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3 Building Envelope

3.1 Chapter Overview

This chapter covers the requirements for efficiency measures used for the building envelope of nonresidential, high-rise residential, hotel and motel occupancy buildings. Building energy use is affected by heating and cooling loads.

- **Heating loads** are affected by infiltration and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors.
- **Cooling loads** are dominated by solar gains through windows and skylights, internal gains due to lighting, plug loads, and occupant use, and from additional ventilation loads needed for indoor air quality.

3.1.1 What's New for 2019

The *2019 Building Energy Efficiency Standards* (Energy Standards) include two important changes to the building envelope component requirements as described below:

- The site-built fenestration requirement is reduced from 1,000 square feet to 200 square feet (NA6).
- Daylighting design power adjustment factors (PAFs) are available for the following daylighting devices: clerestory fenestration, interior and exterior horizontal slats, and interior and exterior light shelves.

3.2 Opaque Envelope Assembly

This section addresses the requirements for thermal control of the opaque portion of the building shell or envelope. Fenestration, windows, skylights and glazed doors are addressed in Section 3.3.

3.2.1 Opaque Envelope Definitions

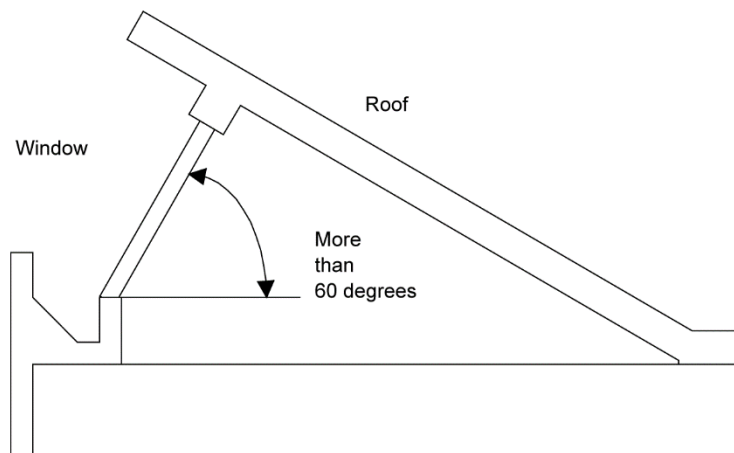
Opaque elements of the building envelope contribute significantly to the energy efficiency of the building and its design intent. Components of the building shell include the walls, floor, the roof or ceiling, doors, and fenestration. Definitions for fenestration are addressed in Section 3.3.

Envelope and other building components definitions are listed in §100.1(b) of the Energy Standards and the Reference Joint Appendices JA1.

- Conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1[b] for full definition.) Indirectly conditioned space is influenced more by directly adjacent conditioned space than it is by ambient (outdoor) conditions.
- Unconditioned space** is an enclosed space within a building that is not directly conditioned or indirectly conditioned.

- C. **Air Leakage.** Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It is a major component of heating and cooling loads. Infiltration can occur through holes and cracks in the building envelope and around doors and fenestration framing areas
- D. **Ventilation** is the *intentional* replacement of conditioned air with unconditioned air through open windows and skylights or mechanical systems.
- 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 degrees from horizontal, it is considered a roof; a slope of 60 degrees or more is a wall. This definition extends to fenestration products, including windows in walls and any skylights in roofs.

Figure 3-1: Slope of a Wall or Window (Roof or Skylight Slope Is Less Than 60°)



- F. **Exterior partition or wall** is an envelope component (roof, wall, floor, window, etc.) that separates conditioned space from ambient (outdoor) conditions. An exterior wall is considered separate from a demising wall or demising partition and has more stringent thermal requirements
- G. **Demising partition or wall** is an envelope component that separates conditioned space from an enclosed unconditioned space.
- H. **Exterior floor** is a horizontal exterior element under conditioned space and above ambient (outdoor) conditions.
- I. **Soffit** is a horizontal demising element, under conditioned space and above an unconditioned space.
- J. **Attic** is a space below an uninsulated roof that has insulation on the attic floor and is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below.
- K. **Plenum** is an air compartment or chamber, including uninhabited crawl space, areas above a ceiling or below a floor, including air spaces below raised floors of computer/data processing centers, or attic spaces, to which one or more

- ducts are connected and which forms part of either the supply-air, return-air or exhaust air system, other than the occupied space being conditioned.
- L. **Exterior roof** has a slope less than 60 degrees from horizontal and has conditioned or indirectly conditioned space below with ambient (outdoor) conditions space above.
 - M. **Ceiling** is a demising element that has a slope less than 60 degrees from horizontal and has conditioned space below with unconditioned space above.
 - N. **Roof deck** is the surface of an exterior roof that is directly above the roof rafter and below exterior roofing materials.
 - O. **Roofing Products (Cool Roofs)**. Roofing products with a high solar reflectance and thermal emittance are referred to as “*cool roofs*.” These roofing types absorb less solar heat and give off more heat to the surroundings than traditional roofing materials. These roofs are cooler and thus help reduce air conditioning loads by reflecting and emitting energy from the sun.
 - P. **Solar reflectance** — the fraction of solar energy that is reflected by the roof surface
 - Q. **Thermal emittance** — the fraction of thermal energy that is emitted from the roof surface
 - R. **Low-sloped roof** is a surface with a pitch less than 2:12 (less than 9.5 degrees from the horizon)
 - S. **Steep-sloped roof** is a surface with a pitch greater than or equal to 2:12 (9.5 degrees from the horizontal or more)
 - T. **Air barrier** is combination of interconnected materials and assemblies joined and sealed together to provide a continuous barrier to air leakage through the building envelope that separates conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses
 - U. **Vapor retarder or barrier** is a special covering over framing and insulation or covering the ground of a crawl space that protects the assembly components from possible damage due to moisture condensation.

