energy Commission. See Section 3.5 and Chapter 11 for a more complete discussion of the performance approach.

3.1.2 Envelope Definitions and Features

Elements of the building envelope contribute significantly to the energy efficiency of the building and its design intent. Several features are important to note when a method is chosen to demonstrate compliance. Components of the building shell include the walls, floor, the roof or ceiling, doors, and fenestration. Details for fenestration compliance for windows, skylights, and doors are addressed in Section 3.3.

3.1.2.1 Walls and Space(s) Surrounding Occupancy Uses

Envelope and other building component definitions are listed in §100.1.

A. Envelope requirements vary by envelope component and are a function of their type of construction and the space conditions on either side of the envelope surface.

B. An **exterior partition** is an envelope component (roof, wall, floor, window, etc.) that separates conditioned space from ambient (outdoor) conditions. A demising partition is an envelope component that separates conditioned space from an enclosed unconditioned space.

C. A **conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1 for full definition.) Indirectly conditioned space is influenced more by directly adjacent conditioned space than it is by ambient (outdoor) conditions. An unconditioned space is an enclosed space within a building that is not directly conditioned or indirectly conditioned.

   Example − A plenum space below an insulated roof and above an uninsulated ceiling is an indirectly conditioned space as there is less thermal resistance to the directly conditioned space below than to the ambient air outside. In comparison, an attic below an uninsulated roof having insulation on the attic floor is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below.

D. An **exterior wall** is considered separate from a demising wall or demising partition and has more stringent thermal requirements.

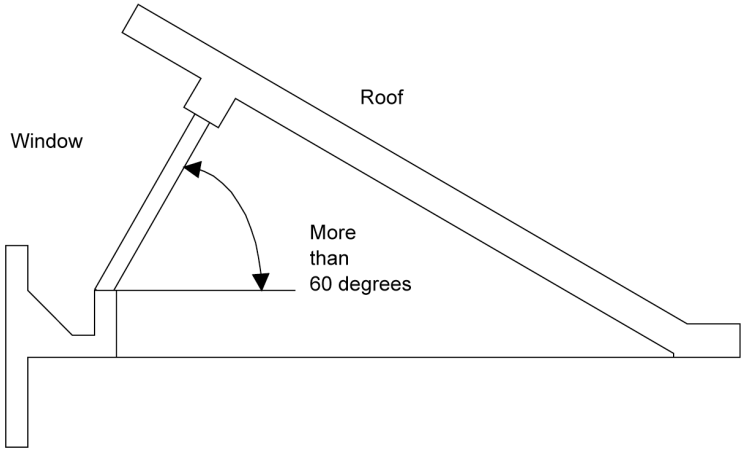
E. **Sloping surfaces** are considered either a wall or a roof, depending on the slope. (See Figure 3-1.) If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including windows in walls and any skylights in roofs.

F. **Floors and roof/ceilings** do not differentiate between demising and exterior. Thus, an exterior roof/ceiling "is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below," ambient conditions or unconditioned space above, "and that is not an exterior door or skylight."

G. Similarly an "exterior floor/soffit is a **horizontal exterior partition**, or a horizontal demising partition, under conditioned space" and above an unconditioned space or above ambient (outdoor) conditions.

H. **Windows** are considered part of the wall because the slope is more than 60°. Where the slope 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°)



3.1.2.2 Roofing Products (Cool Roof)

Roofing products with a high solar reflectance and thermal emittance are referred to as "cool roofs." This roofing type absorbs less solar heat and gives off more heat to the surroundings than traditional roofing material. The roofs are cooler and reduce air-conditioning loads by reflecting and emitting energy from the sun. Roof radiative properties are rated and listed by the Cool Roof Rating Council (CRRC) (http://www.coolroofs.org/).

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

Thermal emittance refers to the ability of heat to escape from a surface once heat energy is absorbed. 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 range of colors that have relatively good cool roof properties. Surfaces with low emittance (usually shiny metallic surfaces) contribute to the transmission of heat into components under the roof surface. Excess heat can increase the air-conditioning load of a building, resulting in increased energy needed for maintaining occupant comfort. High-emitting roof surfaces reject absorbed heat faster (upward and out of the building) than roof surfaces with low-emitting properties that are usually darker.

The Energy Standards prescribe cool roof radiative properties differently for low-sloped and steep-sloped roofs (§140.3(a)1A). A *low-sloped roof* is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizon), while a *steep-sloped roof* is a surface with a pitch greater than 2:12 (9.5 degrees from the horizon). Because heat solar gain is based on the sun's angle of incidence on a surface, low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer, when the sun is high in the sky.

The Energy Standards specify radiative properties that represent minimum "cool roof performance" qualities of roofing products. Performance values are established based on "initial" testing of the roofing product and for the "aged" value, which accounts for the effects of weathering due to climate conditions:

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

- Solar reflectance index (SRI): The relative surface temperature of a surface with respect to standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient conditions. This combined metric is a function of both solar reflectance and thermal emittance. The same SRI can be achieved if the roofing product has a higher solar reflectance but a lower thermal emittance. The SRI metric is a prescriptive alternative to reflectance and emittance requirements and is not used with the performance compliance method.

3.1.2.3 Infiltration and Air Leakage

Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. Poor construction detailing at interfacing points of different construction materials, particularly in extreme climates, can significantly affect heating and cooling loads. Air leakage can occur through holes and cracks in the building envelope, and around doors and fenestration areas. Ventilation is the *intentional* replacement of conditioned air with unconditioned air through open windows or mechanical ventilation.

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

An **air barrier** that inhibits air leakage is critical to good building design and is a prescriptive requirement. (See Section 3.2.1.2.)

3.1.2.4 Thermal Properties of Opaque Envelope Components

Typical opaque envelope assemblies are made up of a variety of components, such as wood or metal framing, masonry or concrete, insulation, and various membranes for moisture and/or fire protection, and may have a variety of interior and exterior sheathings even before the final exterior façade is placed. Correctly calculating assembly U-factors is critical to the selection of equipment to meet the heating and cooling loads of the building. Performance compliance software automatically calculates the thermal effects of component layers making up the envelope assembly, but software programs may use different user input hierarchies. The Reference Appendices, Joint Appendix JA4, “U-factor, C-factor, and Thermal Mass Data,” provide detailed thermal data for many wall, roof/ceiling, and floor assemblies. However, this reference cannot cover every possible permutation of materials, thickness, and so forth, that might be used in a building; thus, the Energy Commission has incorporated a program for calculating material properties of typical envelope assemblies that may not be found from the JA4 reference data into the public domain software CBECC-COM.

Key terms of assembly thermal performance are:

A. **Btu** (British thermal unit): The amount of heat required to raise the temperature of 1 pound of water 1°F.

B. **Btuh or Btu/hr** (British thermal unit per hour): The rate of heat flow during an hour. The term is used to rate the output of heating or cooling equipment or the load that equipment must be capable of handling; that is, the capacity needed for satisfactory operation under stated conditions.

C. **R or R-value** (thermal resistance): The ability of a material or combination of materials to retard heat flow. As the resistance increases, the heat flow is reduced. The higher the **“R-value”**, the greater the insulating value. R-value is the reciprocal of the conductance, **“C-value.”**

R-value = hr x ft^2 x °F/Btu
R = inches of thickness/k

D. **U or U-factor** (thermal transmittance or coefficient of heat transmission): The rate of heat transfer across an envelope assembly per degree of temperature difference on either side of the envelope component. U-factor is a function of the materials and related thickness. U-factor includes air film resistances on inside and outside surfaces. U-factor applies to heat flow through an assembly or system, whereas "**C**" has the same dimensional units and applies to individual materials. The lower the "**U**" the higher the insulating value.

U-factor = Btu/(hr x ft^2 x °F)

E. **k or k-value** (thermal conductivity): The property of a material to conduct heat in the number of Btu that pass through a homogeneous material 1 inch thick and 1 square foot in area in an hour with a temperature difference of 1°F between the two surfaces. The lower the "**k"** the greater the insulating value.

k = Btu x in/(hr x ft^2 x °F)

F. **C or C-value** (thermal conductance): The number of Btu that pass through a material of any thickness and 1 square foot in area in an hour with a temperature difference of 1°F between the two surfaces. The time rate of heat flow through unit area of a body induced by a unit temperature difference between the body surfaces. The C-value does not include the air film resistances on each side of the assembly. The term is applied usually to homogeneous materials but may be used with heterogeneous materials such as concrete block. If **"k"** is known, the **"C"** can be determined by dividing **"k"** by inches of thickness. The lower the "C", the greater the insulating value.

C = Btu/(hr. x ft^2 x °F) or C = k/inches of thickness

G. **HC** (heat capacity – thermal mass): The ability to store heat in units of Btu/ft^2 and is a property of specific heat, density, and thickness of a given envelope component. High thermal mass building components, such as tilt-up concrete walls, can store heat and release stored heat later in the day or night. The thermal storage capability of high mass walls, floors, and roof/ceilings can slow heat transfer and shift heating and cooling energy affecting building loads throughout a 24-hour period, depending on the design, location, and occupancy use of a building.

3.2 Opaque Envelope Assembly

This section addresses the requirements for thermal control of the opaque portion of the building shell or envelope.

3.2.1 General Envelope Requirements

This section contains mandatory measures that are not specific to one envelope component.

3.2.1.1 Mandatory Requirements

A. Certification of Insulation Materials

§110.8(a), §140.3(a)1B

Manufacturers must certify that insulating materials comply with the *California Quality Standards for Insulating Materials*, which became effective January 1, 1982. It ensures that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.

Builders may not install insulating materials, unless the product has been certified by the Department of Consumer Affairs, Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Materials* to verify certification of the insulating material. If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation Program, at (916) 999-2041 or by email: HomeProducts@dca.ca.gov.

Where applicable, the R-value of cavity and/or continuous insulation, or the overall assembly U-factor, may be used to demonstrate compliance with required insulation levels. Reference insulation values are provided in the Reference Appendix JA4, where assembly U-factors are shown for various assemblies and components. U-factors represent the actual thermal conductance of the assembly, including air film coefficients, framing factors, and all layers used to construct the assembly. Assemblies not listed in JA4 tables may calculate U-factors using the assembly calculator in the public domain software, CBECC-COM.

B. Urea Formaldehyde Foam Insulation

§110.8(b)

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

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

C. Flame Spread Rating of Insulation

§110.8(c)

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

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

D. Infiltration and Air Leakage

§110.7

All joints and other openings in the building envelope that are potential sources of air leakage must be caulked, gasketed, weatherstripped, or otherwise sealed to limit air leakage into or out of the building. This applies to penetrations for pipes and conduits, ducts, vents, and other openings. It means that all gaps between wall panels, around doors, and other construction joints must be well sealed. Ceiling joints, lighting fixtures, plumbing openings, doors, and windows should all be considered as potential sources of unnecessary energy loss due to infiltration.

No special construction requirements are necessary for suspended (T-bar) ceilings, provided they meet the requirements of §110.8(e). Standard construction is typically adequate for meeting the infiltration/exfiltration requirements unless an air barrier is required. (See Section 3.2.1.2.)

E. Mandatory Insulation Requirements (Newly Constructed Buildings)

§120.7

Newly constructed nonresidential and high-rise residential buildings and hotels/motels must meet mandatory insulation requirements for opaque portions of the building that separate conditioned spaces from unconditioned spaces or ambient air. The U-factor for each assembly type shall not exceed the values listed in Table 3-2. Determining the total weight-averaged U-factor is allowed for all assembly types except for light and heavy mass walls. Joint Appendix JA-4 of the Reference Appendices illustrates the allowed procedure for calculating U-factors. The representative constructions that meet these requirements are shown in parentheses. U-factors allow greater flexibility in the design choice of components making up a given assembly that meet the maximum U-factor requirement and design conditions of the envelope.

An exception is specified that exempts buildings designed as data centers with high, constant server loads from the mandatory minimum requirements. To qualify for this exception, it should have a design computer room process load of 750 kW or greater.

3.2.1.2 Prescriptive Requirements

A. Air Barrier

§140.3(a)9

Table 140.3-B of the Energy Standards specifies requirements for air barriers in nonresidential buildings. Air barrier requirements apply to nonresidential buildings, but not relocatable public school buildings, and are effectively mandatory requirements, since they cannot be traded off in the performance approach. These requirements reduce the overall building air leakage rate. The reduction in air leakage can be met with a continuous air barrier that seals all joints and openings in the building envelope and is composed of one of the following:

1. Materials having a maximum air permeance of 0.004 cfm/ft2 (see Table 3-1 below).
2. Assemblies of materials and components having an average air leakage not exceeding 0.04 cfm/ft2.
3. An entire building having an air leakage rate not exceeding 0.40 cfm/ft^2.

The air leakage requirements stipulated in §140.3 must be met, either by demonstrating that component air leakage or whole-building air leakage of 0.4 cfm/ft2 is not exceeded. This requirement must be met regardless of the compliance path chosen, so it is effectively mandatory.

Table 3-1: Materials Deemed to Comply As Air Barrier

	MATERIALS AND THICKNESS		MATERIALS AND THICKNESS
1	Plywood – min. 3/8 inches thickness	9	Built up roofing membrane
2	Oriented strand board – min. 3/8 inches thickness	10	Modified bituminous roof membrane
3	Extruded polystyrene insulation board – min. ½ inches thickness	11	Fully adhered single-ply roof membrane
4	Foil-back polyisocyanurate insulation board – min. ½ inches thickness	12	A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inches thickness
5	Closed cell spray foam with a minimum density of 2.0 pcf and a min. 1½ inches thickness	13	Cast-in-place concrete, or precast concrete
6	Open cell spray foam with a density no less than 0.4 pcf and no greater than 1.5 pcf, and a min. 5½ inches thickness	14	Fully grouted concrete block masonry
7	Exterior or interior gypsum board min. 1/2 inches thickness	15	Sheet steel or sheet aluminum
8	Cement board – min. 1/2 inches thickness	_____	_____

3.2.2 Roofs

3.2.2.1 Mandatory Measures

A. Roof/Ceiling Insulation

§120.7(a)

1. Metal Building: Weighted average U-factor of U-0.098 (R-19 screw down roof, no thermal blocks).
2. Wood-Framed and Others: Weighted average U-factor of U-0.075 (2x4 rafter, R-19 insulation).

B. Insulation Placement on Roof/Ceilings

§120.7(a)3

Insulation installed on top of suspended (T-bar) ceilings with removable ceiling panels may not be used to comply with the Energy Standards unless the installation meets the criteria described in the *Exception* to §120.7(a)3 below. Insulation may be installed in this location for other purposes such as for sound control, but it will have no value in terms of meeting roof/ceiling insulation requirements of the Energy Standards.

Acceptable insulation installations include placing the insulation in direct contact with a continuous roof or ceiling that is sealed to limit infiltration and exfiltration as specified in §110.7, including, but not limited to, placing insulation either above or below the roof deck or on top of a drywall ceiling.

When insulation is installed at the roof in nonresidential buildings, the space between the ceiling and the roof is considered to be either directly or indirectly conditioned space. Therefore, this space must not include fixed vents or openings to the outdoors or to unconditioned spaces. This space is not considered an attic for complying with California

Building Code (CBC) attic ventilation requirements. Vents that do not penetrate the roof deck and that are designed for wind resistance for roof membranes are acceptable.

Exception to §120.7(a)3: When there are conditioned spaces with a combined floor area no greater than 2,000 square feet in an otherwise unconditioned building, and when the average height of the space between the ceiling and the roof over these spaces is greater than 12 feet, insulation placed in direct contact with a suspended ceiling with removable ceiling panels shall be an acceptable method of reducing heat loss from a conditioned space and shall be accounted for in heat loss calculations.

C. Wet Insulation Systems

§110.8(h)

Wet insulation systems are roofing systems where the insulation is installed above the roof's waterproof membrane. Water can penetrate this insulation material and 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 before choosing the table column in Reference Appendix JA4 for determining assembly U-factor. See the footnotes in the Reference Appendix JA4 for Tables 4.2.1 through 4.2.7.

D. Roofing Products: Solar Reflectance and Thermal Emittance

§110.8(i)

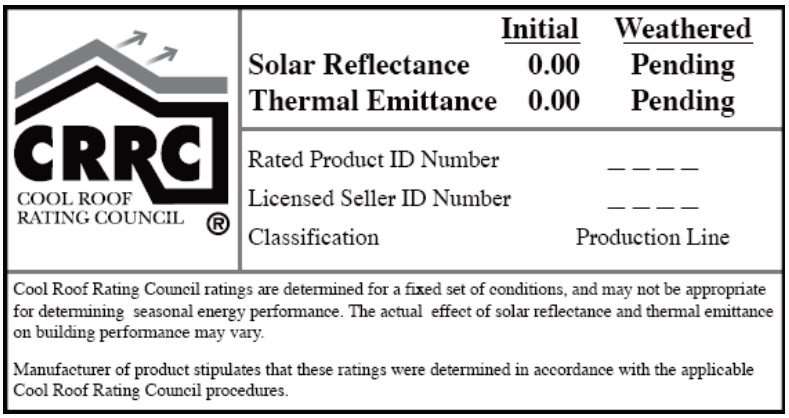
Roofing products must be tested and labeled by the Cool Roof Rating Council (CRRC), and liquid-applied products must meet minimum standards for performance and durability per §110.8(i)4. Installing cool roofs is **not** a mandatory measure. However, to receive credit for product performance, the reflectance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

1. Rating and Labeling

§10-113

When a cool roof is installed to meet the prescriptive requirement or when it is used for compliance credit, the products must be tested and labeled by the CRRC as specified in §10-113. The CRRC is the supervisory entity responsible for certifying cool roof products. The CRRC test procedure is documented in CRRC-1, the *CRRC Product Rating Program Manual.* This test procedure includes tests for both solar reflectance and thermal emittance. See Figure 3-2 for an example of an approved CRRC product label.

Figure 3-2: Sample CRRC Product Label and Information



	Initial	Weathered
Solar Reflectance	0.00	Pending
Thermal Emittance	0.00	Pending

Rated Product ID Number	_ _ _ _
Licensed Seller ID Number	_ _ _ _
Classification	Production Line

Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary.

Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.

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

§110.8(i)1,2, and 3

To demonstrate compliance with the Energy Standards, all cool roofing products must be certified and labeled according to CRRC procedures. The CRRC certification includes solar reflectance and thermal emittance. There are three kinds of solar reflectance listed in the CRRC's Rated Product Directory:

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

All requirements of the Energy Standards are based on the 3-year aged solar reflectance. However, if the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the aged value shall be derived from the CRRC initial value or an accelerated testing 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.

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

Where,

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

β= 0.65 for Field Applied Coating, or 0.70 for Not a Field-Applied Coating

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:

a. For asphalt shingles, 0.08/0.75.
b. For all other roofing products, 0.10/0.75.

The temperature of a surface depends on the solar radiation incident, surface reflectance, and emittance. The SRI measures the relative steady-state surface temperature of a surface with respect to standard white (SRI=100) and standard black

(SRI=0) under the standard solar and ambient condition. A calculator has been produced by Lawrence Berkeley National Laboratory that calculates the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The calculator can be found at http://www.energy.ca.gov/title24/2016standards/documents/solar_reflectance/. 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 prescriptively comply with an emittance lower than 0.85, as long as the aged solar reflectance is higher or a lower aged solar reflectance with a much higher than 0.85 emittance.

3. Field-Applied Liquid Coatings

§110.8(i)4, Table 110.8-C

Liquid roof coatings applied to low-sloped roofs in the field as the top surface of a roof covering shall comply with the following mandatory requirements and descriptions. There are several liquid products, including elastomeric coatings and white acrylic coatings that qualify for field-applied liquid coatings. The Energy Standards specify minimum performance and durability requirements for field-applied liquid coatings in Table 110.8-C. These requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail below.

a. Aluminum-Pigmented Asphalt Roof Coatings

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

This class of field-applied liquid coatings shall be applied across the entire surface of the roof and meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. Also, the aluminum-pigmented asphalt roof coatings shall be manufactured in accordance with ASTM D28241. Standard specification is also required for aluminum-pigmented asphalt roof coatings, nonfibered, asbestos-fibered, and fibered without asbestos that are suitable for applying to roofing or masonry surfaces by brush or spray. Use ASTM D6848, Standard Specification for Aluminum Pigmented Emulsified Asphalt used as a Protective Coating for Roofing, installed in accordance with ASTM

1 A. This specification covers asphalt-based, aluminum roof coatings suitable for application to roofing or masonry surfaces by brush or spray.
B. The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.
C. The following precautionary caveat pertains only to the test method portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

D38052, Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

b. Cement-Based Roof Coatings

This class of coatings consists of a layer of cement and has been used for a number of years in California's Central Valley and other regions. These coatings may be applied to almost any type of roofing product. Cement-based coatings shall be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the manufacturer. Also, cement-based coatings shall be manufactured to contain no less than 20 percent Portland cement and meet the requirements of ASTM D8223, 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 surface of the roof 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 performance and durability requirements as specified in Table 110.8-C of the Energy Standards or the minimum performance requirements of ASTM C836, D3468, D6083, or D6694, whichever are appropriate to the coating material.

3.2.2.2 Prescriptive Measures

A. Insulation Requirements − Exterior Roofs and Ceilings

§140.3(a)1B

Under the prescriptive requirements, roofs or ceilings must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential or high-rise residential buildings. (See Table 3-2.) The U-factor values for exterior roofs and ceilings from Reference Appendix JA4 must be used to determine compliance with the maximum assembly U-factor requirements. Alternatively, the assembly calculator that is incorporated into CBECC-COM, the public domain program, can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

The metal building roof prescriptive requirement has been updated in the 2016 Energy Standards to require a filled cavity insulation technique for improved performance. In the past, a common technique for standing seam metal roofs is to drape a layer of insulation

2 A. This guide covers the application methods for Specification D 2824 Aluminum-Pigmented Asphalt Roof Coatings, Non-Fibered (Type I), Asbestos Fibered (Type II), and Fibered without Asbestos (Type III), for application on asphalt built-up roof membranes, modified bitumen roof membranes, bituminous base flashings, concrete surfaces, metal surfaces, emulsion coatings, and solvent-based coatings. This guide does not apply to the selection of a specific aluminum-pigmented asphalt roof coating type for use on specific projects.
B. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.
C. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given in Section 4.
3 A. This guide is intended for the evaluation of clear and pigmented coatings designed for use on rigid or semi rigid plastic substrates. Coated film and sheeting are not covered by this guide.
B. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

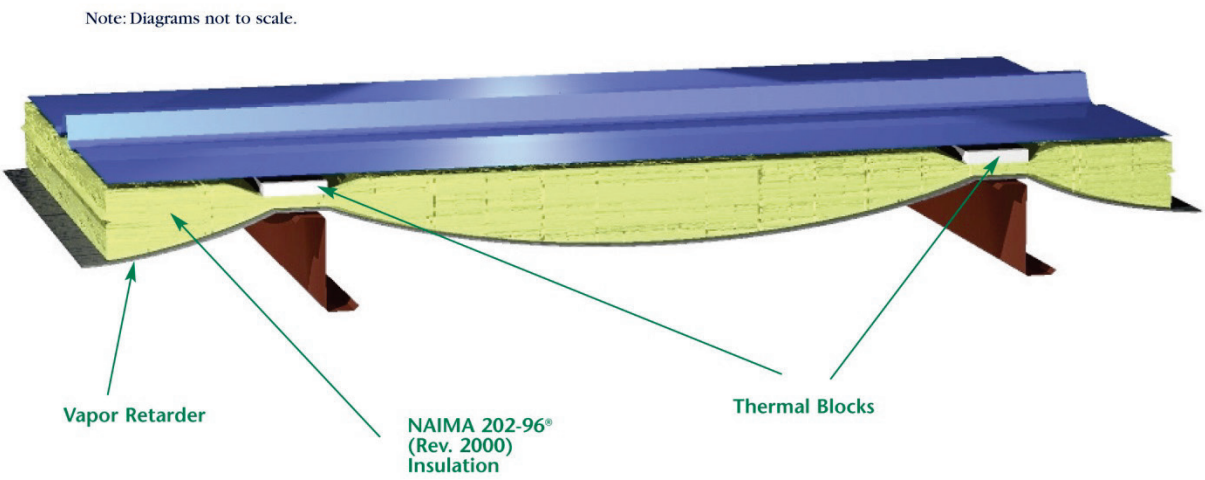
over the purlins, using thermal blocks where the insulation is compressed at the supports. (See Figure 3-3.)