3.2.2 Thermal Properties of Opaque Envelope Components

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 Joint Appendices JA4, “U-factor, C-factor, and Thermal Mass Data,” provide detailed thermal data for many wall, roof/ceiling, and floor assemblies. However, JA4 cannot cover every possible combination of materials and thickness that might be used in a building. For this reason, the Energy Commission has incorporated into the public domain software CBECC-COM, a program for calculating material properties of typical envelope assemblies which are not found in JA4.

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**.”

$$R\text{-value} = \text{hr} \times \text{ft}^2 \times ^\circ\text{F}/\text{Btu}$$

$$R = \text{inches of thickness}/k$$

- 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.

$$U\text{-factor} = \text{Btu}/(\text{hr} \times \text{ft}^2 \times ^\circ\text{F})$$

- 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.

$$k = \text{Btu} \times \text{in}/(\text{hr} \times \text{ft}^2 \times ^\circ\text{F})$$

- 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.

$$C = \text{Btu}/(\text{hr} \times \text{ft}^2 \times ^\circ\text{F}) \text{ or } C = k/\text{inches of thickness}$$

- G. **HC** (heat capacity – thermal mass): The ability to store heat in units of Btu/ft² 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.

3.2.3 General Envelope Requirements

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

3.2.3.1 Mandatory Requirements

A. Certification of Insulation Materials

§110.8(a)

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: bear.enf@dca.ca.gov.

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 Index and Smoke Development Index of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* requires 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 index of 25 and a smoke development index 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 index and smoke density index 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, weather stripped, or otherwise sealed to limit air leakage. This sealing applies to penetrations for pipes and conduits, ducts, vents, and other openings. 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 potential sources of unnecessary energy loss due to infiltration.

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.

See the sections on roof, walls, doors and floors

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, the building should have a design computer room process load of 750 kW or greater.

3.2.3.2 Prescriptive Requirements**A. Air Barrier****§140.3(a)9, TABLE 140.3-B**

Energy Standards Table 140.3-B specifies requirements for air barriers in nonresidential buildings. Air barrier requirements apply to nonresidential buildings, but not relocatable public school buildings, and 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).
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/ft².

The air leakage requirements stipulated in §140.3 must be met, either by demonstrating that component air leakage of 0.04 cfm/ft² or the whole-building air leakage of 0.4 cfm/ft² is not exceeded.

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

MATERIALS AND THICKNESS
Plywood – min. 3/8 inches thickness
Oriented strand board – min. 3/8 inches thickness
Extruded polystyrene insulation board – min. ½ inches thickness
Foil-back polyisocyanurate insulation board – min. ½ inches thickness
Closed-cell spray foam with a minimum density of 2.0 pcf and a min. 2.0 inches thickness
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
Exterior or interior gypsum board min. ½ inches thickness
Cement board – min. ½ inches thickness
Built-up roofing membrane
Modified bituminous roof membrane
Fully adhered single-ply roof membrane
A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inches thickness
Cast-in-place concrete, or precast concrete
Fully grouted concrete block masonry
Sheet steel or sheet aluminum

3.2.4 Roofing Products and Insulation

3.2.4.1 Mandatory Measures

A. Roof/Ceiling Insulation

§120.7(a)

Metal Building: Weighted average U-factor of U-0.098 (R-19 screw down roof, no thermal blocks).

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 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 Joint Appendix JA4 for determining assembly U-factor. See the footnotes in JA4 for Tables 4.2.1 through 4.2.7.

D. Roofing Products: Solar Reflectance (SR) and Thermal Emittance (TE)**§10-113, §110.8(i)**

In general, light-colored, high-reflectance surfaces reflect solar energy (visible light, invisible infrared and ultraviolet radiation) and stay cooler than darker surfaces that absorb the sun's energy and become heated. The Energy Standards prescribe cool roof radiative properties for low-sloped and steep-sloped roofs. Low-

sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is higher in the sky.

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. When installing cool roofs, the solar reflectance and thermal emittance of the roofing product must be tested and certified according to CRRC procedures. The solar reflectance and thermal emittance properties are rated and listed by the Cool Roof Rating Council at www.coolroofs.org. When a CRRC rating is not obtained for the roofing products, the Energy Standards default values for solar reflectance and thermal 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

		<u>Initial</u>	<u>Weathered</u>
	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.			

Source: Cool Roof Rating Council

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

§110.8(i)1-3

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

Solar Reflectance (SR). There are three measurements of solar reflectance:

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

All requirements of the Energy Standards are based on the three-year aged solar reflectance. 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, or a new method of testing is used to find the accelerated solar reflectance, the equation below can be used to calculate the aged rated solar reflectance.

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

Where,

p_{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

Thermal Emittance. 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.

Default Values. 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.

Solar Reflective Index (SRI). The temperature of a surface depends on the solar radiation incidence, 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 that calculates the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The [calculator](http://www.energy.ca.gov/title24/2019standards) can be found at <http://www.energy.ca.gov/title24/2019standards>. To calculate the SRI, the three-year aged solar reflectance value of the roofing product must be used. By using the SRI calculator, a cool roof may comply with a lower emittance, as long as the aged solar reflectance is higher and vice versa.

3. Field-Applied Liquid Coatings

§110.8(i)4, Table 110.8-C

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 depending on the type of coating. 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.

4. 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 D2824.¹ 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 D3805,² Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

a. Cement-Based Roof Coatings

This class of coatings consists of a layer of cement and has been used for several 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

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.

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.

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 D822,³ ASTM C1583, and ASTM D5870.

b. 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.

3.2.4.2 Prescriptive Measures

A. Thermal Emittance and Solar Reflectance

§140.3(a)1A, TABLES 140.3-B,C,D

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 3-2 below. Table 3-3 is for high-rise residential buildings and hotel/motel guest rooms, and Table 3-4 is for relocatable public school buildings where the manufacturer certifies use in all climate zones.

Table 3-2: 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	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63
		Emittance	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
		SRI	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	Steep-Sloped	Aged Reflectance	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
		Emittance	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
		SRI	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Energy Standards Table 140.3-B

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.

Table 3-3: Prescriptive Criteria for Roofing Products for High-Rise Residential Buildings and Guest Rooms of Hotel/Motel Buildings

Climate Zone (CZ)	Low-sloped Aged Reflectance	Low-sloped Emittance	Low-sloped SRI	Steep-Sloped Aged Reflectance	Steep-Sloped Emittance	Steep-Sloped SRI
CZ 1	NR	NR	NR	NR	NR	16
CZ 2	NR	NR	NR	0.2	0.75	16
CZ 3	NR	NR	NR	0.2	0.75	16
CZ 4	NR	NR	NR	0.2	0.75	16
CZ 5	NR	NR	NR	0.2	0.75	16
CZ 6	NR	NR	NR	0.2	0.75	16
CZ 7	NR	NR	NR	0.2	0.75	16
CZ 8	NR	NR	NR	0.2	0.75	16
CZ 9	0.55	0.75	64	0.2	0.75	16
CZ 10	0.55	0.75	64	0.2	0.75	16
CZ 11	0.55	0.75	64	0.2	0.75	16
CZ 12	NR	NR	NR	0.2	0.75	16
CZ 13	0.55	0.75	64	0.2	0.75	16
CZ 14	0.55	0.75	64	0.2	0.75	16
CZ 15	0.55	0.75	64	0.2	0.75	16
CZ 16	NR	NR	NR	NR	NR	16

*Energy Standards Table 140.3-C***Table 3-4: 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	

Energy Standards Table 140.3-D

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 3-5 for nonresidential buildings based on roof type, climate zone and aged reflectance of at least 0.25.

Table 3-5: 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

B. Insulation Requirements – Exterior Roofs and Ceilings

§140.3(a)1B, TABLES 140.3-B,C,D

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 3-6.) The U-factor values for exterior roofs and ceilings from Reference Joint 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, can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

The prescriptive requirement for metal building roofs requires the entire cavity be filled with insulation. A common technique for standing seam metal roofs is to

draped a layer of insulation over the purlins, using thermal blocks where the insulation is compressed at the supports. (See Figure 3-3A.) Either approach on insulation may be used in the Performance approach. However, there are significant benefits to using the “filled cavity” approach as shown in Figure 3-3B.

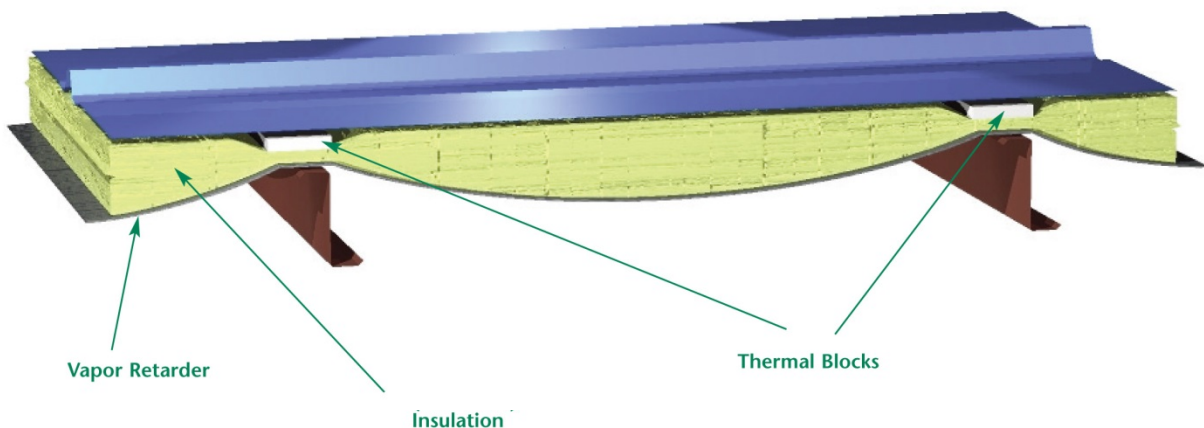
Table 3-6: Roof/Ceiling U-Factor Requirements

Building Type		Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Metal Building	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 Building	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 Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Building	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 Building	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 Building	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 Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Building	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 3-3A: Standing Seam Metal Building Roof with Single Insulation Layer

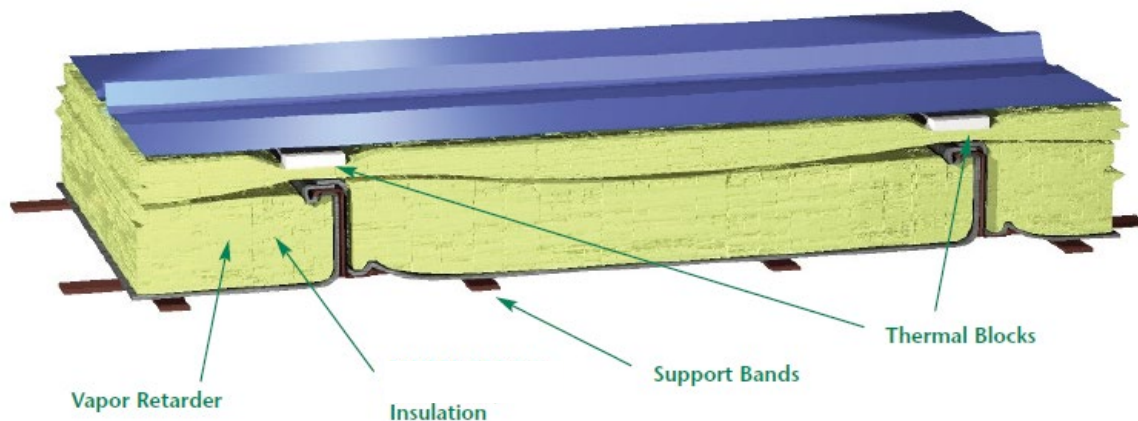
Note: Diagrams not to scale.