Table 3-2: Roof/Ceiling U-Factor Requirements

Building Type		Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.034	0.034	0.034	0.034	0.034	0.049	0.049	0.049
High-Rise Residential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.028	0.028	0.034	0.028	0.034	0.034	0.039	0.028
Relocatable Public School Buildings	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Bldg	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Building Type		**Climate Zones**							
		9	10	11	12	13	14	15	16
Nonresidential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
High-Rise Residential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Relocatable Public School Buildings	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Bldg	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034

Summary of Tables 140.3-B, 140.3-C, and 140.3-D of the Energy Standards

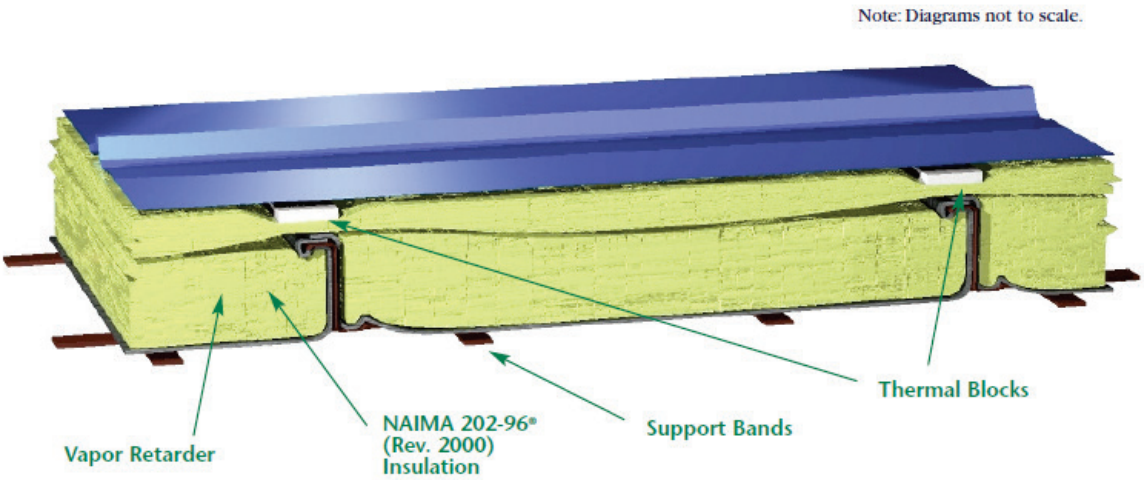
Figure 3-3: Standing Seam Metal Building Roof With Single Insulation Layer



Source: North American Insulation Manufacturers Association (NAIMA)

Recent studies show that the thermal performance of this assembly is not as good as estimated. Therefore, there are significant benefits to using the "filled cavity" approach, shown below.

Figure 3-3A – Filled Cavity Insulation for Metal Building Roofs



Source: North American Insulation Manufacturers Association (NAIMA)

A rigid polyisoyanurate ("polyiso") thermal block with a minimum R-value of R-3.5 should be installed at the supports (a 1-inch-thick thermal block is recommended). The first rated R-value of the insulation is for faced insulation installed between the purlins. The second rated R-value of insulation represents unfaced insulation installed above the first layer, perpendicular to the purlins and compressed when the metal roof panels are attached. A

supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of insulation.

The bottom layer of insulation should completely fill the space between the purlins, and the support bands should be installed tightly to prevent the insulation from sagging.

The configuration above, which corresponds to two layers of R-19 and R-10 insulation, corresponds to the prescriptive requirement of U-0.041, but other insulation combinations exceeding the minimum requirement are readily achievable.

B. Thermal Emittance and Solar Reflectance

§140.3(a)1A

The prescriptive requirements call for roofing products to meet the solar reflectance and thermal emittance in both low-sloped and steep-sloped roof applications for nonresidential buildings. A qualifying roofing product under the prescriptive approach for a nonresidential building must have an aged solar reflectance and thermal emittance greater than or equal to that the values indicated in Table 3-3 below. Table 3-4 is for high-rise residential buildings and hotel/motel guest rooms, and Table 3-5 is for relocatable public school buildings where the manufacturer certifies use in all climate zones.

Table 3-3: Prescriptive Criteria for Roofing Products for Nonresidential Buildings

			Climate Zones															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofing Products	Low-sloped	Aged Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	Steep-Sloped	Aged Reflectance	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Energy Standards Table 140.3-B

Table 3-4: Prescriptive Criteria for Roofing Products for High-Rise Residential Buildings and Guest Rooms of Hotel/Motel Buildings (Energy Standards Table 140.3-C)

			Climate Zones															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofing Products	Low-sloped	Aged Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	0.55	NR	0.55	0.55	0.55	NR
		Emittance	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	0.75	NR	0.75	0.75	0.75	NR
		SRI	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
	Steep-Sloped	Aged Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	NR
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Energy Standards Table 140.3-C

Table 3-5: Prescriptive Criteria for Roofing Products for Relocatable Public School Buildings, Where Manufacturer Certifies Use in All Climate Zones

Roofing Products	Aged Reflectance	Emittance
Low-Sloped	0.63	0.75
SRI	75	
Steep-Sloped	0.20	0.75
SRI	16	

If the aged value for the solar reflectance is not available in the *CRRC Rated Product Directory*, then the equation in Section 3.2.2.1D (Aged Reflectance$_{calculated}$=(0.2+ β[$\rho_{initial}$ – 0.2])) can be used until the aged rated value for the reflectance is posted in the directory.

There are three exceptions to the minimum prescriptive requirements for solar reflectance and thermal emittance:

1. Roof area covered by building-integrated photovoltaic panels and building-integrated solar thermal panels is not required to meet the cool roof requirements.
2. If the roof construction has a thermal mass like gravel, concrete pavers, stone, or other materials with a weight of at least 25 lb/ft² over the roof membrane, then it is exempt from the above requirements for solar reflectance and thermal emittance.
3. Wood-framed roofs in climate zones 3 and 5 with a U- factor of 0.034 are exempt from the low-sloped cool roof requirement.

Where a low-sloped nonresidential roof's aged reflectance is less than the prescribed requirement, insulation tradeoffs are available. By increasing the insulation level of a roof, a roofing product with a lower reflectance than the prescriptive requirements can be used to meet the cool roof requirements. The appropriate U-factor can be determined from Table 3-6 for nonresidential buildings based on roof type, climate zone and aged reflectance of at least 0.25.

Table 3-6: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance

Aged Solar Reflectance	Metal Building Climate Zone 1-16 U-factor	Wood-Framed and Other Climate Zone 6 & 7 U-factor	Wood Framed and Other All Other Climate Zones U-factor
0.62-0.56	0.038	0.045	0.032
0.55-0.46	0.035	0.042	0.030
0.45-0.36	0.033	0.039	0.029
0.35 -0.25	0.031	0.037	0.028

Energy Standards Table 140.3

3.2.2.3 Performance Approach – Compliance Options

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 and additions and alterations to existing buildings.

A. Aggregate Default Roof Reflectance Properties

Some low-sloped roofs of nonresidential buildings use aggregate material made of gravel or crushed stone that is 3/4" or smaller, as the surface layer under a ballasted roof. Such roofing cannot be accurately tested via CRRC procedures because some of the aggregate can become damaged in transit, affecting the performance.

The Energy Commission has stipulated aged reflectance and emittance values that can be used for these types of products that have been tested via ASTM procedures. The default reflectance and emittance values may be used below in the performance compliance approach or prescriptive tradeoff with increased insulation (Table 140.3 of the Energy Standards).

Table 3-7: Default Solar Reflectance on Thermal Emittance for Aggregate Materials Based on Size

Aggregate Size	Required Tested Initial Solar Reflectance	Default Aged Solar Reflectance	Default Thermal Emittance
Built‐Up Roofs Size 6‐8 conforming to ASTM D448 and ASTM D1863	0.50	0.48	0.85
Ballasted Roofs Size 2‐4 conforming to ASTM D448	0.45	0.40	0.85

For example, aggregate with size 2-4 meeting the requirements must have a tested solar reflectance of at least 0.45 to use a default aged reflectance value of 0.40 in the performance method.

Eligibility criteria for aggregate used as the surface layer of low-sloped roofs:

1. Aggregate shall have a tested initial solar reflectance that meets or exceeds 0.50 for built-up roofs and 0.45 for ballasted roofs using the ASTM E1918 test procedure conducted by an independent laboratory meeting the requirement of §10-113(d)4
2. Aggregate shall have a label on bags or containers of the aggregate material stating

(a) the tested initial solar reflectance of the material conforming to ASTM D1863, and
(b) the size of the material conforming to ASTM D448.

Example 3-1

Question:

According to the provisions of the Energy Standards, are cool roofs optional for nonresidential buildings or high-rise residential buildings?

Answer:

The answer depends on the compliance approach you chose. For prescriptive compliance, compliance with solar reflectance and thermal emittance, or SRI is required where indicated in Energy Standards Tables 140.3-B, C, and D. In the performance approach, reflectance, and emittance values less than the minimum prescriptive requirements may be used; however, any deficit that results from this choice must be made up by improving other energy efficiency features in the building, which include envelope, space-conditioning system, and lighting systems.

Example 3-2

Question:

Must all roofing materials used in California, whether cool roof or not, be certified by the CRRC and labeled accordingly?

Answer:

No, but it does depend on the compliance approach you are using. A roof repair, such as for a leak, does not require the roofing product to be cool roof and/or certified by the CRRC.

If you are altering your roof, such as a new reroof, then either the prescriptive envelope component approach or the performance approach can be used for compliance.

In these compliance cases, the answer is yes, the roof must be certified and labeled by CRRC for nonresidential roofs. If you are using the performance approach to receive compliance credit, you can either obtain a CRRC certification, **or** use a default solar reflectance of 0.10 and thermal emittance of 0.75. Using default values instead of CRRC certificates may result in a significant energy penalty that must be made up by increasing energy efficiency in other building features. The default reflectance for asphalt roofs is different than tile and metal roofing products.

Example 3-3

Question:

Can I use solar reflectance and thermal emittance data generated by any nationally recognized and well-respected laboratory in lieu of CRRC ratings? Can in-house testing by the manufacturer be used to qualify my product?

Answer:

No. Only CRRC ratings from the product directory list can be used to establish cool roof product qualification for standards compliance. The CRRC process requires use of a CRRC-accredited laboratory (under most circumstances, an "Accredited Independent Testing Laboratory (AITL) defined by the CRRC program.) Any testing laboratory can become an AITL by following the CRRC accreditation process and satisfying the requirements. The roster of CRRC-accredited laboratories is posted on the CRRC website (http://www.coolroofs.org).

Example 3-4

Question:

Can the reflectance and emittance requirements of ENERGY STAR® cool roofs be substituted for standards requirements?

Answer

No. Only roofing products which are listed by the CRRC in its Rated Product Directory can be used to the standards. CRRC is the only organization that has met the criteria set in §10-113.

Example 3-5

Question:

Can I claim to have a cool roof, or can I get anything higher than a default reflectance, if my roof does not meet the field-applied coating performance requirements of the Energy Standards?

Answer:

No, you cannot claim to have a cool roof and you cannot claim higher energy credits if your roof does not meet the coating performance requirements of the Energy Standards for field-applied coatings.

Example 3-6

Question:

How does a product get CRRC cool roof certification?

Answer:

Any party wishing to have a product or products certified by CRRC should contact the CRRC toll-free (866) 465-2523 from inside the United States or (510) 482-4420, ext. 215, or email info@coolroofs.org. In addition, CRRC publishes the procedures in the *CRRC-1 Program Manual*, available for free on http://www.coolroofs.org or by calling the CRRC. However, working with CRRC staff is strongly recommended.

Example 3-7

Question:

Do alterations to the roof of an unconditioned building trigger cool roof requirements?

Answer:

No, alterations to the roof of an unconditioned building do not trigger cool roof requirements. In general, the lighting requirements are the only requirements applicable for both newly constructed and altered unconditioned buildings; this includes §140.3(c), the skylight requirements. Building envelope (other than skylight requirements) and space-conditioning requirements do not apply to unconditioned buildings.

Example 3-8

Question:

What happens if I have a low-sloped roof on most of my buildings and steep-sloped roof on another portion of the roof? Do I have to meet the two different sets of rules in §140.3(a)1Ai and ii?

Answer:

Yes, your building would have to meet both the low-sloped requirement and the steep-sloped roof requirements for the respective area.

Example 3-9

Question:

I am installing a garden roof (roofs whose surface is composed of soil and plants) on top of an office building. Although garden roofs are not cool roofs by their reflectance properties, will they be allowed under the Energy Standards?

Answer:

Yes, the Energy Commission considers a garden roof as a roof with thermal mass on it.

Under *Exception* 4 to §140.3(a)1Ai, if a garden roof has a dry unit weight of 25 lb/ft², then the garden roof is equivalent to cool roof.

3.2.3 Exterior Walls

3.2.3.1 Mandatory Requirements

A. Wall Insulation

§120.7(b)

1. Metal Building: Weighted average U-factor of U-0.113 (single layer of R-13 batt insulation).
2. Metal-Framed: Weighted average U-factor of U-0.151 (R-8 continuous insulation, or R-13 batt insulation between studs and 1/2" of continuous rigid insulation of R-2). It may be possible to meet the area-weighted average U-factor without continuous insulation, if the appropriate siding materials are used.
3. Light Mass Walls: 6 inches or greater hollow core concrete masonry unit having a U-factor not exceeding 0.440 (partially grouted with insulated cells).
4. Heavy Mass Walls: 8 inches or greater hollow core concrete masonry unit having a U-factor not exceeding 0.690 (solid grout concrete, normal weight, 125 lb/ft3).
5. Wood-Framed and Others: Weighted average U-factor of U-0.110 (R-11 batt insulation).
6. Glass Spandrel Panels and Glass Curtain Wall: Weighted average U-factor of U-0.280.

   Exception: Buildings designed as data centers with high, constant server loads from the mandatory minimum requirements are exempt. To qualify for this exception, it should have a design computer room process load of 750 kW or greater.

3.2.3.2 Prescriptive Requirements

§140.3(a)2

Under the prescriptive requirements, exterior walls must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential and high-rise residential buildings in Table 3-8.

The U-factor for exterior walls from Reference Appendix JA4 must be used to determine compliance with the assembly U-factor requirements. The Energy Standards no longer allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of Reference Appendix JA4; only U-factors may be used to demonstrate compliance.

For metal-framed walls with insulation between the framing sections, continuous insulation may need to be added to meet the U-factor requirements of the Energy Standards. For light mass walls, insulation is not required for buildings in South Coast climates but is required for other climates. For heavy mass walls, insulation is not required for buildings in Central Coast or South Coast climates but is required for other climates.

Table 3-8: Wall U-Factor Requirements

Building Type		1	2	3	4	5	6	7	8
Nonresidential	Metal Bldg	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
	Metal- Frame	0.069	0.062	0.082	0.062	0.062	0.069	0.069	0.062
	Mass Light	0.196	0.170	0.278	0.227	0.44	0.44	0.44	0.44
	Mass Heavy	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690
	Wood-Frame	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102
Residential High-Rise	Metal bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
	Metal-frame	0.069	0.069	0.069	0.069	0.069	0.069	0.105	0.069
	Mass Light	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227
	Mass Heavy	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690
	Wood-Frame	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Relocatable Public Schools	Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Metal - Frame	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Mass /7.0<HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Wood Frame	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
	All Other Walls	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

Building Type		9	10	11	12	13	14	15	16
Nonresidential	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal-Frame	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Mass Light	0.44	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Frame	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
Residential High-Rise	Metal Bldg	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
	Metal-Frame	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
	Mass Light	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Frame	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Relocatable Public Schools	Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Metal - Frame	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Mass /7.0<HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Wood Frame	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
	All Other Walls	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Reference Appendix JA4. Alternatively, the assembly calculator that is incorporated into CBECC-COM can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

There are five classes of wall constructions: wood-framed, metal-framed, metal building walls, light mass, and heavy mass. The following provides additional information about each type of wall system:

1. **Wood-framed walls:** As defined by the 2013 California Building Code, Type IV buildings typically have wood-framed walls. Framing members typically consist of 2x4 or 2x6 framing members spaced at 24 inch or 16 inch OC. Composite framing members and engineered wood products also qualify as wood framed walls if the framing members are nonmetallic. Structurally insulated panels (SIPs) are another construction type that qualifies as wood-framed. SIPs panels typically consist of rigid foam insulation sandwiched between two layers of oriented strand board (OSB). Reference Appendix JA4, Table 4.3.1 has data for conventional wood-framed walls, and Table 4.3.2 has data for SIPs panels.
2. **Metal-framed walls:** Many nonresidential buildings and high-rise residential buildings require noncombustible construction, and this is achieved with metal-framed walls. Often metal-framed walls are not structural and are used as infill panels in rigid framed steel or concrete buildings. Batt insulation is less effective for metal-framed walls (compared to wood-framed walls) because the metal framing members are more conductive. In most cases, continuous insulation is required to meet prescriptive U-factor requirements. Reference Appendix JA4, Table 4.3.3, has data for metal-framed walls.

   For 2016, the continuous insulation requirements for steel-framed walls have increased for climate zones 1, 6, and 7. Two inches of rigid polyisocyanurate insulation (with no cavity insulation) will meet the new requirement.
3. **Metal building walls:** Metal building walls consist of a metal building skin that is directly attached to metal framing members. The framing members are typically positioned in a horizontal direction and spaced at about 4 ft. A typical method of insulating metal building walls is to drape the insulation over the horizontal framing members and to compress the insulation when the metal exterior panel is installed.
4. **Light-mass walls:** Light-mass walls have a heat capacity (HC) greater or equal to 7.0 but less than 15.0 Btu/°F-ft². See the definition below for heat capacity. From Reference Appendix JA4, Tables 4.3.5 and 4.3.6 have U-factor, C-factor, and heat capacity data for hollow unit masonry walls, solid unit masonry and concrete walls, and concrete sandwich panels.
5. **Heavy-mass walls:** Have an HC equal to or greater than 15.0 Btu/°F-ft². See Reference Appendix JA4 for HC data on mass walls.

   *Note: For light- and high-mass walls, **heat capacity (HC)** is the amount of heat required to raise the temperature of the material by 1 degree F. In the Energy Standards, it is defined as the product of the density (lb/ft3), specific heat (Btu/lb-F), and wall thickness (ft). For instance, a 6" medium weight concrete hollow unit masonry wall has a heat capacity of 11.4 and is considered a light mass wall. The same masonry wall with solid grout that is 10 inches thick has a heat capacity of 19.7 and is considered a heavy mass wall.*

6. **Furred walls:** Are a specialty wall component, commonly applied to a mass wall type. See Figure 3-4 below. The Reference Appendix JA4 Table 4.3.5, 4.3.6, or other masonry tables list alternative walls. Additional continuous insulation layers are selected from Reference Appendix JA4 Table 4.3.13 and calculated using either Equation 4-1 or 4-4 from the JA4. The effective R-value of the furred component depends upon the framing thickness, type, and insulation level.

Figure 3-4: Brick Wall With Furring Details

7. **Spandrel panels** and **glass curtain walls:** These wall types consist of metalized or glass panels often hung outside structural framing to create exterior wall elements around fenestration and between floors. See Reference Appendix JA4, Table 4.3.8 for U-factor data.

8. **Continuous insulation:** For some climate zones, mass walls and metal-framed walls require continuous insulation to meet the prescriptive U-factor requirements. When this is the case, the effect of the continuous insulation is estimated by Equation 4-1 in Reference Appendix JA4.

$$U_{prop} = 1 / [(1/U_{col,A}) + R_{cont,insul}]$$

Example 3-10

Question :

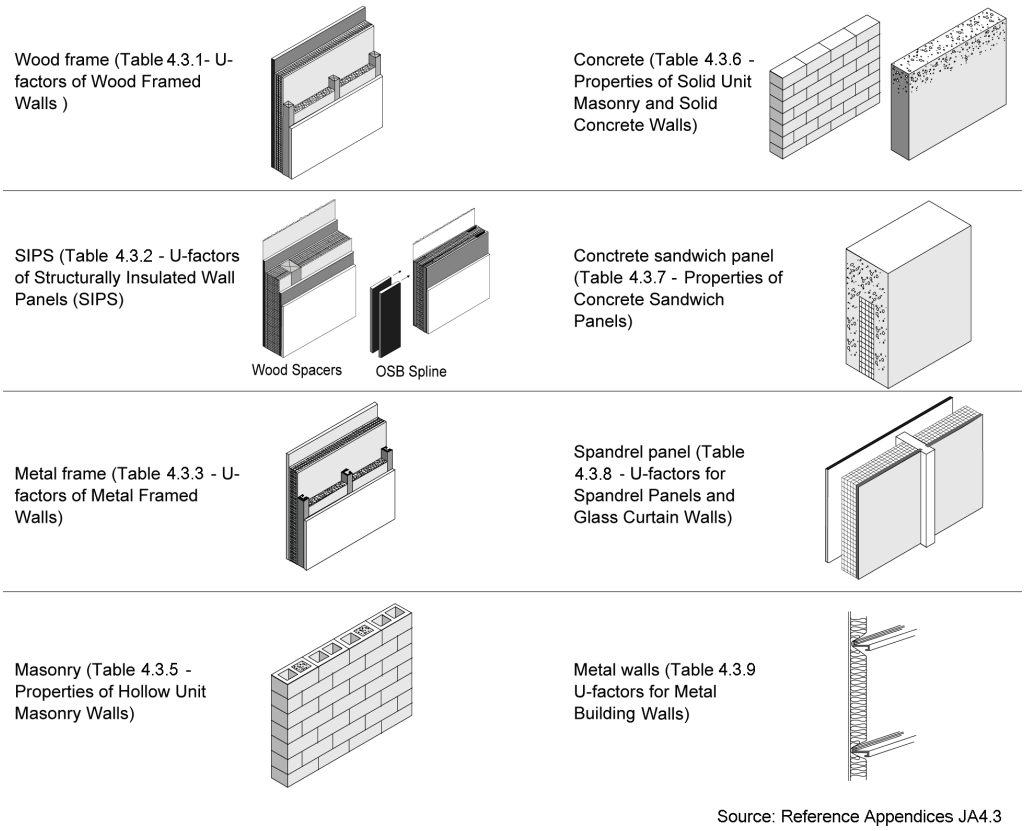
An 8-inch (20 cm) medium-weight concrete block wall with uninsulated cores has a layer of 1 inch (25 mm) thick exterior polystyrene continuous insulation with an R-value of R-5. What is the U-factor for this assembly?