Source: North American Insulation Manufacturers Association (NAIMA)

Figure 3-3B: Filled Cavity Insulation for Metal Building Roofs

Note: Diagrams not to scale.



Source: North American Insulation Manufacturers Association (NAIMA)

A rigid polyisocyanurate (“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.

3.2.4.3 Performance Approach

§10-113, §140.1, TABLE 140.3

Compliance options for roofing products and insulation. See Section 3.5 and Chapter 11 for more on the performance approach.

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 Standards stipulate 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 per Table 140.3.

Table 3-7: Default SR and TE 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 mandatory for nonresidential buildings or high-rise residential buildings?

Answer:

No. Cool roofs are not mandatory. The prescriptive compliance requirements depend on the climate zone, building type and roof slope. Compliance with solar reflectance and thermal emittance, or SRI is required per 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. A roof repair, such as for a leak, or replacement of 50 percent or 2,000ft², whichever is more, does not require the roofing product to be cool roof or certified by the CRRC.

Yes, when altering your roof, such as a new reroof or replacement of 50 percent or 2,000ft², whichever is less, then, either the prescriptive envelope component approach or the performance approach can be used for compliance. In these cases, 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 solar reflectance for asphalt shingles is 0.08.

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) (<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. 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.

3.2.5 Exterior Walls

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Reference Joint 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.

There are five common classes of wall constructions: wood-framed, metal-framed, metal building walls, light mass, and heavy mass. (Figure 3-5.) The following provides information about these wall systems, as well as furred walls and spandrel walls:

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 Joint 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 Joint Appendix JA4, Table 4.3.3, has data for metal-framed walls.
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 Joint 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 a HC equal to or greater than 15.0 Btu/°F-ft². See Reference Joint 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 8.4 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 Joint Appendix JA4 Table 4.3.5, 4.3.6, or other masonry tables list alternative walls. Additional continuous insulation layers are selected from JA4 Table 4.3.13 and calculated using either Equation 4-1 or 4-4 from 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 opaque 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 Joint Appendix JA4, Table 4.3.8 for U-factor data.

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 Joint Appendix JA4.

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

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.

Example 3-10

Question :

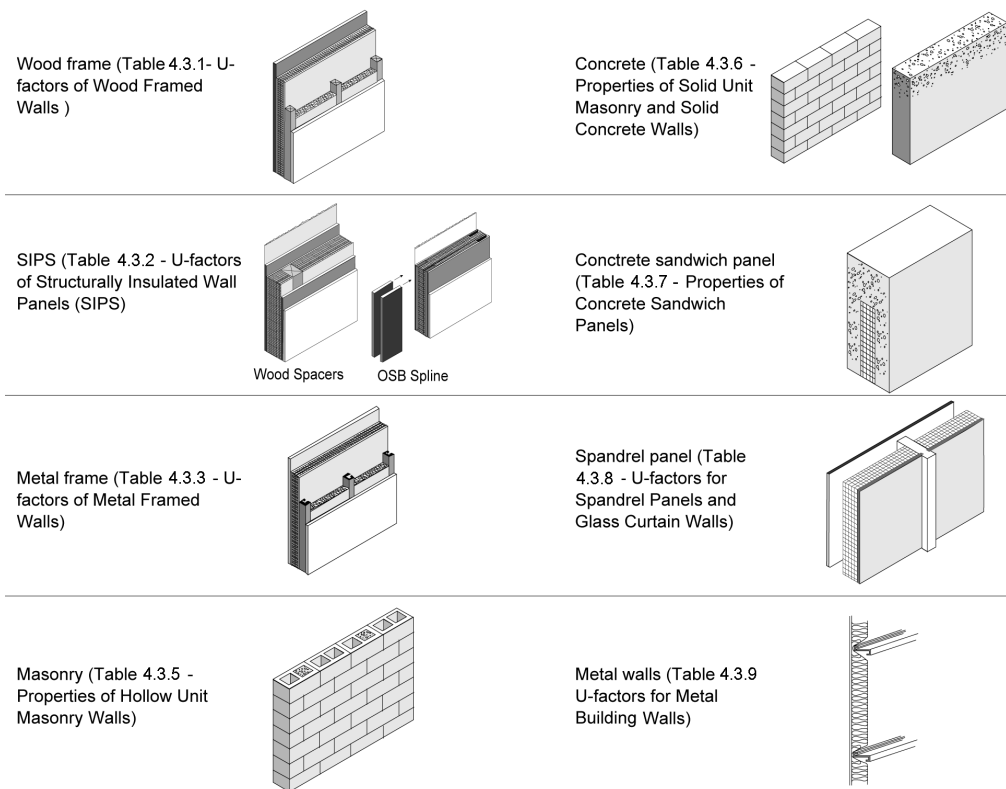
An 8-inch (20 cm) medium-weight concrete block wall with uninsulated cores has a layer of 1 inch (25 mm) thick exterior polystyrene continuous insulation with an R-value of R-5. What is the U-factor for this assembly?

Answer:

From Reference Joint 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



Source: Reference Appendices JA4.3

3.2.5.1 Mandatory Requirements

A. Wall Insulation

§110.8, §120.7(b)

In addition to the mandatory requirements in §110.8 for all buildings, Nonresidential, high-rise residential, hotels and motels must also meet the requirements in §120.7

The opaque portions of walls that separate conditioned spaces from unconditioned spaces or ambient air shall meet these applicable requirements.