Answer:

From Reference Appendix Table 4.3.5, the U-factor for the block wall is 0.53. From Equation 4-1, the U-factor is calculated as:

U= 1 / [(1/0.53) + 5] = 0.145

Figure 3-5: Classes of Wall Construction



Framed or block walls can also have insulation installed between interior or exterior furring strips. The effective continuous R-value of the furring/insulation layer is shown in Table 4.3.13 of Reference Appendix JA4.

3.2.4 Demising Walls

3.2.4.1 Mandatory Insulation for Demising Walls

§120.7(b)7, §140.3(a)3 and Exception to §140.3(a)5A

Demising walls separate conditioned space from enclosed unconditioned space. The insulation requirements include:

- Wood-framed: minimum of R-13 insulation (or have an equivalent U-factor of 0.099) between framing members.
- Metal-framed: minimum R-13 insulation (or a U-factor no greater than 0.151) between framing members plus R-2 continuous insulation.
- If it is not a framed assembly (constructed of brick, concrete masonry units, or solid concrete), then no insulation is required.

This requirement applies to buildings meeting compliance with either the prescriptive or performance approach.

3.2.5 Doors

3.2.5.1 Mandatory Requirements

§110.6(a)1

Manufactured exterior doors shall have an air infiltration rate not exceeding:

- 0.3 cfm/ft2 of door area for nonresidential single doors (swinging and sliding).
- 1.0 cfm/ft2 of door area for nonresidential double doors (swinging).

3.2.5.2 Prescriptive Requirements

§140.3(a)7

The Energy Standards define prescriptive requirements for exterior doors in Tables 140.3-B and 140.3-C. For swinging doors, the maximum U-factor is 0.70, and for nonswinging doors, the maximum allowed U-factor is 1.45 in Climate Zones 2 through 15 and 0.50 in Climate Zones 1 and 16. (See Table 3-9)

The swinging door requirement corresponds to uninsulated double-layer metal swinging doors. The 1.45 swinging door U-factor requirement corresponds to insulated single-layer metal doors or uninsulated single-layer metal roll-up doors and fire-rated doors. The 0.50 U-factor requirement for Climate Zones 1 and 16 corresponds to wood doors with a minimum nominal thickness of 1 ¾ inches. For more information, consult Reference Appendix JA4, Table 4.5.1.

When glazing area exceeds one-half of the entire door area, it is then defined as a fenestration product in the Energy Standards, and the entire door area is modeled as a fenestration unit. (See Section 3.3.2.) If the glazing area is less than half the door area, the glazing must be modeled as the glass area plus 2 inches in each direction of the opaque door surface (to account for a frame). However, exterior doors are part of the gross exterior wall area and must be considered when calculating the window-wall-ratio.

Table 3-9: Door Requirements Summary

Building Type	Door Type	Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
High-Rise Residential	Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Relocatable Public Schools	Non-Swinging	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Building Type	**Door Type**	**Climate Zones**							
		9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Nonresidential	Non-Swinging	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
High-Rise Residential	Non-Swinging	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Relocatable Public Schools	Non-Swinging	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Energy Standards Table 140.3-B, 140.3-C, and 140.3-D

3.2.6 Floors

3.2.6.1 Mandatory Requirements

A. Insulation Requirements for Heated Slab Floors

§110.8(g)

Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A of the Energy Standards (Table 3-10). The top of the insulation must be protected with a rigid shield to prevent intrusion of insects into the building foundation, and the insulation must be capable of withstanding water intrusion.

A common location for the slab insulation is on the foundation perimeter. 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 inside the foundation wall and between the heated slab. In this case insulation must extend downward to the top of the footing and then extend horizontally inward, under the slab, a distance of 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 3-6: Perimeter Slab Insulation

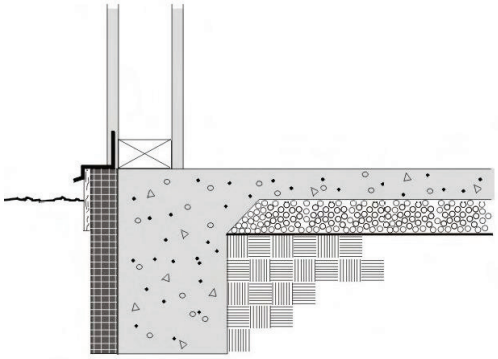


Table 3-10: Slab Insulation Requirements for Heated Slab Floors

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 plain view.	1 – 15	5
			16	10 vertical and 7 horizontal

Energy Standards Table 110.8-A

B. Floor and Soffit Insulation

§120.7(c)

1. Raised Mass Floors: A minimum of 3 inches of lightweight concrete over a metal deck or the weighted average U-factor of the floor assembly shall not exceed U-0.269.
2. Other Floors: Weighted average U-factor of U-0.071.
3. Heated Slab Floor: A heated slab floor shall be insulated to meet the requirements of §110.8(g). See Section 3.2.6.1A above for more information.

3.2.6.2 Prescriptive Requirements

A. Exterior Floors and Soffits

§140.3(a)4

Under the prescriptive requirements, exterior floors and insulated soffits must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential, high-rise residential buildings and relocatable public school buildings in Table 3-11below. The U-factor for exterior floors and soffits from Reference Appendix JA4 shall be used to determine compliance with the maximum assembly U-factor requirements. The Energy Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Appendix JA4; only U-factors may be used to demonstrate compliance. For metal-framed floors, batt insulation between framing section may need continuous insulation to be modeled and installed on the interior or exterior to meet the U-factor requirements of the Energy Standards.

Table 3-11: Floor/Soffit U-Factor Requirements

Building Type	Floor Type	Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269
	Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071
High-Rise Residential	Mass	0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092
	Other	0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039
Relocatable Public Schools	All	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Building Type	**Floor Type**	**Climate Zones**							
		9	10	11	12	13	14	15	16
Nonresidential	Mass	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
	Other	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
High-Rise Residential	Mass	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
	Other	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034
Relocatable Public Schools	All	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48

Summary from Energy Standards Tables 140.3-B, 140.3-C, and 140.3-D

The U-factor criteria for concrete raised floors depend on whether the floor is a mass floor or not. A mass floor is one constructed of concrete with a heat capacity (HC) greater than or equal to 7.0 Btu/°F-ft².

Insulation levels for nonresidential concrete raised floors with HC ≥ 7.0 using U-factor for compliance, from Reference Appendix JA4, Table 4.4.6, are equivalent to no insulation in Climate Zones 3-10 and associated U-factors to continuous insulation of R-8 in Climate Zones 1, 2, 11 through 15; and R-15 in Climate Zone 16.

To determine the U-factor insulation levels for high-rise residential concrete raised floors, use the U-factors that are associated with R-8 continuous insulation in Climate Zones 7

through 9; R-15 in Climate Zones 3-5 and 11-13; with additional insulation required in the desert and mountain Climate Zones 1, 2, 14 and 16.

Table 4.4.6 from Reference Appendix JA4 is used with mass floors while Tables 4.4.1 through 4.4.5 are used for nonmass floors. (See Figure 3-8.)

Figure 3-7: Requirements for Floor/Soffit Surfaces

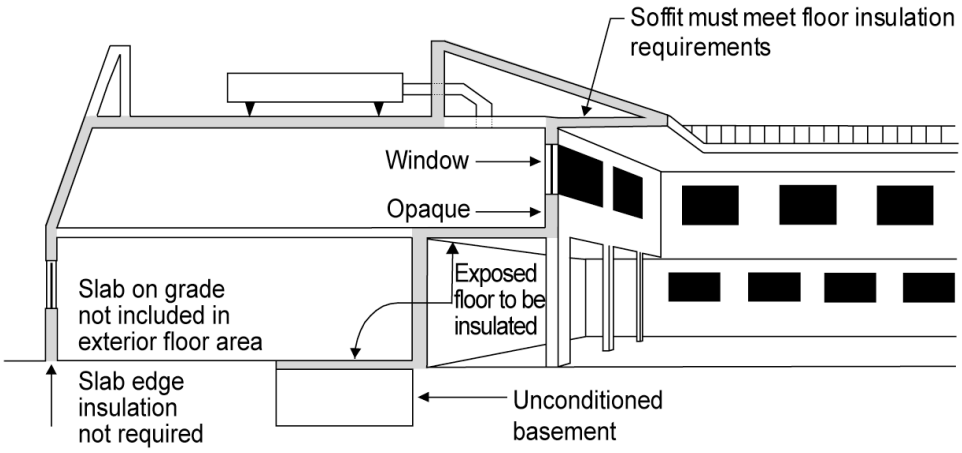
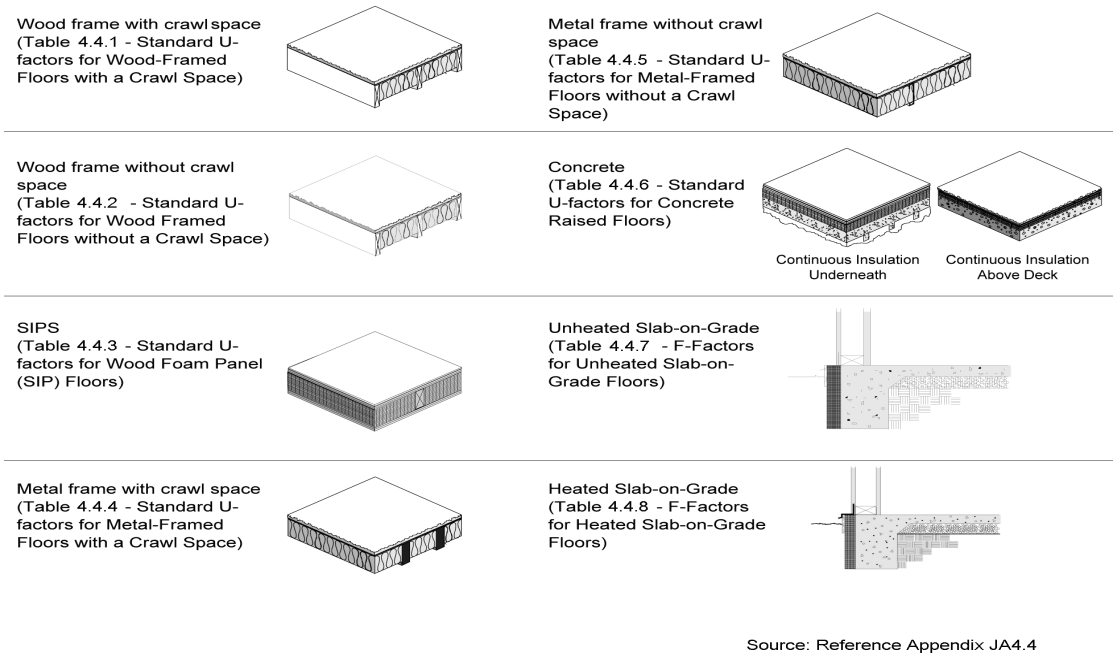


Figure 3-8: Classes of Floor Constructions



Source: Reference Appendix JA4.4

3.3 Fenestration

Choosing the proper windows, glazed doors, and skylights is one of the most important decisions for any high-performance project. The use of high-performance fenestration can actually reduce energy consumption by decreasing the lighting and heating and cooling loads in nonresidential and high-rise residential buildings. The size, orientation, and types of fenestration products can dramatically affect overall energy performance.

This section will specify the mandatory and prescriptive features of fenestration products, the performance of fenestration, ratings and labeling by the National Fenestration Rating Council (NFRC), and details on daylighting through skylights.

3.3.1 General Mandatory Measures

§110.6(a)

The mandatory measures for windows, glazed doors, and skylights address the air-tightness of the units (air leakage), how the U-factor and solar heat gain coefficient (SHGC) are determined, as well as the visible transmittance (VT).

Any fenestration product or glazed door, other than field-fabricated fenestration products and field-fabricated glazed doors, may be installed if the manufacturer has certified to the Energy Commission by using a default label, or if an independent certifying organization approved by the Energy Commission has certified that the product complies.

3.3.1.1 Determining Fenestration Performance

§110.6

A. U-Factor

The *U-factor* describes the rate of heat flow through the entire unit, not just the glass or plastic glazing material. The U-factor includes the heat flow effects of the glass, the frame, and the edge-of-glass conditions. (There also may be spacers, sealants and other elements that affect heat conduction.) The lower the U-factor, the lower the amount of heat loss.

Reference Appendix JA1 lists many of the terms and product characteristics that relate to fenestration U-factors. In particular, see the definitions for window, skylight, window area, skylight area, site-built fenestration, and field-fabricated fenestration.

The preferred methods for determining fenestration U-factor are those in NFRC 100 for manufactured windows and for site-built fenestration. The default U-factors in Table 110.6-A of the Energy Standards (reproduced in Table 3-14 below) must be used when a NFRC label for the U-factor is not available. The U-factors in Table 110.6-A represent the most inefficient possible values, thereby encouraging designers to obtain ratings through NFRC test procedures, when they are available.

Table 3-12: Methods for Determining U-Factor

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)	✓	✓	✓	N/A	N/A
NFRC-100	✓	✓	✓	N/A	N/A
Default Table 110.6-A of the Energy Standards	✓	✓	✓	✓	✓
NA6[1]	N/A	N/A	✓	N/A	N/A
The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may only be used for site-built vertical and skylights having less than 1,000ft^2.					

B. Solar Heat Gain Coefficient (SHGC)

The SHGC measures the rate of heat gain from solar energy passing through a product. The lower the SHGC, the lower the amount of heat gain. SHGC is measured for the whole window, including the effects of the frame. For the SHGC, the methods determining the preferred values are in NFRC 200. If they are not available, Table 110.6-B of the Energy Standards (Table 3-15 below) must be used for default values.

Table 3-13: Acceptable 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)[1]	✓	✓	✓	N/A	N/A
NFRC-200	✓	✓	✓	N/A	N/A
Standards Default Table 110.6-B	✓	✓	✓	✓	✓
NA6[2]	N/A	N/A	✓	N/A	N/A
The NFRC Residential CMA method is an option that may be available in the Energy Standards. *The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may only be used for site-built vertical and skylights having less than 1,000ft^2.*					

C. Visible Transmittance (VT)

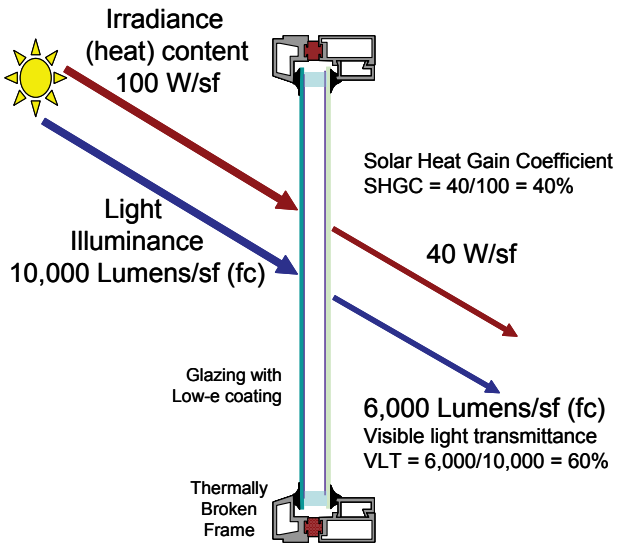
VT is the ratio of light that passes through the glazing material to the light that is incident outside the glazing. VT affects the amount of daylight that enters the space and how well views through windows are rendered. Glazing materials with a very low VT have little daylighting benefit and views appear dark, even on bright days.

The VT of the fenestration shall be rated in accordance with NFRC 200 or ASTM E972. More specifically, the NFRC 200 test method is appropriate only for flat, clear glazing and does not cover curved glazing or diffusing glazing. NFRC 202 is the approved test method for rating the visible transmittance of planar diffusing glazing such as is used in fiberglass

insulating fenestration. NFRC 203 is the approved test method for rating the visible transmittance of tubular skylights, also known as tubular daylighting devices (TDDs). For other types of fenestration, including dome skylights, use ASTM E972 to rate the visible transmittance.

Visible transmittance (VT) is a property of glazing materials that has a varying relationship to SHGC (Figure 3-9). The ideal glazing material for most of California's summer climates would have a high VT and a low SHGC. Such a glazing material allows solar radiation in the visible spectrum to pass while blocking radiation in the infrared and ultraviolet spectrums. Materials that have this quality are labeled "spectrally selective" and have a VT that is up to 2.2 times the SHGC.

Figure 3-9: Solar Heat Gain Coefficient and Visible Transmittance



3.3.1.2 Field-Fabricated Fenestration Product or Exterior Door

Field-fabricated fenestration is fenestration assembled on site that does not qualify as site-built fenestration. It includes windows where wood frames are constructed from raw materials at the building site, salvaged windows that do not have an NFRC label or rating, and other similar fenestration items.

For field-fabricated fenestration, the U-factor and SHGC are default values that can be found in Table 3-14 and Table 3-15, respectively, below. Values are determined by frame type, fenestration type, and glazing composition.

Exterior doors are doors through an exterior partition. They may be opaque or have a glazed area that is less than or equal to one-half of the door area. U-factors for opaque exterior doors are listed in Reference Appendix JA4, Table 4.5.1. Doors with glazing for more than one-half of the door area are treated as fenestration products and must meet all requirements and ratings associated with fenestration.

When a door has glazing of less than one-half the door area, the portion of the door with fenestration must be treated as part of the envelope and fenestration independent of the remainder of the door area.

A field-fabricated product may become a site-built product if all the requirements for receiving a label certificate required of site-built products are met.

Table 3-14: Default Fenestration Product U-Factors

FRAME	PRODUCT TYPE	SINGLE PANE 3, 4	DOUBLE PANE 1, 3, 4	GLASS BLOCK 2,3
Metal	Operable	1.28	0.79	0.87
	Fixed	1.19	0.71	0.72
	Greenhouse/garden window	2.26	1.40	N.A.
	Doors	1.25	0.77	N.A.
	Skylight	1.98	1.30	N.A.
Metal, Thermal Break	Operable	N.A.	0.66	N.A.
	Fixed	N.A.	0.55	N.A.
	Greenhouse/garden window	N.A.	1.12	N.A.
	Doors	N.A.	0.59	N.A.
	Skylight	N.A.	1.11	N.A.
Nonmetal	Operable	0.99	0.58	0.60
	Fixed	1.04	0.55	0.57
	Doors	0.99	0.53	N.A.
	Greenhouse/garden windows	1.94	1.06	N.A.
	Skylight	1.47	0.84	N.A.

1. For all dual-glazed fenestration products, adjust the listed U-factors as follows:
   a. Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide.
   b. Add 0.05 to any product with true divided lite (dividers through the panes).
2. Translucent or transparent panels shall use glass block values when not rated by NFRC 100.
3. Visible transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6.
4. Windows with window film applied that is not rated by NFRC 100 shall use the default values from this table.

Table 110.6-A of the Energy Standards

Table 3-15: Default Solar Heat Gain Coefficient (SHGC)

FRAME TYPE	PRODUCT	GLAZING	FENESTRATION PRODUCT SHGC		
			SINGLE PANE[2,3]	DOUBLE PANE[2,3]	GLASS BLOCK[1,2]
Metal	Operable	Clear	0.80	0.70	0.70
	Fixed	Clear	0.83	0.73	0.73
	Operable	Tinted	0.67	0.59	N.A.
	Fixed	Tinted	0.68	0.60	N.A.
Metal, Thermal Break	Operable	Clear	N.A.	0.63	N.A.
	Fixed	Clear	N.A.	0.69	N.A.
	Operable	Tinted	N.A.	0.53	N.A.
	Fixed	Tinted	N.A.	0.57	N.A.
Nonmetal	Operable	Clear	0.74	0.65	0.70
	Fixed	Clear	0.76	0.67	0.67
	Operable	Tinted	0.60	0.53	N.A.
	Fixed	Tinted	0.63	0.55	N.A.
Translucent or transparent panels shall use glass block values when not rated by NFRC 200. Visible transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6. Windows with window film applied that is not rated by NFRC 200 shall use this table's default values					

Table 110.6-B of the Energy Standards

3.3.1.3 Certification and Labeling

§10-111 and §110.6
Reference Nonresidential Appendices NA6

The Administrative Regulations §10-111 and §110.6 require that fenestration products have labels that list the U-factor, SHGC, VT and the method used to determine those values. The label must also certify that the fenestration product meets the requirements for air leakage from §110.6(a)1.

A. Manufactured (Factory-Assembled) Fenestration Label Certificates

Each manufactured (factory-assembled) fenestration product must have a clearly visible temporary label attached to it, which is not to be removed before inspection by the enforcement agency. For rating and labeling manufactured fenestration products, the manufacturer rates its products for U-factor, SHGC and VT.

The manufacturer can choose to have the fenestration product rated and labeled in accordance with the NFRC Rating Procedure (NFRC 100 for U-factors and NFRC 200 for SHGC and VT) shown in Figure 3-10. If the manufactured fenestration product is rated using the NFRC rating procedure, it must also be permanently labeled in accordance with NFRC procedures.

Where possible, it is best to select a fenestration product that is NFRC-rated and to do so before completing compliance documents. This selection enables the use of NFRC-certified data for compliance.

Figure 3-10: NFRC Manufactured Label

B. Default Temporary Label

Fenestration product manufacturers can choose to use default performance values listed in Tables 110.6-A and 110.6-B in §110.6 for U-factors and SHGC in lieu of testing. For fenestration products requiring a VT value, assume a value of 1.0 as specified in the Reference Nonresidential Appendix NA6. If default values are used, the manufacturer must attach a temporary label to each window (See Figure 3-11), and manufacturer specification sheets or cut sheets must be included with compliance documentation. A NRCC-ENV-05-E will be required to document the thermal performance if no default temporary labels are attached to the window units.
Although there is no exact format for the default temporary label, it must be clearly visible and large enough to be clearly visible from 4 feet so the enforcement agency field inspectors are able to read easily, and it must include all information required by the regulations.

The minimum suggested label size is 4 in. x 4 in., and the label must have the words at the bottom of the label, as noted in the example in Figure 3-11.

> *"This 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."*

If the product claims the default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criteria upon which the default value is based are met by placing a check in the check box:

1. Air space 7/16 in. or greater
2. For skylights, the label must indicate the product was rated with a built-in curb
3. Meets thermal-break default criteria

Figure 3-11: Sample Default Temporary Label

2013 California Energy Commission Default Label XYZ Manufacturing Co.		
Key Features:	☐ Doors	☐ Double-Pane
	☐ Skylight	☐ Glass Block
Frame Type	**Product Type:**	**Product Glazing Type:**
☐ Metal	☐ Operable	☐ Clear
☐ Non-Metal	☐ Fixed	☐ Tinted
☐ Metal, Thermal Break	☐ Greenhouse/Garden Window	☐ Single-Pane
☐ Air space 7/16 in. or greater ☐ With built-in curb ☐ Meets Thermal-Break Default Criteria	----------	To calculate VT see NA6
California Energy Commission Default U-factor =	**California Energy Commission** Default SHGC =	**California Energy Commission** 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 Energy Standards for Residential and Nonresidential Buildings.		

The person taking responsibility for fenestration compliance may choose to attach default temporary labels to each fenestration product as described instead of providing a default label certificate for each product line.

For the visible transmittance (VT) of diffusing skylights that is not covered by NFRC 200 or NFRC 203, a test report should be included using the ASTM E972 method. Manufacturers, specifiers, or a responsible party should include the report with the energy documentation.

C. Field-Fabricated Fenestration

Field-fabricated fenestration is not the same as site-built fenestration. *Field-fabricated fenestration* is a very limited category of fenestration that is made at the construction site out of materials that were not previously formed or cut with the intention of being used to fabricate a fenestration product. No attached labeling is required for field-fabricated fenestration products; only a NRCC-ENV-05-E is needed. Field-fabricated fenestration and field-fabricated exterior doors may be installed only if the compliance performance documentation has demonstrated compliance. The field inspector is responsible for ensuring field-fabricated fenestration meets the specific U-factor, SHGC, and VT, as listed on the NRCC-ENV-05-E. Thermal break values do not apply to field-fabricated fenestration products.

D. Site-Built Label Certificates

The designer should select a U-factor, SHGC, and VT for the fenestration system that meets the design objectives and occupancy needs for the building. Site-built fenestration is field-assembled using specific factory-cut or factory-formed framing and glazing units that are manufactured with the intention of being assembled at the construction site or glazing contractor's shop. Site-built certificates should be filed at the contractor's project office during construction or in the building manager's office. (See the CMA sample on Figures 3-12 and 3-12A and discussion of CMA in subsection F below.)

Note: The highlighted circles in the figures indicate the field inspector's area to inspect and compare to the energy compliance submittal and building plans.

Figure 3-12: NFRC - CMA Label Certificate Page 1

NATIONAL FENESTRATION RATING COUNCIL LABEL CERTIFICATE

PROJECT INFORMATION

LABEL CERTIFICATE ID: ***XYZ-001*** **Issuance Date:** mm/dd/yyyy

This is to be completed by an NFRC Approved Calculation Entity (ACE), based on information provided by the Specifying Authority and calculated in accordance with NFRC procedures.

PROJECT LOCATION:

Address: _____,

City: _____, **State,** _____, **Zip code:** _____,

Contact person:_____, **Title:** _____,

Phone: _____, **Facsimile:** _____, **Email:** _____,

Project name (optional): _____, **Designer (optional):** _____,

Figure 3-12A: NFRC - CMA Label Certificate Page 2

PRODUCT LISTING

FOR CODE COMPLIANCE

LABEL CERTIFICATE ID: ***XYZ-001*** **Issuance Date:** mm/dd/yyyy

NFRC CERTIFIED PRODUCT RATING INFORMATION:*

The NFRC Certified Product Rating Information listed here is to be used to verify that the ratings meet applicable energy code requirements.

PRODUCT LISTING:

						CERTIFIED Performance Rating at NFRC Model Size		
CPD ID	Total Area	Name	Framing Ref	Glazing Ref	Spacer Ref	U**	SHGC**	VT**
	ft^2					Btu/ hr·ft²·°F	-	-
P-PL-010	88.89	PL-2200 / PL-2210	FA-PL2210	GA-TT-001	SA-AM-001	0.53	0.58	0.66
P-PL-005	192.67	PL-3400 / PL-3401	FA-PL3401	GA-TT-001	SA-AM-002	0.56	0.57	0.65
P-PL-012	382.22	PL-5700 / PL-5720	FA-PL5720	GA-TO-002	SA-AM-001	0.52	0.21	0.30
P-PL-002	60.00	PL-1100 / PL-1152	FA-PL1152	GA-TT-001	SA-AM-001	0.42	0.51	0.62
P-PL-022	525.00	PL-9900 / PL-9915	FA-PL9915	GA-TO-003	SA-AM-002	0.45	0.15	0.19

1. For site-built fenestration totaling 1,000 ft^2 or greater, the glazing contractor or specifier must generate a NFRC label certificate from either approach listed below:
   a. A NFRC label certificate generated by the CMA computer program.
   b. Default to the U-factor values from Table 110.6-A, the SHGC values from 110.6-B, and for VT values, use the method specified in NA6.
2. For site-built fenestration totaling less than 1,000 ft^2 or any area of replacement of site-built fenestration that includes vertical windows, glazed doors, and skylights, the glazing contractor or specifier must comply with one of the following:
   a. A NFRC label certificate generated by the CMA computer program.
   b. The center-of-glass values from the manufacturer's product literature to determine the total U-factor, SHGC and VT. (See Reference Nonresidential Appendix NA6 - the *Alternative Default Fenestration Procedure*).
   c. The U-factor values from Table 110.6-A and SHGC values from Table 110.6-B. For VT values, use the method specified in NA6.

NA6 calculations are based on center-of-glass (COG) values from the manufacturer. For example, when using a manufacturer's SHGC center-of-glass specification of 0.27, the NA6 calculation results in an overall SGHC value of 0.312, which may be rounded to 0.31. Rounding to the nearest hundredth decimal place is acceptable to determine the overall fenestration efficiency value with either the prescriptive or performance approach.

E. Fenestration Certificate NRCC-ENV-05-E

For nonrated products where no default label certificates are placed on the fenestration product, use Fenestration Certificate NRCC-ENV-05-E to document thermal performances of each fenestration product that results in a different U-factor, SHGC, and VT. Alternatively, one certificate will suffice when all the windows are the same.

The NRCC-ENV-05-E should indicate the total amount of non-NFRC-rated fenestration products throughout the project. The locations and orientations where fenestration products are being installed should be indicated on the drawings and in a fenestration schedule that lists all fenestration products.

The NRCC-ENV-05-E should clearly identify the appropriate table or equation that is used to determine the default U-factor and SHGC and, if applicable, the center of glass, $SHGC_C$, used in calculating the $SHGC_{fen}$. Manufacturer's documentation of these product characteristics that list the center-of-glass values must also be attached to the NRCC-ENV-05-E and located at the job site for verification.

F. Component Modeling Approach (CMA)

NFRC has developed a performance base calculation, the *component modeling approach* (CMA), to make the rating process quicker and simpler and serve as an energy ratings certification program for windows and other fenestration products used in nonresidential projects. This approach allows users to assemble fenestration products in a virtual environment. The approach draws data for NFRC-approved components from online libraries choosing from preapproved glazing, frame, and spacer components. CMA users are able to obtain preliminary ratings for various configurations of their designs. CMA is a fair, accurate, and credible method based on NFRC 100 and 200 program documents, which are verified by third-party rating procedures.

Architects and others can use this tool to:

1. Help design energy-efficient windows, curtain wall systems, and skylights for high-performance building projects.
2. Determine whether a product meets the specifications for a project and local/state building energy codes.
3. Model different fenestration designs to compare energy performance.

Once the user is satisfied with the product, he or she creates a bid report containing the data for all fenestration products to be reviewed. This report can serve as an indication that the products comply with the energy-related requirements of the project and building energy codes. The windows are then built, either on-site or in a factory. The final products are reviewed and are rated by an NFRC-approved calculation entity (ACE); then a license agreement is signed with NFRC.

At this point, NFRC issues a CMA label certificate for the project. This label certificate, unlike NFRC's residential window label that is applied to individual units, is a document that lists the certified fenestration ratings at the NFRC standard testing size for the entire building project. Once approved, the CMA label certificate is available online immediately. This certificate serves as code compliance documentation for fenestration energy performance, and the certified products may be applied to future projects without repeating the certification process.

Benefits of CMA

CMA provides facility managers, specifiers, building owners, and design teams with a simple method for designing and certifying the energy performance of fenestration systems for their buildings without having to test every possible permutation of glazing and framing. This is significantly less expensive than building sample wall sections and testing them in a large test enclosure. However, there are several additional advantages gained by using the CMA:

1. CMA's online tool has the ability to output a file with values for use in building energy analysis software programs.
2. The program can export detailed information for angular-dependent SHGC and VT values, seamlessly transferring the data to the analytical software.
3. A 2010 study[1] conducted in California demonstrated that fenestration modeled with the CMA program can provide an increase in compliance margins by as much as 11.7 percent over the Energy Commission's default calculation methods.
4. CMA can help demonstrate above-code performance, which is useful for environmental rating programs such as Leadership in Energy and Environmental Design (LEED™) or local green building programs.

Use of the CMA can help lead to a more efficient building and enable cost savings due to more accurate fenestration performances and potential energy benefits from above-code utility incentives. Details are available at www.NFRC.org/.

1 Study conducted by the Heschong Mahone Group for NFRC, "Compared to alternative fenestration rating values detailed in California's Title 24, Using CMA provides a maximum increase of 11.7% in energy compliance margins. This means that compared to other available options, CMA provides the most accurate values on window energy and visible performance."

3.3.1.4 Air Leakage

§110.6(a)1

Manufactured and site-built fenestration such as doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-16. For field-fabricated products or an exterior door, the Energy Standards require that the unit be caulked, gasketed, weatherstripped, or otherwise sealed. Unframed glass doors and fire doors are the two exceptions to these air leakage requirements. Field-fabricated fenestration and field-fabricated exterior doors are not required to comply with Table 3-16.

Table 3-16: Maximum Air Infiltration Rates (§110.6(a)1)

Class	Type	Rate
Windows (cfm/ft²) of window area	All	0.3
Residential Doors (cfm/ft²) of door area	Swinging, Sliding	0.3
All Other Doors (cfm/ft²) of door area	Sliding, Swinging (single door)	0.3
	Swinging (double door)	1.0

Example 3-11

Question:

A 150,000 ft² "big box" retail store has 800 ft² of site-built vertical fenestration at the entrance. An operable double-pane aluminum storefront framing system is used without a thermal break. What are the acceptable methods for determining the fenestration U-factor and SHGC? What are the labeling requirements assuming a center of glass U-factor of 0.50 and SHGC of 0.70 and a center glass visible transmittance of 0.75?

Answer:
For site-built fenestration less than 1,000 ft^2 then one of the following three methods may be used:
1. The easiest method for site-built fenestration is to rate the fenestration using the component modeling approach (CMA), which will yield the most efficient values possible.
2. In this case, use the default U-factor and SHGC values from equations in Reference Nonresidential Appendix NA6 as described in the following bullets:

- The Alternate U-factor may be calculated from the Reference Nonresidential Appendix NA6, Equation NA6-1, $U_T = C_1 + C_2 X U_C$. From Table NA-1 for metal–framed, site-built fenestration, C_1= 0.311 and C_2 = 0.872, therefore the overall U-factor is calculated to be 0.311 + 0.872 x 0.50 = 0.47.
- Likewise, the SHGC is determined from the Reference Nonresidential Appendix, NA6, Equation NA6-2, $SHGC_T = 0.08 + 0.86 \times SHGC_C$. Therefore, the SHGC is calculated to be 0.08 + 0.86 x 0.70 = 0.68.
- For VT, from Appendix NA6, the visible transmittance of the frame is 0.88 for a curtain wall, so the $VT_T = VT_{F\,X}\,VT_C$ = 0.88 X 0.75 = 0.66.

3. The third option for determining U-factor and SHGC may be to select from Default Table 110.6-A and 110.6-B of the Energy Standards. From these tables, the U-factor is 0.79 and the SHGC is 0.70. An Energy Commission Default Label Certificate, NRCC-ENV-05-E, should be completed for each fenestration product unless the responsible party chooses to attach a default temporary label to each fenestration unit throughout the building.

Example 3-12

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 a space [generally ¼ inch (6 mm) to ¾ inch (18 mm)] filled with air or other inert gases. Two panes of glazing laminated together do not constitute double-pane glazing, but are treated as single pane.

3.3.2 Vertical Fenestration (Windows and Doors)

3.3.2.1. Site-Built Fenestration

§110.6

Manufactured fenestration products are factory-assembled as a unit, and the manufacturer is able to assume the burden of testing and labeling. However, with site-built fenestration, multiple parties are responsible. The steps of producing site-built fenestration are as follows:

1. Architects and/or engineers design the basic glazing system by specifying the components, the geometry of the components, and, sometimes, the assembly method.
2. An extrusion manufacturer provides the mullions and frames that support the glazing and is responsible for thermal breaks.
3. A glazing manufacturer provides the glazing units, cut to size and fabricated as insulated glass (IG) units. The glazing manufacturer is responsible for tempering or heat strengthening, the tint of the glass, any special coatings, the spacers, and the sealants.
4. A glazing contractor (usually a subcontractor to the general contractor) puts the system together at the construction site, or the contractor’s shop and is responsible for many quality aspects. Predetermining the energy performance of site-built fenestration as a system is more challenging than for manufactured units.
5. One of the parties (architect, glazing contractor, extrusion manufacturer, IG fabricator, or glass manufacturer) must take responsibility for testing and labeling of the site-built fenestration system under the most recent NFRC 100 procedure. The responsible party must obtain a label certificate as described in §10-111.
6. The glazing contractor or other appropriate party assumes responsibility for acquiring the NFRC label certificate. Each label certificate has the same information as the NFRC temporary label for manufactured products but includes other information specific to the project, such as the name of the glazing manufacturer, the extrusion contractor, the places in the building where the product line is used, and other details.

It is typical for the glazing contractor to assume responsibility for the team and to coordinate the certification and labeling process. A common procedure is for the design team to include language in the contract with the general contractor that requires that the general contractor be responsible; the general contractor typically assigns this responsibility to the glazing contractor, once the responsible party has established a relationship with an NFRC.

It is not necessary to complete the NFRC testing and labeling prior to completing the compliance documentation and filing the building permit application. However, plans examiners should verify that the fenestration performance shown in the plans and specifications and used in the compliance calculations is “reasonable” and achievable. This requires some judgment and knowledge on the part of the plans examiner. Generally,

designers will know the type of glass that they plan to use and whether the frame has a thermal break or is thermally improved. This information is adequate to consult the default values for U-factor and SHGC in Reference Nonresidential Appendix NA6.

The label certificate remains on file in the construction office for the building inspector to view. After construction is complete, the label certificate should be filed in the building office with the as-built drawings and other operations and maintenance data. This will give building managers the information needed for repairs or replacements.

3.3.2.2. **Prescriptive Measures**

There are four aspects of the envelope component approach for windows:

1. Maximum total area plus west-facing.
2. Maximum U-factor.
3. Maximum relative solar heat gain coefficient (RSHGC).
4. Minimum visible transmittance (VT).

A. Window Area

§140.3(a)5.A.

In the prescriptive approach, the total window area may not exceed 40 percent of the gross wall area (encompassing total conditioned space) for the building. Likewise, the west-facing window area may not exceed 40 percent of the west gross wall area (encompassing total conditioned space for the building). This maximum area requirement will affect those buildings with very large glass areas, such as high-rise offices, automobile showrooms, or airport terminals.

The maximum area may be determined by multiplying the length of the display perimeter (see definition below in this section) by 6 ft in height and use the larger of the product of that multiplication or 40 percent of gross exterior wall area.

Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the prescriptive U-factor, relative solar heat gain coefficient (RSHGC), and visible light transmittance (VT) requirements for the climate zone.

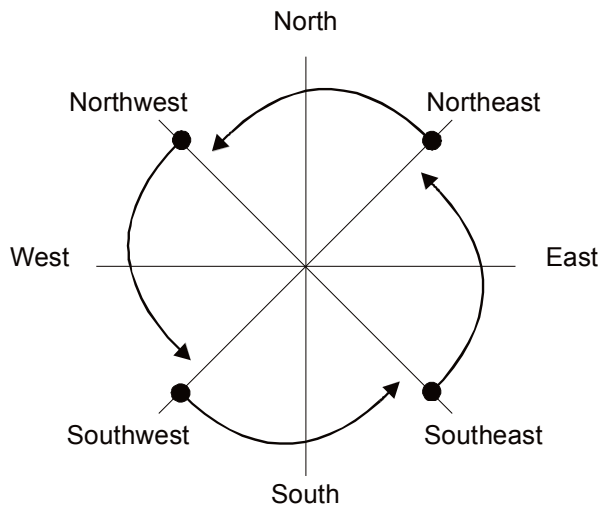
As a practical matter, window area is generally taken from the rough opening dimensions. To the extent this opening is slightly larger than the frame, the rough opening area will be slightly larger than the formally defined window area.

For glazed doors, also use the rough opening area, except where the door glass area is less than 50 percent of the door, in which case the glazing area may be either the entire door area or the glass area plus 2 inches added to all four sides of the glass (to represent the “window frame”) for a window in a door. Calculate the window area from the rough opening dimensions and divide by the gross exterior wall area, which does not include demising walls.

Display perimeter is the length of an exterior wall in a Group B; Group F, Division 1; or Group M occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk. This generally refers to retail display windows, although other occupancies such as offices can also have a display perimeter. Public sidewalks are accessible to the public at large (no obstructions, limits to access, or intervening nonpublic spaces). Demising walls are not counted as part of the display perimeter.

In general, any orientation within 45° of true north, east, south, or west will be assigned to that orientation. The orientation can be determined from an accurate site plan. Figure 3-13 demonstrates how surface orientations are determined and what to do if the surface is oriented exactly at 45° of a cardinal orientation. For example, an east-facing surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

Figure 3-13: Four Surface Orientations



B. Window U-Factor

§140.3(a)5B

Fenestration products are required to use default U-factors and SHGC (see Tables 110.6-A (Table 3-14) and Table 110.6-B (Table 3-15) of the Energy Standards) or have the performance characteristics certified by NFRC. However, each window must meet the prescriptively required maximum U-factor criteria in Tables 140.3-B and 140.3-C of the Energy Standards (see Table 3-17 below) for each climate zone. In general, most NFRC-rated double-glazed windows with a low-e coating and a thermally broken frame will comply with the U-factor criterion; however, other window constructions may also comply. See http://www.nfrc.org/, Certified Product Directory database, or use Equation NA6-1in Reference Appendix NA6.

Table 3-17: Window Prescriptive Requirements U-factors

	All Climate Zones				
Space Type	**Criterion**	**Fixed Window**	**Operable Window**	**Curtainwall/Storefront**	**Glazed Doors**
Nonresidential	Max U-factor	0.36	0.46	0.41	0.45
	Max Relative Solar Heat Gain (RSHGC)	0.25	0.22	0.26	0.23
	Min VT	0.42	0.32	0.46	0.17
	Maximum WWR%	40%			
	All Climate Zones				
Residential High-Rise	Max U-Factor	0.36	0.46	0.41	0.45
	Max Relative Solar Heat Gain (RSHGC)	0.25	0.22	0.26	0.23
	Min VT	0.42	0.32	0.46	0.17
	Maximum WWR%	40%			

From Energy Standards Tables 140.3-B and 140.3-C

C. Overhang Factor

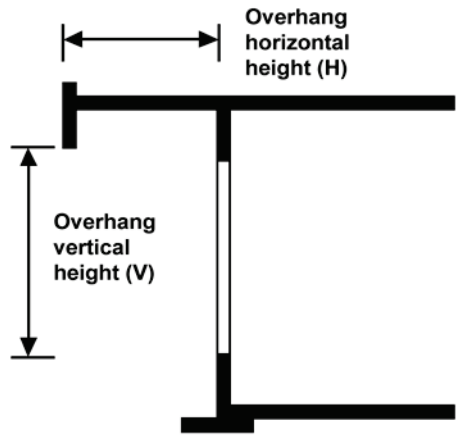
§140.3(a)5C

Relative solar heat gain (RSHGC) is essentially the same as SHGC, except for the external shading correction. It is calculated by multiplying the SHGC of the fenestration product by an overhang factor. If an overhang does not exist, then the overhang factor is 1.0. Relative solar heat gain is applicable only when using the prescriptive compliance approach.

Tables 140.3-B and 140.3-C of the Energy Standards (Table 3-17 above) specify the maximum area-weighted average RSHGC, excluding the effects of interior shading.

Overhang factors may either be calculated or taken from Table 3-18 below and depend upon the ratio of the overhang horizontal length (H) and the overhang vertical height (V). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing, as shown in Figure 3-14. An overhang factor may be used if the overhang extends beyond both sides of the window jamb a distance equal to the overhang projection (§140.3(a)5Cii). The overhang projection is equal to the overhang length (H), as shown in Figure 3-14. If the overhang is continuous along the side of a building, this restriction will usually be met. If there are overhangs for individual windows, each must be shown to extend far enough from each side of the window.