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. Spandrel Panels and Opaque Curtain Wall: Weighted average U-factor of U-0.280.

Exception to Section 120.7: 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.

3.2.5.2 Prescriptive Requirements

§140.3(a)2, TABLES 140.3-B,C,D

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 Tables 140.3-B,C,D (see Table 3-8).

The U-factor for exterior walls from Reference Joint Appendix JA4 must be used to determine compliance with the assembly U-factor requirements. The Energy Standards does not allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of Reference Joint 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		Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Metal Building	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 building	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		Climate Zones							
		9	10	11	12	13	14	15	16
Nonresidential	Metal Building	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 Building	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

3.2.6 Demising Walls

3.2.6.1 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.

EXCEPTION to Section 140.3(a)5A: Window area in demising walls is not counted as part of the window area for this requirement. Demising wall area is not counted as part of the gross exterior wall area or display perimeter for this requirement.

3.2.7 Exterior Doors

When an exterior door has 25 percent or more glazed area it is considered fenestration. See more on fenestration in Section 3.3.

3.2.7.1 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).

3.2.7.2 Prescriptive Requirements

§140.3(a)7, TABLES 140.3-B,C,D

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 non-swinging 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 is 25 percent or more 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. If the glazing area is less than 25 percent of the door area, the glazing must be modeled as the glass area plus two 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 to wall ratio.

Table 3-9: Exterior Door U-factor Requirements

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

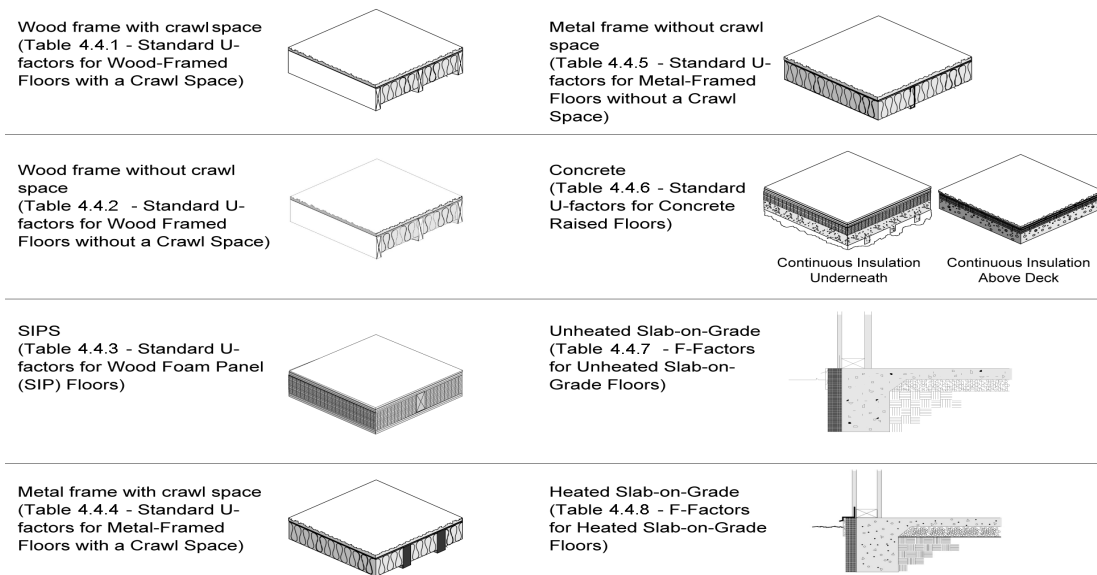
3.2.8 Floors

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 Joint 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 climate zones 1, 2, 14 and 16.

Table 4.4.6 from Reference Joint Appendix JA4 is used with mass floors while Tables 4.4.1 through 4.4.5 are used for non-mass floors. (See Figure 3-6.)

Figure 3-6: Classes of Floor Constructions

Source: Reference Appendix JA4.4

3.2.8.1 Mandatory Requirements

A. Insulation Requirements for Heated Slab Floors

§110.8(g), TABLE 110.8-A

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 feet 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.

Note: The California Mechanical Code should be consulted when constructing a heated slab.

Figure 3-7: Perimeter Slab Insulation

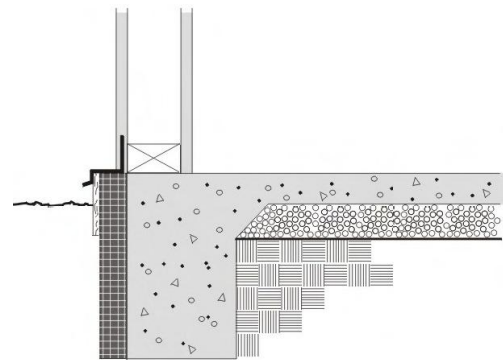


Table 3-10: Slab Insulation Requirements for Heated Slab Floors

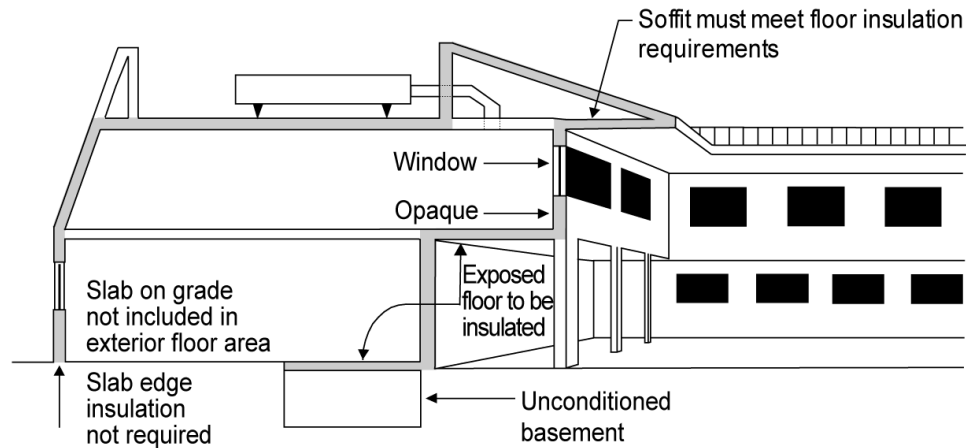
Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Value
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop 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 plan view.	1 – 15	5
			16	10 vertical and 7 horizontal

Energy Standards Table 110.8-A

B. Floor and Soffit Insulation

§110.8(g), §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).