Figure 3-14: Overhang Dimensions



Equation 3-1 – Relative Solar Heat Gain Coefficient

$RSHGC = SHGC_{win} \times OHF$

Where:

RSHGC = Relative solar heat gain Coefficient

$SHGC_{win}$ = Solar heat gain coefficient of the window

Equation 3-2 – Overhang Factor

$$OHF = OverhangFactor = 1 + \frac{aH}{V} + b\left(\frac{H}{V}\right)^2$$

Where:

H = Horizontal projection of the overhang from the surface of the window in ft, but no greater than V

V = Vertical distance from the windowsill to the bottom of the overhang, in ft.

a = -0.41 for north-facing windows, -1.22 for south-facing windows, and -0.92 for east- and west-facing windows

b =0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east- and west-facing windows

Table 3-18: Overhang Factors

H/V	North	South	East/West
0.00	1.00	1.00	1.00
0.10	0.96	0.88	0.91
0.20	0.93	0.78	0.83
0.30	0.90	0.69	0.76
0.40	0.87	0.62	0.69
0.50	0.85	0.56	0.63
0.60	0.83	0.51	0.57
0.70	0.81	0.47	0.53
0.80	0.80	0.45	0.49
0.90	0.79	0.44	0.46
1.00 or greater	0.79	0.44	0.43

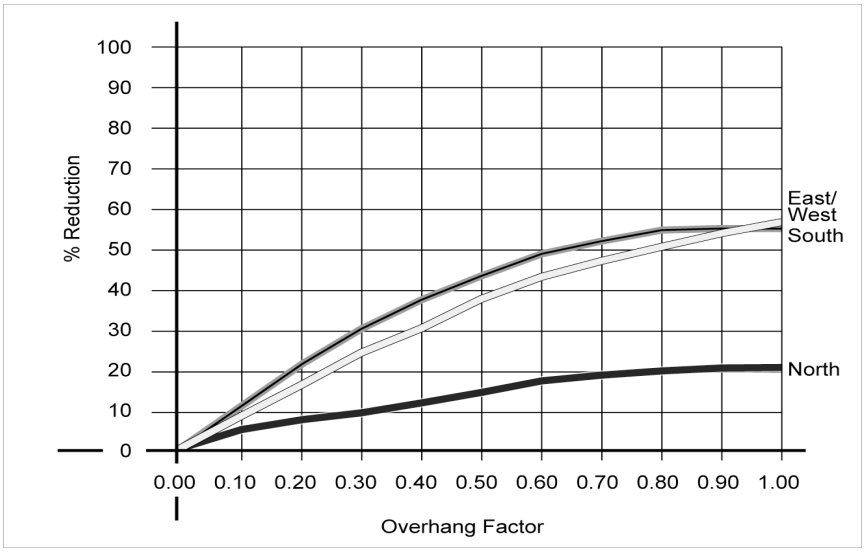
To use Table 3-18:

1. Measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cutoff point of the overhang (V).
2. Calculate H/V.
3. Enter the table at that point.
4. Choose the next higher value to the calculated H/V value if the calculated H/V falls between two values in the table
5. Move across to the column that corresponds to the orientation of the window and find the overhang factor.

Any value of H/V greater than 1 has the same overhang factor (for a given orientation) shown in the last row of the table.

Figure 3-15 graphs the overhang factors of the various orientations as a function of H/V. It shows that overhangs have only a minor effect on the north. (Maximum reduction in SHGC is only about 20 percent.) East, west, and south overhangs can achieve reductions of 55–60 percent. The benefits of the overhang level off as the overhang becomes larger. (This graph is presented only to illustrate the benefits of overhangs.)

Figure 3-15: Graph of Overhang Factors



Example 3-13

Question:
An east-facing window has glass with a solar heat gain coefficient of 0.71. It has a fixed overhanging eave that extends 3 ft out from the plane of the glass (H = 3) and is 6 ft above the bottom of the glass (V = 6). The overhang extends more than 3 ft beyond each side of the glass, and the top of the window is less than 2 ft vertically below the overhang. What is the RSHGC for this window?

Answer:
First, calculate H/V. This value is 3 / 6 = 0.50. Next, find the overhang factor from Table 3-18. For east-facing windows, this value is 0.63. Finally, multiply it by the solar heat gain coefficient to obtain the RSHGC: 0.63 x 0.71 = 0.45.

D. Visible Light Transmittance (VT)

§140.3(a)5D

The prescriptive requirements of Tables 140.3-B and 140.3-C (Table 3-17) of the Energy Standards prescribe specific VT values for all climate zones and glass types. The visible light transmittance is used in the performance method in the calculation of the interior illumination levels and lighting energy savings due to daylight controls. This is discussed in more detail in Chapter 5 of this manual.

Fenestration must meet the climate zone-specific prescriptive requirement of having an area-weighted average VT of 0.42 or greater for fixed windows, 0.32 or greater for operable windows, 0.46 or greater for curtain walls and 0.17 or greater for glazed doors. Products with spectrally selective “low-e” coatings (also known as single, double or triple silver low-e) are available to meet this requirement.

A combination of high VT glazing in the upper part of a window (clerestory) and lower VT glazing at the lower part of the window (view window) can be used, as long as the area-weighted average meets the prescriptive requirement. This allows daylight to enter the space through the high VT glazing making a better daylighting design.

The Energy Standards also allow a slight variance if the window-to-wall ratio (WWR) is greater than 40 percent. For this case, assume 0.40 for the WWR in the equation below, or if the glazing can comply with the prescriptive requirements if the area-weighted average VT meets the following minimum requirement:

Equation 3-3 – Visible Light Transmittance

VT ≥ 0.11 / WWR

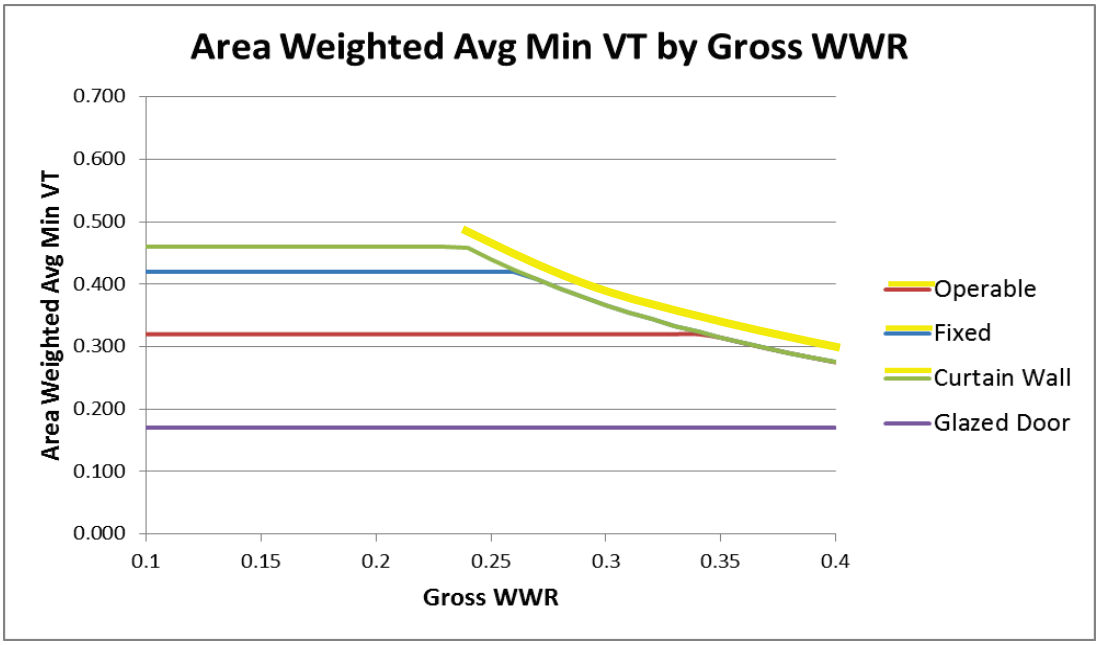
Where:

VT = the visible transmittance of the framed window

WWR = the gross window-to-wall ratio

The graph below shows the allowed area weighted average minimum VT's by gross WWR for four types of windows

Figure 3-16: Area Weighted Average Minimum VT by Gross Window-to-Wall Ratio

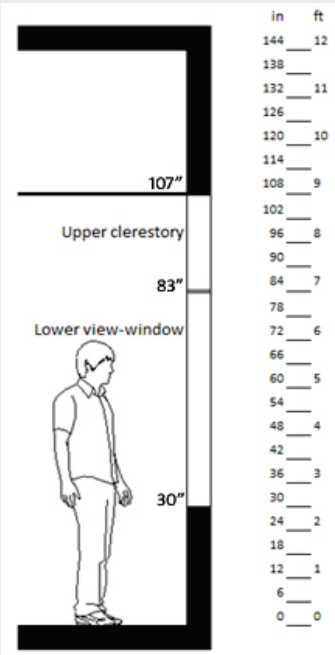


The average VT requirements apply separately to chromatic (dynamic or color changing) glazing and nonchromatic glazing. For chromatic glazing, higher ranges of VT can be used to meet the prescriptive requirements. However, all glazing that is not chromatic must separately meet the area-weighted VT prescriptive requirements.

Example 3-14

Question:

A space has a gross window-to-wall ratio of 30 percent and has a fixed window with a sill height of 2'6" (30") and a head height of 8'11" (107"), which runs 10' wide (120"). The window has a break at 6'11" (83") such that the upper portion or clerestory portion of the window is 2' (24") tall and can have a glazing different from that in the lower portion (view window). Can a designer use 0.30 VT glazing in the view window?



Answer:

Using the formula VT ≥ 0.11 / WWR, staff determines the minimum area weighted average VT for this space,

VT ≥ 0.11 / 0.3 = 0.367

So the area weighted minimum VT we need for this window is 0.367.

I.e. (View window Area x View window VT) + (Clerestory Area x Clerestory VT) / Total Window Area = 0.367

In this case:

Clerestory area = 24" height x 120" width = 2,880 sq.in

View window area = (83" - 30") height x 120" width = 6,360 sq.in.

If the designer wants to use a 0.30 VT glazing in the view window then View window VT = 0.30

Total window area = (107" - 30") height x 120" width = 9,240 sq.in.

Solving the above equation for Clerestory VT, staff gets:

Clerestory VT = 0.515

(6360 x 0.367) + (2880 x VT_{CL})/9240

So, to use a 0.3 VT glazing in the view window, the designer must use a 0.515 VT window in the clerestory.

3.3.2.3. Compliance Options

A. Dynamic Glazing − Chromatic Glazing

Chromatic-type fenestration has the ability to change performance properties (U-factor, SHGC, and VT). The occupant can manually or automatically control his or her environment by tinting or darkening a window with the flip of a switch or by raising/lowering a shade positioned between panes of glass. Some windows and doors change the performance automatically in response to a control or environmental signal.

These “smart windows” provide a variety of benefits, including reduced energy costs due to controlled daylighting and unwanted heat gain or heat loss. While still a relatively new technology, high-performance windows are expected to grow substantially in the coming years.

Look for the NFRC Dynamic Glazing Label to compare and contrast the energy performance for these new products. See the example of a Dynamic Glazing NFRC label in Figure 3-17 below. The unique rating identifiers help consumers understand the “dynamics” of the product and allow comparison with other similar fenestration products.

If the product can operate at intermediate states, a dual directional arrow, **(↔),** with the word “variable” underneath 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 position), and the high value rating is displayed to the right (in the open position). This lets the consumer know at a glance the best and worst case performance of the product and what the default or de-energized performance level will be.

Figure 3-17: Dynamic Glazing NFRC Label

The label references the following information:

1. **U-factor** measures the rate of heat loss through a product. Therefore, the lower the U-factor, the lower the amount of heat loss. In cold climates where heating bills are a concern, choosing products with lower U-factors will reduce the amount of heat that escapes from inside the house.
2. The **solar heat gain coefficient (SHGC)** measures the rate of heat gain from solar energy passing through a product. Therefore, the lower the SHGC, the less amount of solar heat gain. In hot climates where air conditioning bills are a concern, choosing products with a lower SHGC will reduce the amount of heat that comes in from the outside.

3. **Visible transmittance (VT)** measures the amount of light that comes through a product. The higher the VT rating, the more light is allowed through a window or door.
4. **Air Leakage (AL)** is a measurement of heat loss and gain by infiltration through cracks in the window assembly which affects occupant comfort. The lower the AL, the less air will pass through cracks in the window assembly.

To receive chromatic glazing credit, the following must be met:

1. Optional prescriptive − default to Table 140.3-B and 140.3-C, U-factor and SHGC
2. Performance approach compliance − maximum credit allowance for best rating
3. Automatic controls to receive best rating values or
4. NFRC Dynamic Glazing Compliance Label is required; otherwise, default to Table 110.6-A and 110.6-B values.

B. Window Films

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

Polyester film can be metalized and easily laminated to other layers of polyester film.

There are three basic categories of window films:

1. Clear (nonreflective) films are used as safety or security films and to reduce ultraviolet (UV) light, which contributes to fading of finished surfaces and furnishings. 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 absorptance and can be used in applications where the primary benefit desired is glare control with energy savings as secondary benefit.
3. Metalized (reflective) films can be metalized though vacuum coating, sputtering, or reactive deposition and may be clear or colored. Metalized (reflective) films are the preferred window films in most energy-saving applications, since they reduce transmission primarily through reflectance and are manufactured to selectively reflect heat more than visible light through various combinations of metals.

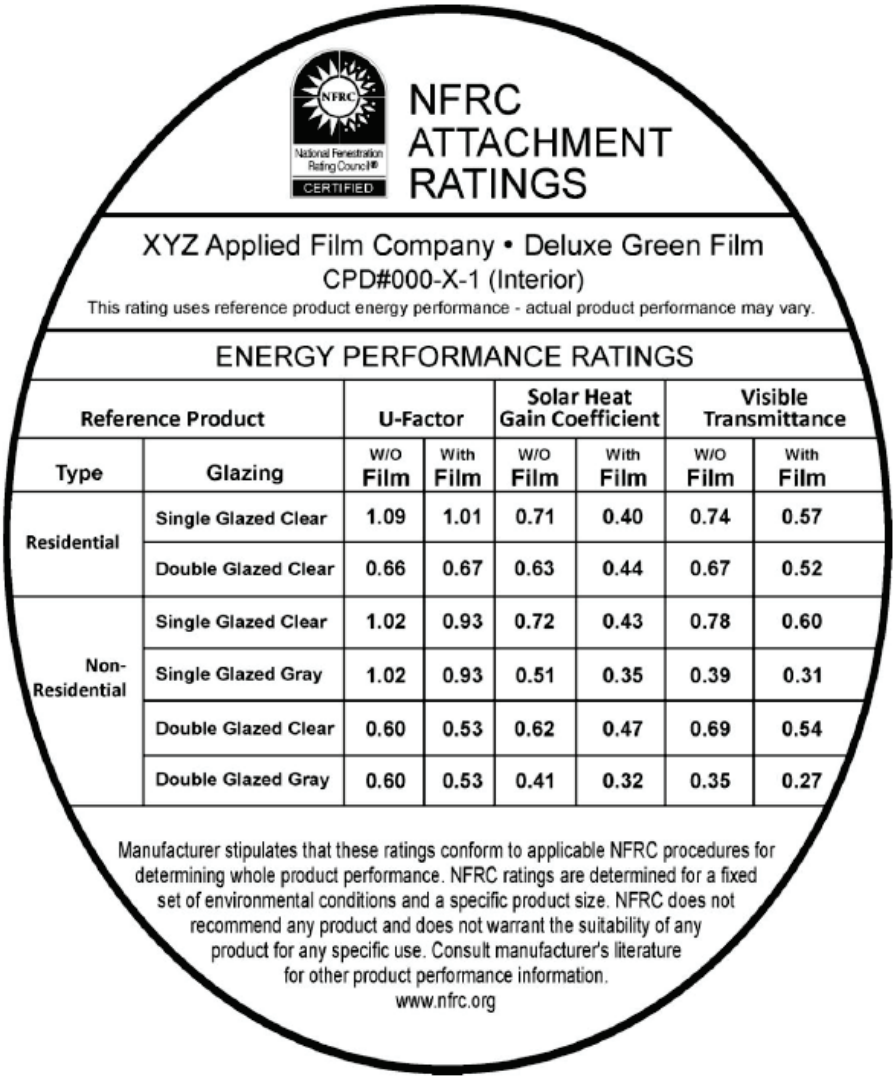
Look for the NFRC–certified attachment ratings energy-performance label, which helps consumers understand the contrast in energy performance of window films. An example of a window film energy performance label is shown on Figure 3-18 given below.

Window Film Compliance

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

1. The performance approach must be used.
2. Use only the alteration to existing building compliance method.
   a. The NFRC window film energy performance label is required for each film; otherwise, use the Default Table 110.6-A and 110.6-B values.
   b. Window films shall have a 10-year or longer warranty.

Figure 3-18: Window Film Energy Performance Label



NFRC ATTACHMENT RATINGS

XYZ Applied Film Company • Deluxe Green Film
CPD#000-X-1 (Interior)
This rating uses reference product energy performance - actual product performance may vary.

ENERGY PERFORMANCE RATINGS

Reference Product		U-Factor		Solar Heat Gain Coefficient		Visible Transmittance	
Type	Glazing	W/O Film	With Film	W/O Film	With Film	W/O Film	With Film
Residential	Single Glazed Clear	1.09	1.01	0.71	0.40	0.74	0.57
	Double Glazed Clear	0.66	0.67	0.63	0.44	0.67	0.52
Non-Residential	Single Glazed Clear	1.02	0.93	0.72	0.43	0.78	0.60
	Single Glazed Gray	1.02	0.93	0.51	0.35	0.39	0.31
	Double Glazed Clear	0.60	0.53	0.62	0.47	0.69	0.54
	Double Glazed Gray	0.60	0.53	0.41	0.32	0.35	0.27

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

3.3.3 Skylights

There are two ways that skylights can be mounted into a roof system, either flush-mounted or curb-mounted. To ensure water flows around them, skylights are often mounted on "curbs" set above the roof plane. These curbs, rising 6 to 12 inches above the roof, create additional heat loss surfaces.

When skylights are specified, the designer must show the skylit daylight zones on the building plans. Automatic daylighting controls are required when the installed power in the daylit zones of a room is greater than 120W. See Chapter 5 of this manual for a detailed discussion of the daylight zones.

3.3.3.1. Skylight Mandatory Measures

There are no mandatory measures for skylights, so the prescriptive or performance approach must be used. However, there are mandatory requirements for lighting controls related to daylighting, as discussed below.

A. Controls

§130.1(d)

Electric lighting in skylight daylit zones shall meet the mandatory control requirements in §130.1(d). Chapter 5 contains information about lighting control requirements and daylighting control requirements. As described above, obstructions are ignored for evaluating the architectural area served by skylights. However, for controlling lighting, one must consider the area shaded that is behind permanent obstructions that are greater than half the ceiling height. As a result, those luminaires behind tall obstructions are not part of the skylit daylit area and, therefore, not controlled by automatic daylighting controls.

3.3.3.2. Skylight Prescriptive Requirements

140.3(a)6

As with windows, there are four aspects of the prescriptive envelope approach for skylights:

1. Maximum total area.
2. Maximum U-factor.
3. Maximum solar heat gain coefficient (SHGC).
4. Minimum visible transmittance (VT).

Table 3-19: Skylight Requirements (Area-Weighted Performance Rating)

		All Climate Zones		
		Glass, Curb Mounted	Glass, Deck-Mounted	Plastic, Curb-Mounted
Nonresidential	U-factor	0.58	0.46	0.88
	SHGC	0.25	0.25	NR
	VT	0.49	0.49	0.64
	Maximum SRR%	5%		
High-Rise Residential	U-factor	0.58	0.46	0.88
	SHGC	0.25	0.25	NR
	VT	0.49	0.49	0.64
	Maximum SRR%	5%		

Excerpt from Energy Standards Tables 140.3-B and 140.3-C, Skylight Roof Ratio, SRR

A. Skylight Area

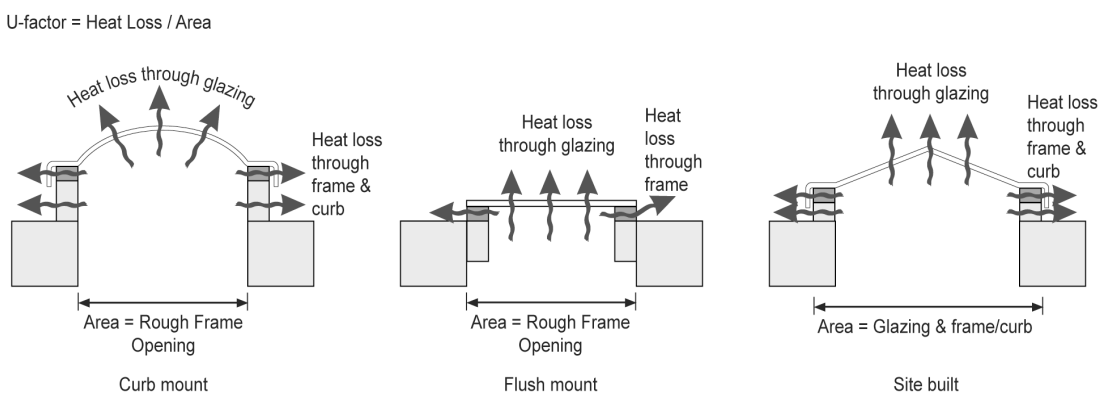
§140.3(a)6A

Skylight area is defined in JA1 as the area of the rough opening of a skylight. The area limit for skylights is 5 percent of the gross exterior roof area, sometimes called the skylight roof ratio (SRR). The limit increases to 10 percent for buildings with an atrium more than 55 ft high. .) The 55-ft height is also the threshold at which the California Building Code requires a mechanical smoke-control system for atriums (CBC Sec. 909). In practice, this means that the 10 percent SRR is not allowed for atriums unless they also meet this smoke control requirement.

Site-built monumental or architectural skylights equipped with integral built-in or site-built curbs (that is not part of the roof construction) are often used for atrium roofs, malls, and other applications that need large skylights. These are treated differently within the Energy Standards: in these cases the skylight area is the surface area of the glazing and frame/curb, *not the area of the rough-framed opening*. This is regardless of the geometry of the skylight, that is, it could be flat pyramid, bubble, barrel vault, or other three-dimensional shape – what matters is the anticipated heat exchanged through the glazing, which is a function of its area. Also, for special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5 of this manual.

§140.3(c)4 also requires that the skylight area be at least 3 percent of the floor area (not accounting for obstructions), or that the product of the skylight area and the area-weighted average visible transmittance of the skylights be at least 1.5 percent of the floor area (not accounting for obstructions). This assures that enough light reaches the skylighted spaces. The visual transmittance option acknowledges that more skylight area is not needed for buildings with highly transmitting skylights. For example, if plastic skylights are installed with the prescriptive minimum transmittance of 0.64, the maximum ratio of skylight area to floor area within 0.7 times the ceiling height of skylights is 2.3 percent.

Figure 3-19: Skylight Area



B. Skylight U-Factor

§140.3(a)6B

The U-factor for skylights is an inclusive measurement of its heat losses, and includes heat losses through the glazing, the frame, and the integral curb (when one exists). If an NFRC rating does not exist, such as for projecting plastic skylights, the designer can make use of default fenestration U-factors found in Table 110.6-A of the Energy Standards.

For skylights, the U-factor criteria depend on whether the skylight glazing material is plastic or glass, and whether the skylight is curb-mounted, noting that plastic skylights are assumed to be mounted on a curb. These criteria are shown in Tables 140.3-B, C, and D.

C. Skylight SHGC

§140.3(a)6C

Skylights are regulated for SHGC rather than RSHGC because skylights cannot have overhangs. The SHGC criteria vary with the SRR, and the criteria can be found in Tables 140.3-B, C, and D (Table 3-19). The designer can make use of default SHGC values in Table 110.6-B of the Energy Standards, or can use the Nonresidential Reference Appendix NA6 if all site-built fenestration (skylights and vertical fenestration) is less than 1,000 ft².

D. Visible Transmittance (VT)

§140.3(a)6D

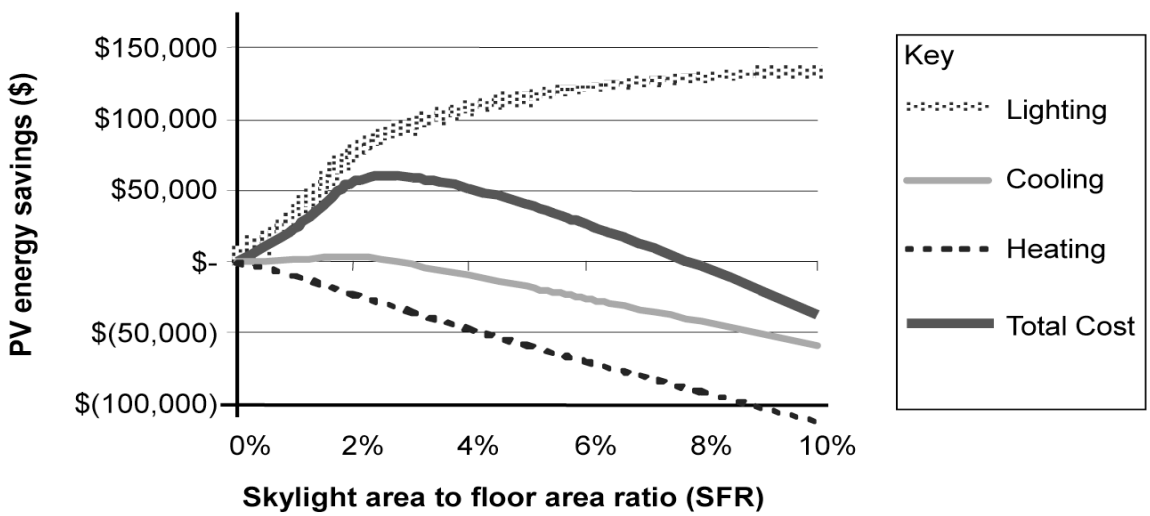
Skylights shall have an area-weighted average visible transmittance (VT) of no less than the value required by §140.3(a)6D.

E. Minimum Daylighting Prescriptive Requirements in Large Enclosed Spaces

§140.3(c)

Appropriately sized skylight systems can dramatically reduce the lighting energy consumption of a building when combined with appropriate daylighting controls. Daylighting control requirements under skylights are discussed in Chapter 5 of this manual. Sizing is important: with too little skylight area, insufficient light is available to turn off electric lighting; with too much skylight area, solar gains and heat losses through skylights negate the lighting savings by adding heating and cooling loads.

Figure 3-20: Present Value Savings of Skylight 50,000 ft² Warehouse in Sacramento



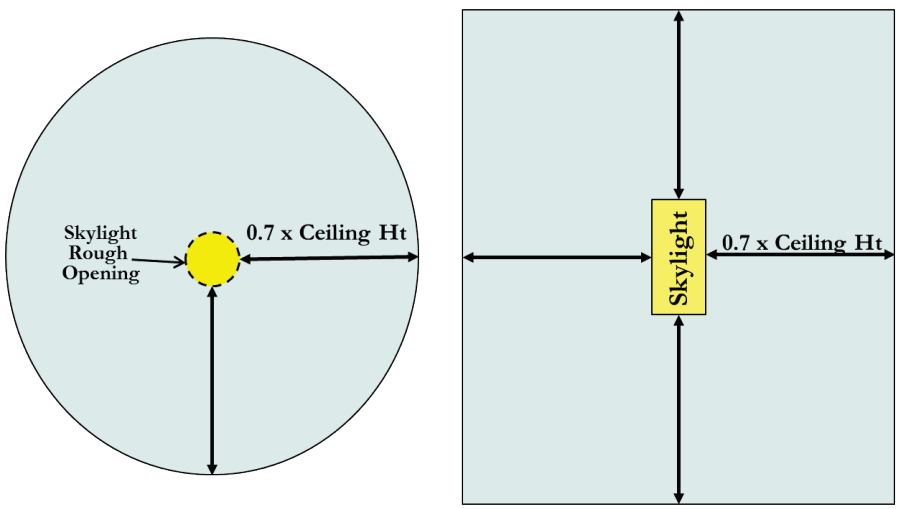
Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required in enclosed spaces (rooms) that:

- Are larger than 5,000 ft².
- Are directly under a roof.
- Have ceiling heights greater than 15 ft.
- Have lighting power densities greater than 0.3 W/ft².

The Energy Standards require that at least 75 percent of the floor area be within one or more of the following:

1. A skylit daylit zone, meaning an area in plan view that is directly under a skylight or within 0.7 times the average ceiling height in each direction from the edges of the rough opening of the skylight (see Figure 3-21), or
2. A primary sidelit daylit zone, meaning an area in plan view that is directly adjacent to vertical glazing, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window based on §130.1(d).

Figure 3-21: Area Within 0.7 Times Ceiling Height of Rough Opening of Circular Skylight and Rectangular Skylight

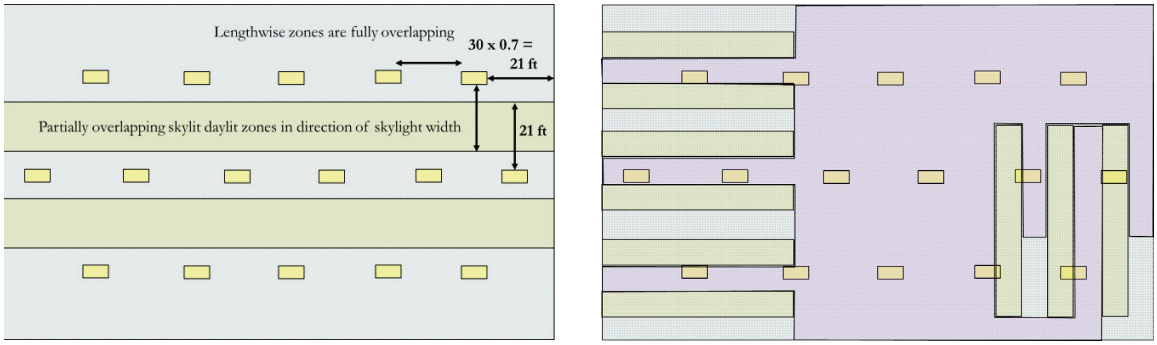


The shape of the skylit daylit zone will be similar in shape to the rough opening of the skylight, as shown in Figure 3-21.

Examples: If the skylight is circular, the area that is within a horizontal distance 0.7 times the average ceiling height from the edge of the rough opening, is also a circle, with the radius of the circle being the radius of the skylight + 0.7 x the ceiling height.

If the skylight is rectangular, the zone is rectangular, with the edges increased in each direction by 0.7 times the ceiling height.

Figure 3-22: Comparison of Skylit Area for Calculating Minimum Skylit Area and the Skylit Daylit Zone for Controlling Luminaires in §130.1(d)



a) Entire space is within 0.7 x ceiling height of skylights for meeting minimum daylit area (§140.3(c))

b)Skylit daylit zone (§130.1(d)) for controlling luminaires is limited by racks blocking daylight

The specifications for daylighting controls in §130.1(d) describe which luminaires must be controlled, and consider the daylight obstructing effects of tall racks, shelves, and partitions taller than one-half the distance from the floor to the bottom of the skylight when determining if daylight will reach a given space. As shown in Figure 3-22, it is considerably easier to calculate.

(a) The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

Versus

(b) The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights, minus any area on a plan beyond a permanent obstruction that is taller than the following: A permanent obstruction that is taller than one-half the distance from the floor to the bottom of the skylight.

(a) is required to be calculated to comply with minimum skylight area requirements of §140.3(c), and (b), is required to comply with the automatic daylighting control requirements of §130.1(d) (essentially, to ensure that daylighting controls are not installed where they would not be effective).

In §130.1(d), the skylit daylit areas are required to be drawn on the plans, and any general lighting luminaires that are in the daylit zones must be separately controlled by automatic daylighting controls. (See the daylighting requirements in Chapter 5 Lighting).

Two exemptions from §140.3(c) include:

1. *Auditoriums, churches, museums and movie theaters due to the demanding lighting control needs.*
2. *Refrigerated warehouses to minimize heat gains.*

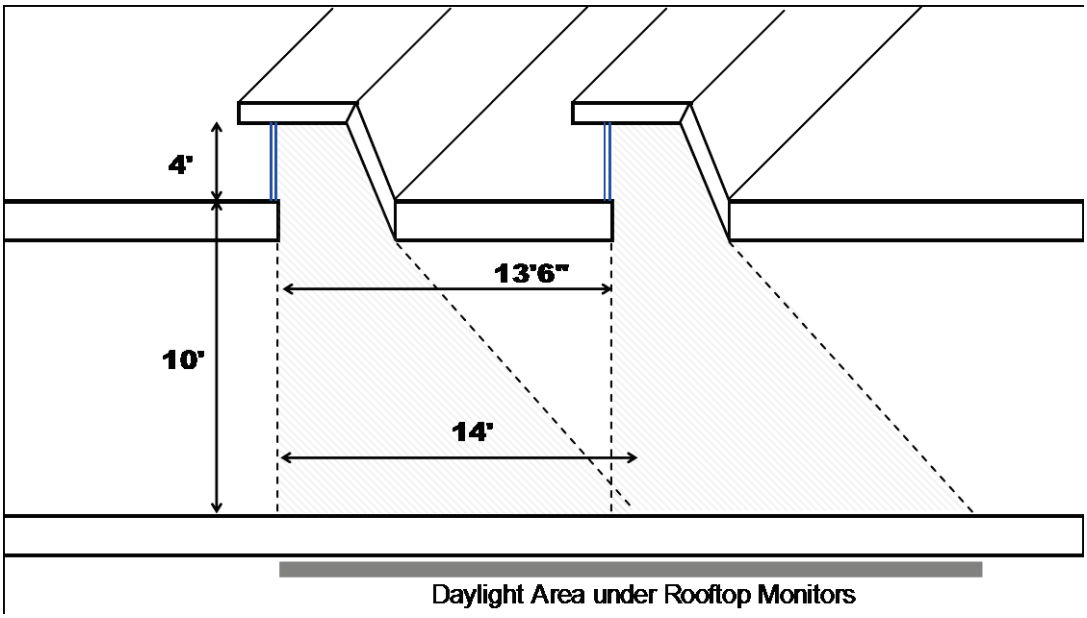
Since skylights paired with daylighting controls can significantly reduce energy demands from lighting, they are mandatory on all nonresidential occupancies that meet the above criteria *whether the space is conditioned or unconditioned*. Further information can be found in Section 3.3.3.1.

For large buildings with high ceilings, skylighting 75 percent of the floor area can be achieved by evenly spacing skylights across the roof of the building. As a general rule, a space can be fully skylighted by having skylights spaced so that the edges of the skylights are not further than 1.4 times the ceiling height apart. For example, in a space having a ceiling height of 20 feet, the space can be fully skylighted if the edges of skylights are no more than 28 feet apart.

F. Rooftop Monitors

Rooftop monitors are considered vertical fenestration, and the daylight area next to them is the same as the daylit area next to other vertical fenestration. The daylit area is from the inward facing plane of the fenestration one window head height and in the direction parallel to the fenestration 0.5 window head heights on either side.

Figure 3-23: Daylight Area Under Rooftop Monitors (Primary Sidelit Daylit Zone)



G. Exceptions for Shading

Occasionally there is not a solar resource available for skylighting. This situation occurs, for example, if a short building is shadowed by surrounding taller buildings. To account for this, minimum daylighting requirements are exempted for spaces where permanent architectural features of the building, existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m. This can be documented to the local building official using a variety of tools including equipment that superimposes the sun path diagram on a photograph of the sky taken at the site[4], hand calculation tools such as the sun path calculator[5], and computer-aided design software tools that automate this calculation.

4 Resource noted for information only, not intended as an endorsement: http://www.solarpathfinder.com/

5 Resource noted for information only, not intended to be an endorsement https://www.pilkington.com/resources/pilkingtonsunanglecalculatormanual.pdf

3.3.3.3. Ignoring Partitions and Shelves

The rationale for ignoring the presence of partitions for specifying minimum skylight area and spacing is that the design of the envelope may be developed before there is any knowledge of the location of the partial height partitions or shelves, as is often the case for core and shell buildings. Thus, the architectural daylit zone requirement of 75 percent of the space area indicates the possibility of the architectural space being mostly daylit. By not accounting for partial ceiling height partitions and racks, the Energy Standards are consistent in addressing architectural daylit areas, regardless of whether the design is core and the shell or a complete design development, including interior design. This approach does not require the addition of extra skylights or windows if racks and partial height partitions are added later.

Example 3-15

Question:

What is the maximum spacing and recommended range for skylights in a 40,000 ft^2 warehouse with 30-foot-tall ceiling and a roof deck?

Answer:

From the definition of *Skylit Daylit Zone* in Section 130.1(d), the maximum spacing of skylights that will result in the space being fully skylit is:

Maximum skylight spacing = 1.4 x Ceiling Height + Skylight width

Spacing skylights closer together results in more lighting uniformity and thus better lighting quality, – but costs more as more skylights are needed. However as a first approximation, one can space the skylights 1.4 times the ceiling height. For this example, skylights can be spaced 1.4 x 30 = 42 feet. In general the design will also be dictated by the size of roof decking materials (such as 4’ by 8’ plywood decking) and the spacing of roof purlins so the edge of the skylights line up with roof purlins. For this example, staff assumes that roof deck material is 4’ by 8’ and skylights are spaced on 40-foot centers.

Each skylight is serving a 40-foot by 40-foot area of 1,600 sf. A standard skylight size for warehouses is often 4’ by 8’ (so it displaces one piece of roof decking). The ratio of skylight area to daylit area is 2 percent (32/1600 = 0.02). Assuming this is a plastic skylight and it has a minimally compliant visible light transmittance of 0.64, the product of skylight transmittance and skylight area to daylit area ratio is

(0.64)(32/1,600) = 0.013 = 1.3%

This is a little less than the 2 percent rule of thumb described earlier for the product of skylight transmittance and skylight area to daylit area ratio. If one installed an 8 ft by 8 ft skylight (two 4 ft by 8 ft skylights) on a 40 foot spacing, it would yield a 2.6 percent product of skylight transmittance and skylight area to daylit area ratio and provide sufficient daylight. With 64 square feet of skylight area for each 1,600 square feet of roof area, the skylight-to-roof area ratio (SRR) is 4 percent, which is less than the maximum SRR of 5 percent allowed by Section 140.3(a) and thus complies with the maximum skylight requirement.

An alternate (and improved) approach would be to space 4 ft x 8 ft skylights closer together, which would provide more uniform daylight distribution in the space and could more closely approach the desired minimum VT skylight area product. A 32-foot center-to-center spacing of skylights results in (32 x 32) = 1,024 square feet of daylit area per skylight. By taking the product of the skylight VT and the skylight area and dividing by 0.02 (the desired ratio), it yields the approximate area the skylight should serve. In this case, with a VT of 0.65 and a skylight area of 32 square feet, each skylight should serve around:

(0.64 x 32 /0.02) = 1,024 sf.

For a minimally compliant 4 ft by 8 ft plastic skylight with a visible light transmittance of 0.65, the product of skylight transmittance and skylight area to daylit area ratio is:

(0.64)(32/1,024) = 0.020 = 2.0%

Energy savings can be improved than this rule of thumb approach by using a whole-building energy performance analysis tool that enhances the trade-offs among daylight, heat losses and gains, and electric lighting energy consumption.

3.3.3.4. Glazing Material and Diffusers

§140.3(a)6E

Skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 (notwithstanding its scope) or other test method approved by the Energy Commission.

For conditioned spaces the Energy Standards require the use of double-glazed skylights. When the skylights are above unconditioned spaces, there is no limitation placed on the maximum skylight area or the U-factor or SHGC.

Regardless of whether the space is conditioned, the code requires that the skylights diffuse and bring in enough sunlight so that, when the electric lights are turned off, the occupants have relatively uniform daylight in the space. If the space is unconditioned, single-glazed skylights will comply with the code requirements as long as they are sufficiently diffusing (that is, the glazing or diffuser material has a haze rating greater 90 percent) and the visible transmittance is above the VT requirements in Table 140.3-B or C of the Energy Standards. Products that have such a rating include prismatic diffusers, laminated glass with diffusing interlayers, pigmented plastics, and so forth. This requirement assures that light is diffused over all sun angles. Any unconditioned space that later becomes conditioned must meet the new construction envelope requirements. Therefore, if the space may become conditioned in the future, it is recommended that the envelope meet the conditioned envelope thermal requirements.

Other methods of diffusion that result in sufficient diffusion of light over the entire year would also be acceptable in lieu of using diffusing glazing. Acceptable alternatives are baffles or reflecting surfaces that ensure direct beam light is reflected off a diffuse surface before entering the space over all sun angles encountered during a year. This alternative method of diffusion would have to be documented by the designer and approved by the code authority in your jurisdiction.

Figure 3-24: Daylit Area Under Skylights

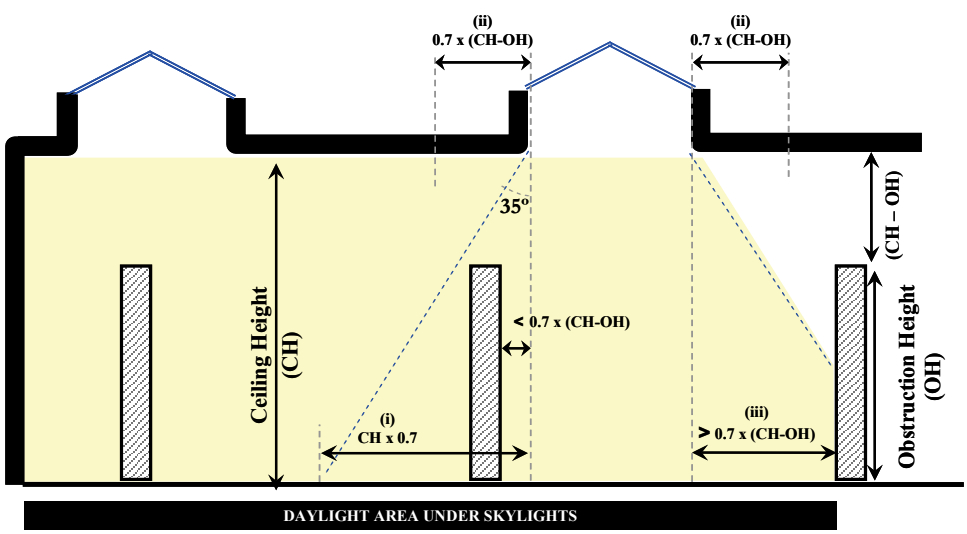
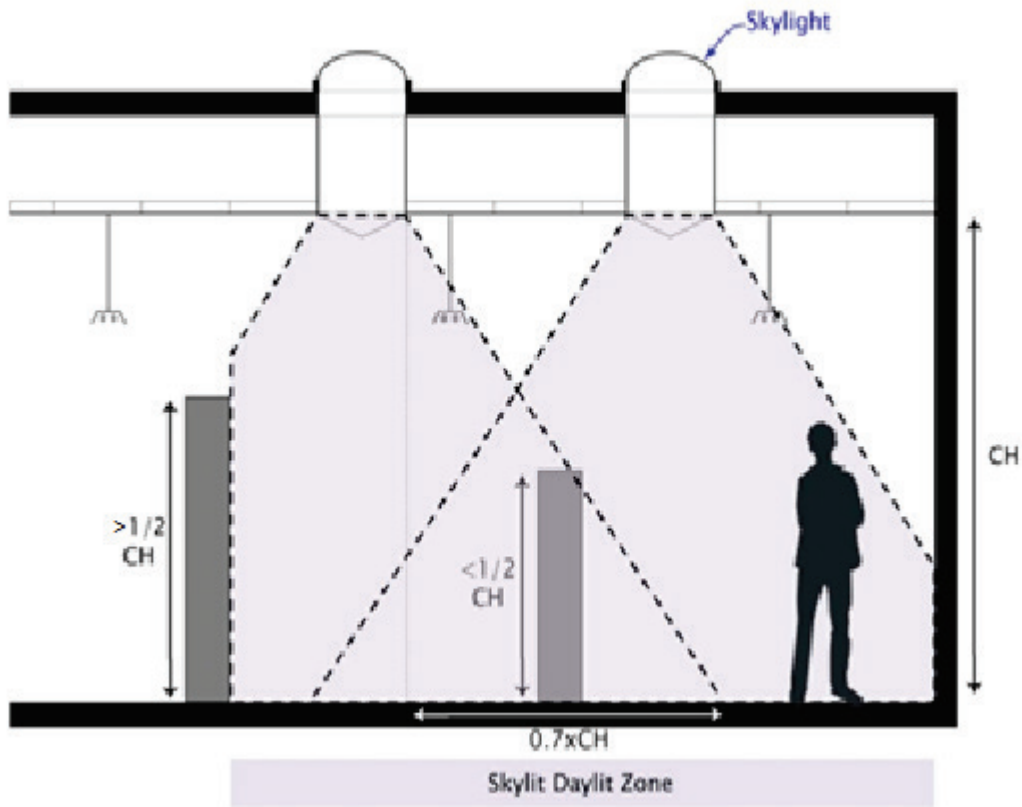


Figure 3-25: Daylit Area Tradeoff Between Skylights



Example 3-16

Question:

A designer is using a U-factor of 0.57 for compliance with a curtain wall system. The glazing system uses two lites of 1/4 in (6mm) glass with a low-e= 0.1 coating on the second surface. The air gap is 1/2 in (12 mm). A standard metal frame is proposed for the curtain wall system. Is 0.57 a reasonable U-factor for compliance, and can it reasonably be achieved by the glazing contractor through the NFRC process for site-built fenestration?

Answer:

The default U-factor for this glazing combination from Reference Nonresidential Appendix NA6 is 0.59. If no NFRC rating information is available, a U-factor of 0.59 must be used. The design U-factor of 0.57 cannot be used.

3.4 Relocatable Public School Buildings

Table 140.3-D of the Energy Standards
Reference Nonresidential Appendix NA4

Public school building design is defined by these prescriptive requirements:

- Table 140.3-B covers prescriptive requirements for climate-specific relocatable public school buildings.
- Table 140.3-D covers prescriptive requirements for relocatable public school buildings that can be installed in any climate zone.

- Building envelopes must meet the prescriptive requirements in §140.3. For additional design requirements, refer to §140.3 and Reference Nonresidential Appendix NA4.

Manufacturers must certify compliance and provide documentation according to the chosen method of compliance. Performance compliance calculations must be performed for multiple orientations, with each model using the same proposed design energy features rotated through the different orientations (north, east, south and west) and the 12 climate zones (Reference Nonresidential Appendix NA4). Also see §140.3(a)8 and §141.0(b)2.

When the manufacturer/builder certifies a relocatable public school building for use in any climate zone, the building must be designed and built to meet the energy budget for the most severe climate zones (as specified in the Reference Nonresidential Appendix NA4), assuming the prescriptive envelope criteria in Table 140.3-D of the Energy Standards.