Figure 3-8: Requirements for Floor/Soffit Surfaces

3.2.8.2 Prescriptive Requirements

A. Exterior Floors and Soffits

§140.3(a)4, TABLES 140.3-B,C,D

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 Tables 140.3-B,C,D (Table 3-11). The U-factor for exterior floors and soffits from Reference Joint Appendix JA4 shall be used to determine compliance with the maximum assembly U-factor requirements. The Energy Standards do not allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of 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 and 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

3.3 Fenestration (Window/Skylight/Glazed Door)

Choosing energy efficient 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.

The Energy Standards 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 Fenestration Definitions

Windows. A window is a vertical fenestration product that is an assembled unit consisting of a frame and sash component holding one or more pieces of glazing. Window performance is measured with the U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT).

Windows are considered part of an exterior wall when the slope is 60° or more. When the slope of fenestration is less than 60°, the glazing is considered a skylight and part of the roof.

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

Glazed Doors. Glazed door is an exterior door having a glazed area of 25 percent or more of the area of the door. When the door has less than 25 percent glazing material, it is no longer considered a glazed door. (See exterior doors in previous section). All glazed areas, will be counted toward the overall glazed area of the conditioned space in any calculations.

There are two options for measuring the glazed area of a door: Count the entire door area for glazed doors or count the area of the glazing in the door plus a 2" frame around the glass (i.e., if you have 1' by 1' glazing in a door you would measure the area as 1'4" by 1'4").

Fenestration Categories

- A. **Manufactured fenestration** is a fenestration product constructed of materials that are factory-cut or otherwise factory-formed with the specific intention of being used to fabricate a fenestration product. Knocked down or partially assembled products may be sold as a fenestration product when provided with temporary and permanent labels, as described in §10-111, or as a site-built fenestration product when not provided with temporary and permanent labels, as described in §10-111.
- B. **Site-built fenestration** is designed to be field-glazed or field-assembled units, using specific factory-cut or other factory-formed framing, and glazing units that are manufactured with the intention of being assembled at the construction site. These include storefront systems, curtain walls or large-track sliding glass walls, and atrium roof systems.
- C. **Field-fabricated fenestration** is when the windows are fabricated at the building site from elements that are not sold together as a fenestration product (that is, separate glazing, framing, and weather stripping elements). Field-fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked-down products, sunspace kits, and curtain walls).

Additional Fenestration Definitions

Reference Joint Appendix JA1 lists additional terms that relate to fenestration.

- A. **Center of Glass.** U-factor, SHGC, and VT are measured only through glass at least 2.5 inches from the edge of the glass or dividers.
- B. **Clear glass** has little, if any, observable tint.

- C. **Chromogenic** is a class of switchable glazing which includes active materials (e.g. electrochromic) and passive materials (e.g. photochromic and thermochromic) permanently integrated into the glazing assembly
- D. **Divider (Muntin)**. An element that actually or visually divides different lites of glass. It may be a true divided lite, between the panes, and/or applied to the exterior or interior of the glazing.
- E. **Double Pane Window**. Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by space (generally 1/4" [6 mm] to 3/4" [18 mm]) filled with air or other gas. Two panes of glazing laminated together do not constitute double-pane glazing
- F. **Dynamic Glazing**. Glazing systems that have the ability to reversibly change their performance properties, including U-factor, solar heat gain coefficient (SHGC), and/or visible transmittance (VT) between well-defined end points. Includes active materials (electrochromic) and passive materials (photochromic and thermochromic) permanently integrated into the glazing assembly. Electrochromatic glass darkens by demand or lightens up when more free daylight or solar heat is desired. Improved glazing decreases the SHGC in the summer and reduces heat loss in the winter and has the ability to reversibly change their performance properties, including U-factor, SHGC, and/or VT between well-defined end points.
- G. **Integrated shading systems**. A class of fenestration products including an active layer: for example, shades, louvers, blinds, or other materials permanently integrated between two or more glazing layers and that has the ability to reversibly change performance properties, including U-factor, SHGC, and/or VT between well-defined end points.
- H. **Fixed glass**. The fenestration product cannot be opened.
- I. **Gap Width**. The distance between glazing in multi-glazed systems (e.g., double-or triple-glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit thickness which is measured from outside surface to outside surface.
- J. **Insulating glass unit (IG Unit)**. An IG unit includes the glazing, spacer(s), films (if any), gas infills, and edge caulking.
- K. **Hard Coat**. A pyrolytic low-e coating that is generally more durable but less effective than a soft coat. See separate glossary term for low-e coating.
- L. **Light or Lite**. A layer of glazing material, especially in a multi-layered IG unit. Referred to as panes in §110.6 when the lites are separated by a spacer from inside to outside of the fenestration.
- M. **Low-e Coatings**. Low-emissivity coatings are special coatings applied to the second, third or fourth surfaces in double-glazed windows or skylights. As the name implies the surface has a low emittance. This means that radiation from that surface to the surface it "looks at" is reduced. Since radiation transfer from the hot side of the window to the cool side of the window is a major component

of heat transfer in glazing, low-e coatings are very effective in reducing the U-factor. They do nothing, however, to reduce losses through the frame.

Low-e coatings can be engineered to have different levels of solar heat gain. Generally, there are two kinds of low-e coatings:

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

Another advantage of low-e coatings, especially low solar gain low-e coatings, is that when they filter the sun's energy, they generally remove between 80 percent and 85 percent of the ultraviolet light that would otherwise pass through the window and damage fabrics and other interior furnishings.

- N. **Mullion.** A frame member that is used to join two individual windows into one fenestration unit.
- O. **Nonmetal Frame.** Includes vinyl, wood, or fiberglass. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics. Non-metal frames may have metal strengthening bars entirely inside the frame extrusions or metal-cladding only on the surface.
- P. **Operable.** The fenestration product can be opened for ventilation.
- Q. **Soft Coat.** A low-e coating applied through a sputter process. See separate glossary term for low-e coating.
- R. **Solar Heat Gain Coefficient (SHGC).** A measure of the relative amount of heat gain from sunlight that passes through a fenestration product. SHGC is a number between zero and one that represents the ratio of solar heat that passes through the fenestration product to the total solar heat that is incident on the outside of the window. A low SHGC number (closer to 0) means that the fenestration product keeps out most solar heat. A higher SHGC number (closer to 1) means that the fenestration product lets in most of the solar heat. SHGC or SHGCt is the SHGC for the total fenestration product and is the value used for compliance with the Standards.
- S. **Spacer or Gap Space.** A material that separates multiple panes of glass in an insulating glass unit.
- T. **Thermal Break Frame.** Includes metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl or urethane, with a significantly lower conductivity.

- U. **Tinted.** Darker gray, brown or green visible tint. Also, low-e or IG unit with a VT less than 0.5.
- V. **U-factor.** A measure of how much heat can pass through a construction assembly or a fenestration product. The lower the U-factor, the more energy efficient the product is. The units for U-factor are Btu of heat loss each hour per square foot (ft²) of window area per degree °F of temperature difference (Btu/hr-ft²-°F). U-factor is the inverse of R-value. The U-factor considers the entire product, including losses through the center of glass, at the edge of glass where a metal spacer typically separates the double-glazing panes, losses through the frame, and through the mullions. For metal-framed fenestration products, the frame losses can be significant.
- W. **Visible Transmittance (VT)** is the ratio of visible light transmitted through the fenestration. The higher the VT rating, the more light is allowed through a window.
- X. **Window Films** are composed of a polyester substrate to which a special scratch resistant coating is applied on one side, with a mounting adhesive layer and protective release liner applied to the other side.

Example 3-11**Question:**

What constitutes a double-pane window?

Answer:

Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by 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 Mandatory Requirements

§10-111, §10-112, §110.6(a)

The mandatory measures for windows, glazed doors, and skylights address product certification and labeling, the air-tightness of the units (air leakage), how to determine the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT).

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

3.3.2.1 Certification and Labeling

§10-111 §10.112 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 (Figure 3-9), which is not to be removed before inspection by the enforcement agency. The manufacturer rates and labels its fenestrations 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). If the manufactured fenestration product is rated using the NFRC rating procedure, it must also be permanently labeled in accordance with NFRC procedures.

Figure 3-9: NFRC Manufactured Label

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

B. Default Temporary Label

Fenestration product manufacturers can choose to use default performance values for U-factors in Table 110.6-A and SHGC in Table 110.6-B. (Table 3-14 and Table 3-15) For fenestration products requiring a VT value, assume a value of 1.0 as specified in the Reference Nonresidential Appendix NA6. 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.

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 for the enforcement agency field inspector to read easily. 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 following words at the bottom of the label.

"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 3-10:
Sample Default Temporary Label**

2019 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 2019 Energy Standards for Residential and Nonresidential Buildings.		

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.

C. Component Modeling Approach (CMA)

NFRC has developed a performance base calculation, the *component modeling approach* (CMA), to make the rating process quick and simple. This serves as an energy ratings certification program for fenestration products used in nonresidential projects. The CMA allows users to assemble fenestration products in a virtual environment. CMA 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. This tool helps users to:

1. 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, they create a bid report containing the data for all fenestration products to be reviewed. 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) and a license agreement is signed with NFRC. Then the NFRC issues a CMA label certificate for the project. This label certificate 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 variation of glazing and framing. This is significantly less expensive than building sample wall sections and testing them in a large test enclosure. 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 study¹ 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 Standard'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 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.

Figure 3-11: 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):** _____

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 percent in energy compliance margins. This means that compared to other available options, CMA provides the most accurate values on window energy and visible performance."

Figure 3-11A: 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:

CPD ID	Total Area ft ²	Name	Framing Ref	Glazing Ref	Spacer Ref	CERTIFIED Performance Rating at NFRC Model Size		
						U**	SHGC**	VT**
						Btu/ hr·ft ² ·°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

D. 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.

E. Site-Built Label Certificates

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.

1. For site-built fenestration totaling 200 ft² 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 200 ft² 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.

Site-built certificates should be filed at the contractor's project office during construction or in the building manager's office. Site-built fenestration has multiple responsible parties. 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 and to coordinate the certification and labeling process. The design team may 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 the NFRC.

It is not necessary to complete the NFRC testing and labeling prior to completing the building permit application. Designers should specify the type of glass and whether the frame has a thermal break or is thermally improved. Plans examiners should verify that the fenestration performance shown in the plans and used in the compliance calculations is reasonable and achievable, by consulting the default values for U-factor and SHGC in Reference Nonresidential Appendix NA6.

F. Field-Fabricated Fenestration and Field-Fabricated 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.

No attached labeling is required for field-fabricated fenestration products; only the NRCC-ENV-05-E with the default values is required. Field-fabricated fenestration and field-fabricated exterior doors may be installed only if the documentation has demonstrated compliance with the Energy Standards.