However, when the relocatable building is manufactured for use in specific climate zones and cannot be lawfully used in other climate zones, the energy budget must be met for each climate zone that the manufacturer/building certifies, using prescriptive envelope criteria in Table 140.3-B. The energy budget and the energy use of the proposed building must be determined using the multiple orientation approach specified in the Reference Nonresidential Appendix NA4. The manufacturer/builder shall meet the requirements for identification labels specified in §140.3(a)8.

3.5 Performance Approach

§140.1 Performance

Under the performance approach, energy use of the building is modeled by compliance software approved by the Energy Commission. The compliance software simulates the time-dependent value (TDV) energy use of the proposed building, including a detailed accounting of envelope heat transfers using the assemblies and fenestration input, and the precise geometry of any exterior overhangs or side fins. The most accurate tradeoffs between different envelope components – and among the envelope, the space-conditioning system, and the installed lighting design – are accounted for and compared with the standard design version of the building. The proposed design has to have TDV energy less than or equal to the standard design.

This section presents some basic details on the modeling of building envelope components. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program. All compliance software, however, are required to have the same basic modeling capabilities. A discussion on the performance approach, and fixed and restricted inputs, is included in Chapter 9.

The following modeling capabilities are required by all approved nonresidential compliance software. These modeling features affect the thermal loads seen by the HVAC system model. More information may be found in the *ACM Reference Manual* and the CBECC-Com User Guide.

3.5.1 Opaque Surface Mass Characteristics

Heat absorption, retention, and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled.

Typical inputs are:

- Spacing

- Thickness
- Standard U-factor
- Reference Appendix JA4 table
- Framed cavity R-value
- Proposed assembly U-factor.

The heat capacity of concrete masonry unit walls and solid concrete walls is provided in Tables 4.3.5 and 4.3.6 of Reference Appendix JA4. Effective R-values for interior and exterior insulation are provided in Table 4.3.13 of Reference Appendix JA4.

3.5.2 Opaque Surface

Heat gains and heat losses are modeled through opaque surfaces of the building envelope. The following inputs or acceptable alternative inputs are used by this modeling capability:

1. Surface areas by opaque surface type.
2. Surface orientation and slope.
3. Thermal conductance of the surface. The construction assembly U-factor is developed by specifying a construction as a series of layers of building materials, each of which may be insulation, framing, homogenous construction material, or a combination of framing and cavity insulation.
4. Surface absorptance = 1– solar reflectance. Surface absorptance is a restricted input (except for roofs).

Note for roofs: Surface absorptance and emittance are variable inputs in the proposed design for roofs to provide design flexibility where a cool roof is not specified. The roof reference design is set with a cool roof surface absorptance for nonresidential buildings in all climate zones. The difference in surface absorptance creates a credit that can be used with the whole-building performance method. For more information on cool roofs, see Section 3.2.2.1.

To model the proposed design as a cool roof, the roofing product must be listed in the directory of the CRRC. If the roof is not rated, a default aged reflectance of 0.08 is used for asphalt or composition shingles and 0.10 for other roofing products. If the proposed design does not have a cool roof, the performance method may be used to trade off with other measures, such as increased insulation or HVAC equipment efficiency, so that the TDV energy of the proposed design does not exceed that of the standard design.

3.5.3 Fenestration Heat Transfer

Heat transfer through all fenestration surfaces of the building envelope are modeled using the following inputs:

1. Fenestration areas. The glazing width and height dimensions are those of the rough-out opening for the window or fenestration product. Window area of the standard design is limited to the prescriptive limit of 40 percent of the gross exterior wall area (that is adjacent to conditioned space) or six times the display perimeter, whichever is greater. If the proposed design window area exceeds this limit, a trade-off may be made with measures such as increased envelope insulation or increased equipment efficiency to offset the penalty from fenestration.
2. Fenestration orientation and slope. Vertical windows installed in a building located in any of the four cardinal orientations, north, south west, and east. Skylights are

considered less than 60° from the horizontal, and all windows and skylights provide solar gain that can affect the overall energy of the building unless they are insulated glass.

3. Fenestration thermal conductance (U-factor). The overall U-factor shall be taken from NFRC rating information, default values in Table 110.6-A of the Energy Standards, or from Reference Nonresidential Appendix NA6 if less than 1,000 ft².
4. Fenestration solar heat gain coefficient (SHGC). The SHGC shall be taken from NFRC rating information default values in Table 110.6-B of the Energy Standards or from Reference Nonresidential Appendix NA6 if less than 1,000 ft². The baseline building uses a SHGC equal to the value from Tables 140.3-B, 140.3-C, or 140.3-D. The baseline building has no overhangs, but overhangs can be modeled in the baseline building, as described below.

3.5.4 Overhangs and Vertical Shading Fins

Approved compliance software programs are able to model overhangs and vertical fins. Typical inputs for overhangs are:

- Overhang projection.
- Height above window.
- Window height.
- Overhang horizontal extension past the edge of the window.
  - If the overhang horizontal extension (past the window jambs) is not an input, then the program assumes that the extension is zero (that is, overhang width is equal to window width), which results in fewer benefits from the overhang.

Vertical fins are modeled with inputs of horizontal and vertical position relative to the window, the vertical height of the fin and the fin depth (projection outward perpendicular to the wall).

3.5.5 Slab-on-Grade Floors and Basement Floors

Heat transfer through slab-on-grade floors and basement floors is modeled by calculating perimeter heat losses and interior slab heat losses. The heat losses from the perimeter and the interior are modeled by the use of an F-factor that accounts for the rate of heat transfer from the slab to the soil. Reference Appendix JA4 contains F-factors for common insulation conditions (vertical insulation outside or a combination of the two). The insulation depth and insulation R-value affect heat loss through basement floors.

3.6 Additions and Alterations

The Energy Standards offer prescriptive approaches and a performance approach to additions and alterations, but they do not apply to repairs. Relevant definitions from §100.1(b) are provided below:

A. Addition is a change to an existing building that increases conditioned floor area and volume. See §141.0(a) and §100.1(b) for a detailed definition.

When an unconditioned building or unconditioned part of a building adds heating or cooling so that it becomes conditioned, this area is treated as an addition.

B. Alteration is a change to an existing building that is not an addition. An alteration could include a new HVAC system, lighting system, or change to the building envelope, such as a new window. See §141.0(b) and §100.1(b). Roof replacements (reroofing) and reconstructions and renewal of the roof are considered alterations and are subject to all applicable Energy Standards requirements. For alterations, the compliance procedure includes:

1. The prescriptive envelope component approach.
2. The addition alone approach.
3. The existing-plus-alteration performance approach.
4. The existing-plus-addition-plus alteration performance approach.

C. Repair is the reconstruction or renewal of any part of an existing building for maintenance. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration. See §141.0(b) and §100.1(b).

For example, a repair could include the replacement of a pane of glass in an existing multilite window without replacing the entire window.

Additions and alterations to the building envelope must meet the prescriptive insulation requirements in §141.0 or comply with the performance compliance approach.

3.6.1 Mandatory Requirements

3.6.1.1. Additions

All additions must meet the applicable mandatory measures from the following Energy Standards sections:

- §110.6 − Mandatory Requirements for Fenestration Products and Exterior Doors
- §110.7 − Mandatory Requirements for Joints and Other Openings
- §110.8 − Mandatory Requirements for Insulation and Roofing Products (Cool Roofs)
- §120.7− Mandatory Requirements for Insulation.

3.6.1.2. Alterations

§141.0(b)1

All alterations must meet the mandatory requirements stated above for additions, with the exception of the insulation requirement of §120.7 for opaque envelope components (roofs, ceilings, walls, and floors).

A. Wall Insulation

Insulation for walls that separate conditioned space from either unconditioned space or the exterior shall comply with the mandatory requirements of §141.0(b)1B. This section provides two options for wall insulation compliance: either a minimum insulation R-value or a maximum assembly U-factor. The mandatory requirements are determined by the wall type:

- Light mass and heavy mass walls do not have mandatory requirements for minimum R-value and maximum U-factor.

- Metal buildings - A minimum of R-13 insulation between framing members or an area-weighted average U-factor no greater than 0.113 is required.
- Metal-framed walls - A minimum of R-13 insulation between framing members or an area-weighted average U-factor no greater than 0.217 is required.
- Wood-framed walls and other wall types - A minimum of R-11 insulation between framing members, or an area-weighted average U-factor no greater than 0.110 is required.
- Spandrel panels and glass curtain walls - A minimum of R-4 insulation or an area-weighted average U-factor no greater than 0.280 is required.

B. Floor Insulation

Insulation for floors that separate conditioned space from either unconditioned space or the exterior shall comply with the mandatory requirements of §141.0(b)1C. This section provides two options for compliance with the mandatory requirements: either a minimum insulation R-value or a maximum assembly U-factor. For floors, the mandatory requirements are determined by both building type and floor type.

- Raised framed floors - A minimum of R-11 insulation between framing members or the weighted average U-factor no greater than 0.071 is required.
- Raised mass floors in high-rise residential and hotel/motel guest rooms - A minimum of R-6 insulation or an area-weighted average U-factor no greater than 0.111 is required.
- Raised mass floors in all other occupancies - No minimum U-factor is required.

3.6.2 Prescriptive Requirements

3.6.2.1 Additions

§141.0(a)1

Prescriptive compliance for the building envelope of additions is addressed in §141.0(a)1 and §140.3. §140.3(a) provides prescriptive compliance alternatives for the building envelope, including tradeoffs between roofing insulation and the solar reflectance of roofing products (cool roofs) in Table 140.3-A. Tradeoffs between other envelope components are not allowed in the prescriptive method. The performance method may be used for tradeoff for both new construction and alterations.

All additions must also comply with §140.3(c), Minimum Skylight Area, for large enclosed spaces in buildings with three or fewer stories.

For more details on the prescriptive requirements for additions, see Section 3.2 for envelope requirements and Section 3.3 for fenestration requirements.

Alternatively, the addition may meet compliance by using the performance compliance approach of §140.1, which compares the TDV energy (space conditioning, lighting, and water heating) of the proposed building addition to a TDV energy budget that complies with prescriptive requirements.

3.6.2.2 Alterations

§141.0(b)2

In general, any alteration to an existing building that involves changes to a portion of the building envelope triggers the Energy Standards. The prescriptive requirements for alterations to building envelopes are in §141.0(b)2A and B of the Energy Standards.

The altered components of the envelope shall meet the applicable mandatory requirements of §110.6 and §110.8.

A. Fenestration

When fenestration is altered that does not increase the fenestration area, it shall meet the requirements of Table 141.0-A of the Energy Standards (Table 3-20 below) based on climate zone.

When new fenestration area is added to an alteration, it shall meet the requirements of §140.3(a) and Tables 140.3-B, C or D of the Energy Standards. Compliance with §140.3(a) is not required when the fenestration is temporarily removed and then reinstalled.

In cases where small amounts of fenestration area are changed, several options exist.

- If less than 150 ft² of fenestration area is replaced throughout the entire building, then the Energy Standards require that only the U-factor requirements in Tables 140.3-B, C, or D are met. The SHGC, RSHGC, or VT requirements need not be met.
- The same requirements and exceptions apply if 50 ft² or less of fenestration (or skylight) area is added. A typical example of this may be changing a door from a solid door to a glass door.

Table 3-20: Altered Window Maximum U-Factor and Minimum RSHGC and VT

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	0.47	0.47	0.58	0.47	0.58	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
RSHGC	0.41	0.31	0.41	0.31	0.41	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.41

		Fixed Window	Operable Window	Curtain Wall/ Storefront	Glazed Doors
VT	Vertical	0.42	0.32	0.46	0.17
		Glass, Curb-Mounted	Glass, Deck-Mounted	Plastic, Curb-Mounted	
	Skylights	0.49	0.49	0.64	

Energy Standards Table 141.0-A

Example 3-17

Question:

The envelope and space conditioning system of an office building with 120,000 ft² of conditioned floor area is being altered. The building has 24,000 ft² of vertical fenestration. Which of the following scenarios does the NFRC label certificate requirement apply to?

1. Existing glazing remains in place during the alteration.

2. Existing glazing is removed, stored during the alteration period, and then reinstalled (glazing is not altered in any way).

3. Existing glazing is removed and replaced with new site-built glazing with the same dimensions and performance specifications.

4. Existing glazing on the north façade (total area 800 ft²) is removed and replaced with site-built fenestration.

Answer:

NFRC label certificate or California Energy Commission default values requirements do not apply to Scenarios 1 and 2 but do apply to Scenario 3.

1. Requirement does not apply because the glazing remains unchanged and in place.

2. *Exception* to §110.6(a)1 applies in this case. (This exception applies to fenestration products removed and reinstalled as part of a building alteration or addition.)

3. Use either NFRC label certificate or use Table 110.6-A default values; applies in this case as 24,000 ft² (more than the threshold value of 1,000 ft²) of new fenestration is being installed.

4. Since the site-built fenestration area is less than 1,000 ft², use either the NFRC label certificate, the applicable default U-factor or SHGC set forth in Reference Nonresidential Appendix NA6, or California Energy Commission default values.

B. Walls and Floors

All nonresidential building alterations involving exterior walls, demising walls, external floors, or soffits must either comply as a component with the requirements in Tables 140.3-B, C, or D in the Energy Standards, or by approved compliance software following the rules of the *ACM Reference Manual* that demonstrates that the overall TDV energy use of the altered building complies with the Energy Standards.

C. Roofs

Existing roofs being replaced, recovered, or recoated for nonresidential, high-rise residential and hotels/motels buildings shall meet the requirements of §110.8(i). When the alteration is being made to either 50 percent of the existing roof area or when more than 2,000 ft^2 of the roof is being altered, the requirements of this section apply. Thus, when a small repair is made, these requirements do not apply. For example, the requirements of regarding roof insulation would not be "triggered" if the existing roof surface were overlaid instead of replaced.

These requirements do apply to roofs over conditioned, nonprocess spaces even if the building has a portion that is a process space. These roof areas can be delineated by the fire separation walls between process areas and conditioned, nonprocess areas.

The California Building Code and local amendments place limitations on the number of new roof covering layers that are allowed to overlay an existing roof covering in accordance with CBC 1510. When this limit is reached, the existing roof covering must be removed down to the roof deck or to the insulation recover boards.

When a roof is exposed to the roof deck or to the roof recover boards, and alteration complies with the prescriptive requirements for roofing products, the exposed roof area shall be insulated to the levels specified in Table 141.0-C of the Energy Standards (Table 3-21 below).

The amount of insulation required varies by climate zone and building type. The requirements are given in terms of a continuous layer of insulation (usually installed on top

of the roof deck) or an overall roof U-factor based on the default tables and calculation method in Reference Appendix JA4. The U-factor method provides the most flexibility, as insulation can be added continuously on top of the roof deck, below the roof deck between roof joists, or a combination of insulation above and below the roof deck.

Table 3-21: Insulation Requirements for Roof Alterations

	Nonresidential		High-Rise Residential and Guest Rooms of Hotel/Motel Buildings	
Climate Zone	Continuous Insulation R-value	U-Factor	Continuous Insulation R-Value	U-Factor
1	R-8	0.082	R-14	0.055
2	R-14	0.055	R-14	0.055
3-9	R-8	0.082	R-14	0.055
10-16	R-14	0.055	R-14	0.055

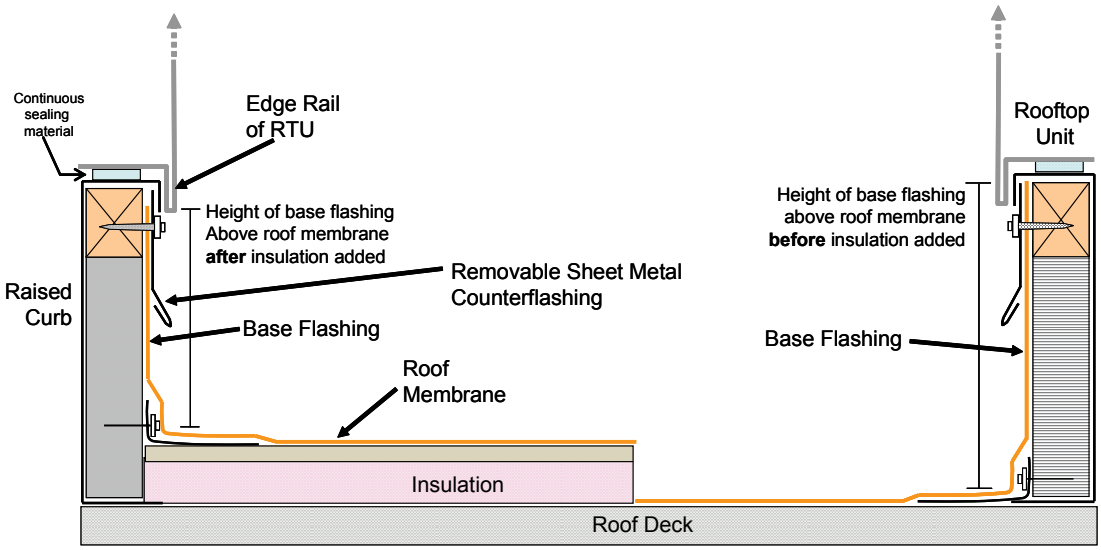
Energy Standards Table 141.0-C

For reroofing, when roofs are exposed to the roof deck and meet the roofing products requirements in §141.0(b)2Bi or ii, the exposed area must be insulated to levels specified in the Energy Standards Table 141.0-C. For nonresidential buildings, this level is R-8 continuous insulation in Climate Zones 1 and 3 through 9 and R-14 continuous insulation in Climate Zones 2 and 10 through 16. Several exceptions are provided:

1. No additional insulation is required if the roof is already insulated to a minimum level of R-7.
2. When insulation is added on top of a roof, the elevation of the roof membrane is increased. As shown in Figure 3-26, when insulation is added to a roof and the curb height (or reglet or counterflashing for walls) is unchanged, the height of the base flashing above the roof membrane will be reduced. In some cases when the overhanging edge of the space-conditioning equipment is very close to the side of the curb, this may also limit how far up the curb the base flashing may be inserted. Many manufacturers and the National Roofing Contractors Association (NRCA) recommend maintaining a minimum base flashing height of 8 inches above the roofing membrane.

Thus, when adding insulation on top of a formerly uninsulated or underinsulated roof, one must consider the effects on base flashing height. It may be desirable to increase curb heights or counterflashing heights to maintain the same or higher base flashing heights above the roof membrane. In other cases, where leak risk is low, one can ask the roofing manufacturer for a variance on installation requirements for a roofing warranty; this may require additional waterproofing measures to obtain the manufacturer's warranty. Installing insulation under the roof deck when access is feasible doesn't change the base flashing height and, in some cases, may be the least expensive way to insulate the roof.

Figure 3-26: Base Flashing on Rooftop Unit Curb Detail



In some circumstances it is costly or difficult to increase the curb or counterflashing height for maintaining the base flashing at a suitable height above the roof membrane. In the following situations, added insulation is limited to the thickness that will still maintain a base flashing height of 8 inches (20 cm) above the surface of the roof membrane.

If there is any space-conditioning equipment on the roof that is not disconnected and lifted during reroofing, the condition of this "undisturbed" equipment will determine how much, if any, insulation must be added to the entire roof. That is, if the equipment that is not disconnected and lifted is situated on a curb that is 9 inches above the roof membrane, only 1 inch of insulation must be added to the roof. If the undisturbed equipment is situated on a curb that is 8 inches (20 cm) or less above the roof membrane, no additional insulation is required.

If adding the required insulation will reduce the base flashing height to less than 8 inches at penthouse or parapet walls, the insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches from the roof membrane surface to the top of the base flashing. For the above exemption to apply, the following conditions must be met:

1. The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material.
2. The penthouse or parapet walls have exterior cladding material that must be removed to install the new roof covering membrane to maintain a base flashing height of 8 inches.
3. For nonresidential buildings, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for Climate Zones 2 and 10 through 16, and less than 100 square feet per linear foot for Climate Zones 1 and 3 through 9.
4. For high-rise residential buildings, hotels, or motels, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for all climate zones.

5. Increasing the elevation of the roof membrane by adding insulation may also affect roof drainage. The Energy Standards allow tapered insulation to be used that has a thermal resistance less than that prescribed in Table 141.0-C at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds the value that is specified in Table 141.0-C.

For more details on the prescriptive requirements for alterations, see Section 3.2 for the opaque envelope assembly requirements and Section 3.3.2.2 for the requirements for fenestration.

1. Thermal Emittance and Solar Reflectance Prescriptive Requirements

§141.0(b)2B

For nonresidential buildings, the prescriptive requirements for roofing products are based on roof slope and climate zone:

- Low-sloped roofs in Climate Zones 1 through 16 have a required minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75, or a minimum SRI of 75.
- Steep-sloped roofs in Climate Zones 1 through 16 have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

For high-rise residential buildings and hotels and motels, the prescriptive requirements for roofing products are based on roof slope and climate zone:

- Low-sloped roofs in Climate Zones 10, 11, 13, 14 and 15 have a required minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.
- Steep-sloped roofs in Climate Zones 2 through 15 have a required minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

There are three exceptions to the prescriptive requirements:

Nonresidential buildings:

1. *An aged solar reflectance less than 0.63 is allowed, provided that additional insulation is installed.*

High-rise residential buildings and hotels and motels:

1. *For roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels, roofing products are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.*
2. *For roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft² roofing products are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.*

Table 141.0-B (Table 3-22 below) has been added to the Energy Standards to simplify the process of making insulation/aged solar reflectance trade-off. The table expresses the trade-off requirements in terms of overall roof U-factors, rather than in terms of continuous insulation R-value.

Table 3-22: Roof/Ceiling Insulation Trade-Off for Aged Solar Reflectance

Aged Solar Reflectance	Climate Zone 1, 3-9 U-factor	Climate Zone 2, 10-16 U-factor
0.62 - 0.60	0.075	0.052
0.59 - 0.55	0.066	0.048
0.54 - 0.50	0.060	0.044
0.49 - 0.45	0.055	0.041
0.44 - 0.40	0.051	0.039
0.39 - 0.35	0.047	0.037
0.34 - 0.30	0.044	0.035
0.29 - 0.25	0.042	0.034

Energy Standards Table 141.0-B

U-factors measure the thermal performance of the entire roof assembly, both above and below the roof deck. Utilizing U-factors provides flexibility. Trade-offs can be made by installing additional insulation continuously above the roof deck, between the joists below the roof deck, or a combination of both approaches.

Simplified trade-off process:

- Locate in Table 141.0-B of the Energy Standards the maximum roof/ceiling U-factor that applies to the aged solar reflectance of the roofing products to be installed.
- Locate the climate zone of the building.
- Consult the U-factor tables in Reference Appendix JA4 and then determine what configurations of above and/or below-deck insulation satisfy the trade-off.
    - Reference Appendix JA4 contains U-factor tables for many common roof constructions (wood-framed, metal-framed, span deck, and concrete roofs, and others).

See the examples at the end of this section for illustrations of insulation/reflectance trade-offs.

Table 141.0-B of the Energy Standards not only takes account of the amount of insulation necessary to compensate for using a noncompliant roofing product, it also accounts for the minimum insulation requirements that apply to roof alterations generally.

Example 3-18

Question:

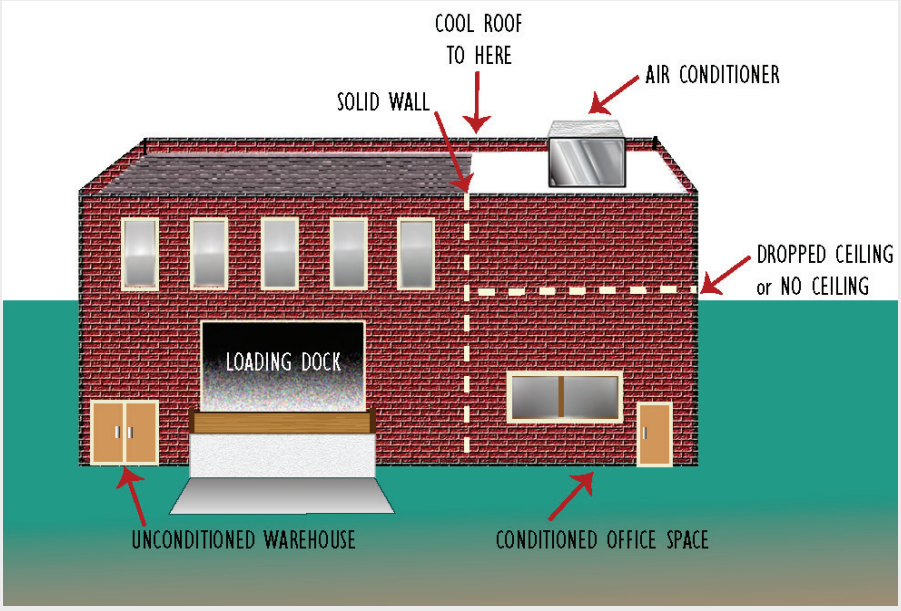
What are the Energy Standards requirements for cool roofs when reroofing an unconditioned warehouse containing conditioned office space? The warehouse has a low-sloped roof.

Answer:

Scenario 1.

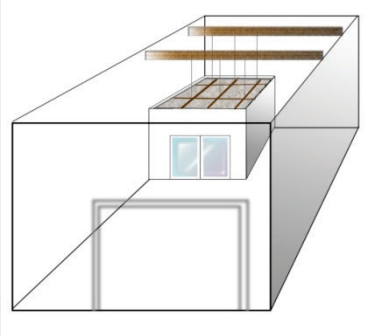
In this situation (see picture below), there is either directly or indirectly conditioned space under the roof. The cool roof requirements apply to just the portion(s) of the warehouse roof over the conditioned space(s). The rest of the roof (over unconditioned warehouse space) is not required to be a cool roof.

The walls of the conditioned space go all the way up to the underside of the warehouse.



Scenario 2.

The walls of the conditioned space do not reach all the way to the warehouse roof. (See picture below.) In this case, the roof requirements do not apply because the space directly below the roof is unconditioned and communicates with the rest of the unconditioned portion of the warehouse.



Example 3-14

Question:

I have a barrel roof on nonresidential conditioned building that needs to be reroofed. Must I follow the Energy Standards roofing product requirement?

Answer:

Yes, the roof would need to meet the aged solar reflectance and thermal emittance for a steep-sloped roof. The reason is that a barrel roof, although it has both low-sloped and steep-sloped roofing areas, has a continuous gradual slope change that would allow the steep-sloped section of the roof to be seen from ground level. This was the reason to allow barrel roofs to only meet the steep-sloped requirement for the entire roof area.

Example 3-20

Question:

40 percent of the low-sloped roof on a 500 ft by 100 ft retail building in Concord, California (CZ12,) is being reroofed. The roofing is removed down to the roof deck, and there is no insulation. The building has a stucco-clad parapet roof, and the current base flashing is 9 inches above the level of the roof. Must insulation be added before reroofing?

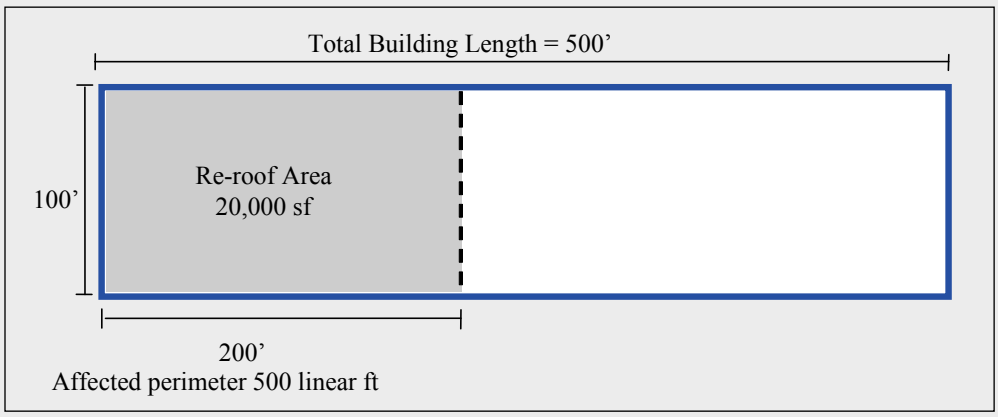


Figure 3-27: Plan View of Partial Building Re-roofing Project

Answer:

Yes, §141.0(b)2B requires when either 50 percent (or more) of the roof area or 2,000 ft² (whichever is less) is reroofed down to the roof deck or recover boards, that insulation be installed if the roof has less than R-7 insulation. Though the reroofing covers only 40 percent of the roof area, the requirements still apply because the 20,000 ft² of replacement roof area is greater than the threshold area of 2,000 ft². As stated in the question, the roof does not have any insulation and, therefore, is required to add insulation.

Concord, California, is in Climate Zone 12[6]. As per Energy Standards Table 141.0-C "Insulation Requirements for Roof Alterations," for nonresidential buildings in Climate Zone 12, the requirement for insulation is either R-14 continuous insulation or an effective roof U-factor of 0.055 Btu/h•ft²•°F. If the ratio of replaced roof area to affected clad wall length is less than 25 ft² of roof per linear ft of wall, then the insulation thickness is allowed to be limited to the maximum thickness that will maintain a base flashing height of no less than 8 inches above the roof membrane.

The ratio of the replaced roof to the affected wall area is 20,000 ft² / 500 linear ft = 40:1. Since this ratio is greater than 25:1, the full required insulation must be installed regardless of the existing base flashing height. This may require changing the height of the base flashing, removing some of the parapet wall cladding and moving the counterflashing (or reglet) higher up on the wall. Alternatively, the installer may ask for the roofing manufacturer to provide a variance in the warrantee to accept a slightly lower base flashing height above the roof surface. The specific risk of roof leakage at a given site has to be considered carefully before reducing the base flashing height. When access to the underside of the roof deck is available, an alternative method of compliance that does not affect base flashing heights is to add insulation below the roof deck to the overall U-factor levels given in Energy Standards Table 141.0-C.

Example 3-21

Question:

If the building in the question above was located in San Francisco, would the insulation requirements be different on the building?

Answer:

Yes. San Francisco (as shown in Reference Appendix JA2) is in Climate Zone 3. In Energy Standards Table 141.0-C from §141.0(b)2B, the insulation requirement for roof alterations for nonresidential buildings in Climate Zone 3 is R-8 or a U-factor of 0.081.

The criteria for limiting the insulation thickness based on the existing base flashing height are different for Climate Zone 3 than for Climate Zone 12. For nonresidential buildings in Climate Zone 3, if the ratio of replaced roof area to affected clad wall length is less than 100 ft² of roof per linear foot of wall, then the insulation thickness is limited to the thickness that will maintain a base flashing height of no less than 8 inches above the roof membrane. The ratio of the replaced roof to the affected wall area is 20,000 ft² / 500 linear ft = 40:1. Since this ratio is less than 100:1, only the amount of insulation (and recover board) that will still maintain a base flashing height of 8 inches above the roofing membrane is required. Thus, one could still add 1 inch of insulation board.

Example 3-22

Question:

A nonresidential building is having 5,000 ft² of roofing replaced. During roofing replacement the roof deck will be exposed. This building has a rooftop air conditioner that is sitting on an 8-inch-high curb above the roof membrane level. The roof is uninsulated. If the rooftop air-conditioner unit is not disconnected and not lifted off the curb during reroofing, is adding insulation required?

6 A listing of climate zones by city is found in Reference Appendix JA2.

Answer:

No, the exception to §141.0(b)2Biii, specifically exempts reroofing projects when space-conditioning equipment is not disconnected and lifted. In this case, the requirements for adding insulation are limited to the thicknesses that result in the base flashing height to be no less than 8 inches above the roofing membrane surface, Adding insulation increases the height of the membrane surface and thus for a given curb would reduce the base flashing height above the roof membrane. Since the base flashing height is already 8 inches above the roof membrane, no added insulation is required.

Example 3-23

Question:

What if the rooftop air conditioner from Example 3-22 is lifted temporarily during reroofing to remove and replace the roofing membrane? Is added insulation required?

Answer:

Yes, insulation is required.

The exception to §141.0(b)2Biii specifically applies when the space-conditioning equipment is not disconnected and lifted. Since the roof membrane level will be higher after the addition of insulation, the base flashing height will no longer be 8 inches above the roof membrane. When the rooftop unit is lifted as part of the reroofing project, the incremental cost of replacing the curb or adding a curb extension is reduced.

Thus to maintain the 8-inch base flashing height, one can replace the curb or add a curb extension before reinstalling the roof top unit. Alternatively, one can ask for a roofing manufacturer's variance to the warranty from the typical minimum required 8 Inches base flashing height above the roof membrane to the reduced amount after the roof insulation is installed. The specific risk of roof leakage at a given site has to be considered carefully before reducing the base flashing height. An alternative method of compliance that does not affect base flashing heights is to add insulation below the roof deck to the overall U-factor levels given in Table 141.0-C of §141.0(b)2B.

Example 3-24

Question:

A nonresidential building is having 5,000 ft² of roofing replaced. During roofing replacement, the roof deck will be exposed. This building has several unit skylights that are sitting on an 8–inch-high (20 cm) curb above the roof membrane level. The roof is uninsulated. Is added insulation required?

Answer:

Yes, insulation is required. The exception to §141.0(b)2Biii specifically applies when space-conditioning equipment is not lifted. Unit skylights are not space-conditioning equipment; thus, the exception does not apply. Removing a unit skylight and increasing its curb height is substantially less effort than that for space-conditioning equipment.

Example 3-25

The rooftop unit with the 9-inch base flashing is disconnected and lifted during reroofing. However, the rooftop unit on the curb with the 14-inch (36 cm) base flashing is not lifted. In this situation, is the insulation added limited to the amount of insulation that will result in an 8-inch base flashing on the unit with the lower curb?

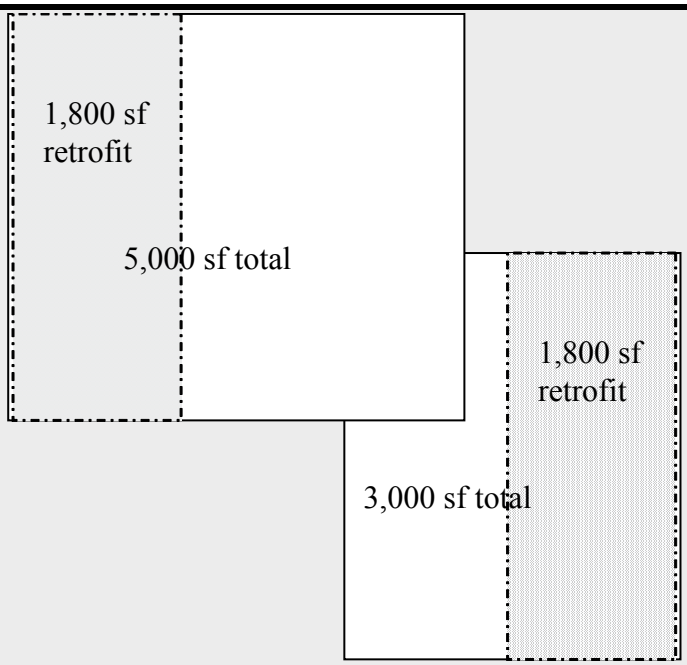


Figure 3-28: Building with Two Roof Configurations

Scenario 1:

A building has low-sloped roofs at two elevations (Figure 3-28). One roof is 18 feet above grade and has a total area of 5,000 ft²; the other roof is 15 feet above grade and has a total area of 3,000 ft². Both roofs are uninsulated and are above conditioned space. If 1,800 ft² of the 3,000 ft² roof is being reroofed and the roof deck is exposed, is that portion of the roof required to be insulated and be a "cool roof" (high reflectance and emittance)?

Answer:

Yes, the reroofed section of the roof must be insulated and have a "cool roof". Section 141.0(b)2B requires insulation and cool roofs for low-sloped roof alterations if the alteration is greater than 2,000 ft² or greater than 50 percent of the roof area. Since 1,800 ft² is 60 percent of 3,000 ft², the cool roof and insulation requirements apply.

Scenario 2:

If the 1,800 ft² of roofing being replaced was on the 5,000 ft² uninsulated roof, would the portion of the roof replaced be required to have "cool roof" radiative properties and have insulation installed?

Answer:

No. The 1,800 ft² retrofit is 36 percent of the 5,000 ft² roof. Thus, the 1,800 ft² retrofit is less than 50 percent of the roof area and it is less than 2,000 ft²; thus, it is not required to comply with the insulation and cool roof requirements in §141.0(b)2B.

Example 3-26

A 10,000 ft² building in Climate Zone 10 with an uninsulated roof above conditioned space is having roofing removed so that the roof deck is exposed. There are two rooftop units on this section of the roof that is being altered. One rooftop unit has a curb with a 9-inch base flashing, and the other has a modern curb with a 14-inch base flashing. Consider the following three scenarios:

Scenario 1:

Answer:

No. The unit with the 9 inches base flashing was disconnected and lifted and thus it does not qualify for the exception to §141.0(b)2Biii:

"Not be disconnected and lifted as part of the roof replacement." One could add as much as 6 inches or more of insulation before the base flashing height would be reduced below 8 inches on the unlifted rooftop unit with a 14-inch curb. The Climate Zone 10 roof insulation requirement is R-14. The thickness of rigid insulation that provides this amount of R-value is substantially thinner than 6 inches. Thus, the full R-14 insulation would be required.

Scenario 2:

The rooftop unit with the 9-inch base flashing is not disconnected and lifted during reroofing. In this situation, is the insulation that must be added limited to the amount of insulation that will result in an 8-inch base flashing on the unit with the lower curb?

Answer:

Yes. The unit with the 9-inch (23 cm) base flashing was not disconnected and lifted, and thus it qualifies for the exception to §141.0(b)2Biiia. One could add only 1 inch (2.5 cm) of insulation before the base flashing height would be reduced below 8 inches (20 cm) on the unlifted rooftop unit with a - inch (23 cm) base flashing. The insulation requirement is R-14, but the thickness of rigid insulation that provides this amount of R-value is greater than 1 inch (2.5 cm). Therefore, only 1 inch (2.5cm) of additional insulation is required because adding any more insulation would reduce the base flashing height below 8 inches (20 cm) on the unlifted rooftop unit with a 9-inch (23 cm) base flashing.

Scenario 3:

In Scenario 2 above, does this reduced amount of required insulation apply only to the area immediately surrounding the unlifted unit or to the entire roof?

Answer:

The added insulation for the entire roof would be limited to 1 inch (2.5 cm) so that the base flashing of the unlifted unit is not reduced to less than 8 inches (20 cm). However, if a building has multiple roofs, the limitation would apply only to any roof with a rooftop unit that was not disconnected and lifted and that has a low curb.

Example 3-15

Question:

In reroofing, is existing roofing that is a rock or gravel surface equivalent to a gravel roof over an existing cap sheet, and therefore qualify for the exception discussed in the previous question?

Answer:

No, the two roofs are not equivalent (rock or gravel roofs do not perform the same as gravel roofs over an existing cap sheet), and, therefore, the gravel roof over existing cap sheet may not qualify for the exception.

Example 3-16

Question:

If I am doing a reroof, would Exceptions 1 through 4 to §140.3(a)1Ai apply to reroofing and roof alterations?

Answer:

Yes, these exceptions apply to reroofing and alterations, and the roofs that meet one or more of these exceptions are exempt from the cool roof requirements.

Example 3-17

Question:

What happens if I have a low-sloped roof on most of the building but steep-sloped on another portion of the roof? Do I have to meet two sets of rules in §141.0(b)2Bi and ii?

Answer:

Yes, the low-sloped portion of the roof must comply with the requirements for low-sloped roofs, while the steep-sloped portion of the roof must comply with the requirements for steep-sloped roofs. These requirements are climate zone-based and vary based on the density of the outer roofing layer.

Example 3-18

Question:

A low-sloped nonresidential building in Santa Rosa needs to be reroofed. It has a wood-framed rafter roof. The rafters are 2 x 4's spaced 16 inches on center. The owner wants to install a roofing product with an aged reflectance of 0.60, which is less than the prescriptive standard of 0.63. Can I install additional insulation to make up for the shortfall in reflectance?

Answer:

Yes. There are two ways to make an insulation/reflectance trade-off when reroofing a low-sloped nonresidential building.

Scenario1:

The Simplified Performance Tradeoff Approach has been modified for the *2013 Standards*. It is a software tool that allows users to make roof insulation/reflectance trade-offs through a simplified process. The user enters a limited number of inputs, such as building type, building vintage, roof insulation, and reflectance details. The software analyzes the inputs and generates for the user a range of compliant design options. The software does all the work. There is no need for the user to consult reference appendices or make manual calculations. The software tool can be accessed on the Energy Commission's website at *http://www.energy.ca.gov/title24/2013standards*

Scenario 2:

Another way to make an insulation/reflectance trade-off is to use Table 141.0-B. First, look up in the table the maximum roof/ceiling insulation U-factor for the aged solar reflectance of the roofing product and the climate zone in which the building is located. In this case, the roofing product has an aged reflectance of 0.60, and Santa Rosa is in Climate Zone 2, so the appropriate U-factor is found in row 1, column 2 of the table. It is 0.052.

Next, consult Section 4.2 (Roofs and Ceilings) of Reference Appendix JA4 to find the U-factor table for the type of roof in question. Reference Appendix JA4 can be accessed on the Commission's website at http://www.energy.ca.gov/title24/2016standards/

The appropriate table in this case is Table 4.2.2, U-factors of Wood Framed Rafter Roofs. Locate the section of the table that pertains to 2 x 4 rafters spaced 16 inches on center. There are several U-factors in this area of the table that are equal to or less than 0.052. A combination of R-11 cavity insulation and R-8 continuous insulation, for example, has a U-factor of 0.050. Similarly, a combination of R-13 cavity insulation and R-6 continuous insulation has a U-factor of 0.052. Any U-factor that is equal to or less than 0.052 represents a combination of above- and below-deck insulation that complies with the requirements for the proposed trade-off.

Example 3-19

Question:

There several exceptions to the minimum insulation requirements for roof alterations. Can these be used to limit the insulation required to make a trade-off under Table 141.0-B?

Answer:

No. The exceptions to §141.0(b)2Biii do not apply to trade-off situations. They apply only when a compliant roofing product is being installed and no trade-off is involved.

3.6.3 Performance Requirements

A. Additions

The envelope and indoor lighting in the conditioned space of the addition, and any newly installed space-conditioning system or water-heating system serving the addition, shall meet the applicable requirements of §110.0 through §130.5; and either 1 or 2 below:

1. The addition alone shall comply with §141.0(a).
2. Existing plus addition plus alteration. The standard design building is the reference building against which the altered building is compared. The standard design building uses equivalent building envelope, lighting, and HVAC components when those components are not altered. For components that are altered or added, the standard design uses either the prescriptive requirements for new construction or the envelope baseline specified in §141.0. The proposed design energy use is the combination of the unaltered components of the existing building to remain and the altered component's energy features, plus the proposed energy features of the addition.

   EXCEPTION to Additions - Performance Approach: Additions that increase the area of the roof by 2,000 square feet or less are exempt from the requirements of §110.10.

B. Alterations

The envelope and indoor lighting in the conditioned space of the alteration shall meet the applicable requirements of §110.0 through §130.5 and either A or B below:

1. The altered envelope, space–conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of §110.0 through §110.9, §120.0 through §120.6, and §120.8 through §130.5.

   EXCEPTION to §141.0(b)3A: Window Films. Applied window films installed as part of an alteration complies with the U-factor, RSHGC and VT requirements of Table 141.0-D (Table 3-23 below).

2. The standard design for an altered component shall be the higher efficiency of existing conditions or the requirements stated in Table 141.0-D. For components not being altered, the standard design shall be based on the existing conditions. The proposed design shall be based on the actual values of the altered components.

Notes to Alterations – Performance Approach:

1. *If an existing component must be replaced with a new component, that component is considered an altered component for determining the energy budget and must meet the requirements of §141.0(b)3.*
2. *The standard design shall assume the same geometry and orientation as the proposed design.*

Table 3-23: The Standard Design for an Altered Component

Altered Component	Standard Design Without Third-Party Verification of Existing Conditions Shall be Based On	Standard Design With Third-Party Verification of Existing Conditions Shall be Based On
Roof/Ceiling Insulation, Wall Insulation, and Floor/Soffit Insulation	The requirements of §141.0(b)2.	
Fenestration. The allowed glass area shall be the smaller of the a. or b. below: a. The proposed glass area: or b. The larger of: 1.The existing glass area that remains; or 2.The area allowed in §140.3(a)5A.	The U-factor and RSHGC requirements of TABLE 141.0-A.	The existing U-factor and RSHGC levels
Window Film	The U-factor, RSHGC and VT shall be based on TABLE 140.1-A. The existing fenestration in the alteration shall be based on TABLE 110.6-A and Table 110.6-B. Third Party verification not required.	
Roofing Products	The requirements of §141.0(b)2B.	
All Other Measures	The proposed efficiency levels.	

Energy Standards Table 141.0-D

3.6.4 Historical Buildings

§100.0(a), Exception 1, states that qualified historic buildings, as defined in the California Historical Building Code (Title 24, Part 8 or California Building Code, Title 24, Part 2, Volume I, Chapter 34, Division II) are not covered by the Energy Standards. However, nonhistorical components of the buildings, such as new or replaced space-conditioning, plumbing, and electrical (including lighting) equipment, additions and alterations to historic buildings, and new appliances in historic buildings must comply with the Energy Standards and *Appliance Efficiency Regulations*, as well as other codes. Additions and alterations to historical buildings must also meet applicable requirements of the Energy Standards. For more information about energy compliance requirements for historical buildings, see Section 1.7.1, Building Types Covered.