For field-fabricated fenestration, the U-factor and SHGC default values can be found in Table 3-12 and Table 3-13, respectively, below. Values are determined by frame type, fenestration type, and glazing composition.

Exterior doors with glazing for 25 percent or more 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 25 percent 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.

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.

Table 3-12: 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 3-13: 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.
<i>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</i>					

*Table 110.6-B of the Energy Standards***3.3.2.2 Determining Fenestration Performance**

§110.6, TABLES 110.6-A,B

A. U-Factor

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 must be used when a NFRC label for the U-factor is not available (Table 3-14). The U-factors in Table 110.6-A represent the least efficient possible values, thereby encouraging designers to obtain ratings through NFRC test procedures, when they are available.

B. Solar Heat Gain Coefficient (SHGC)

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 3-14) must be used for default values.

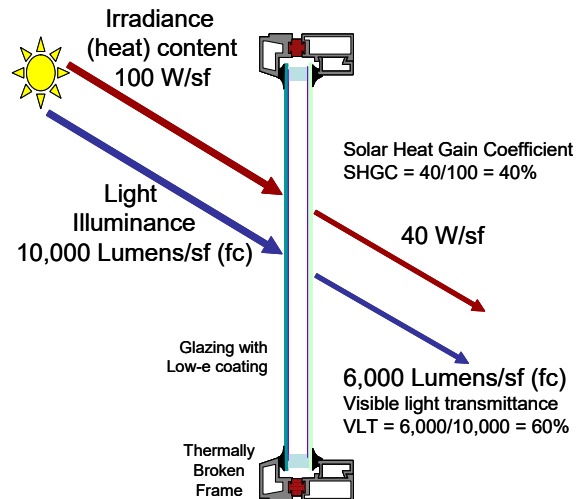
Table 3-14: Methods for Determining U-Factor and SHGC

U-factor and SHGC	Fenestration Category				
	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-100	✓	✓	✓	N/A	N/A
Default Tables 110.6-A (U-factor) 110.6-B (SHGC)	✓	✓	✓	✓	✓
NA6 ²	N/A	N/A	✓	N/A	N/A
¹ The NFRC Residential CMA method is an option that may be available in the Energy Standards.					
² The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may only be used for site-built vertical and skylights having less than 200 ft ² .					

C. Visible Transmittance (VT)

The visible transmittance (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.

VT is a property of glazing materials that has a varying relationship to SHGC (Figure 3-12). The ideal glazing material for most hot 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 3-12: Solar Heat Gain Coefficient and Visible Transmittance

3.3.2.3 Air Leakage

§110.6(a)1, §110.7

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 3-15. For field-fabricated products or exterior doors, the Energy Standards require that the unit be caulked, gasketed, weather stripped, or otherwise sealed. Unframed glass doors and fire doors are the two exceptions to these air leakage requirements.

Table 3-15: Maximum Air Infiltration Rates (§110.6(a)1)

Class	Type	Rate
Windows (cfm/ft ²) of window area	All	0.3
Residential Doors (cfm/ft ²) of door area	Swinging, Sliding	0.3
All Other Doors (cfm/ft ²) of door area	Sliding, Swinging (single door)	0.3
	Swinging (double door)	1.0

Example 3-12**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 200 ft² then one of the following three methods may be used:

1. Rate the fenestration using the component modeling approach (CMA), which will yield the most efficient values possible.
2. Use the default U-factor and SHGC values from equations in Reference Nonresidential Appendix NA6:
 - U-factor may be calculated from NA6, Equation NA6-1, $U_T = C_1 + C_2 \times U_C$. 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 $0.311 + 0.872 \times 0.50 = 0.47$.
 - SHGC is determined from NA6, Equation NA6-2, $SHGC_T = 0.08 + 0.86 \times SHGC_C$. The SHGC is calculated to be $0.08 + 0.86 \times 0.70 = 0.68$.
 - VT from NA6, the visible transmittance of the frame is 0.88 for a curtain wall, so the $VT_T = VT_F \times VT_C = 0.88 \times 0.75 = 0.66$.
3. Select from default Tables 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. A Fenestration Certificate Label, NRCC-ENV-05-E, should be completed for each fenestration product. Or the responsible party may attach a default temporary label to each fenestration unit throughout the building.

3.3.3 Vertical Fenestration (Windows and Doors)**3.3.3.1 Prescriptive Measures****§140.3(a)5**

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 by 6 feet in height and use the larger of the product of that multiplication or 40 percent of gross exterior wall area.

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.

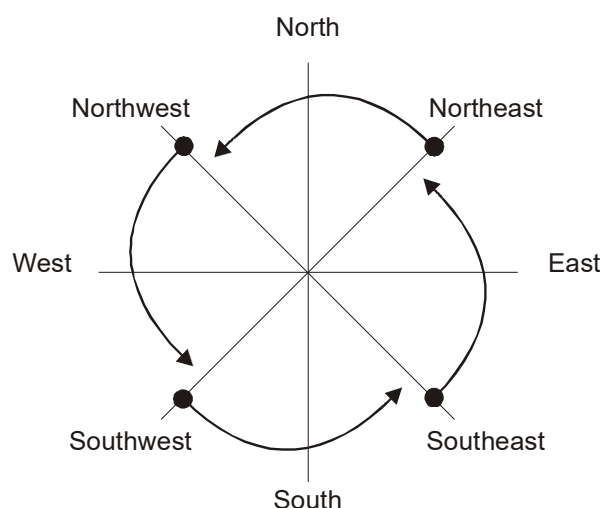
Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the prescriptive U-factor requirements for the climate zone.

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.

Glazed doors, 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.

The orientation can be determined from an accurate site plan. Any orientation within 45 degrees of true north, east, south, or west will be assigned to that orientation. Figure 3-13 demonstrates how surface orientations are determined and what to do if the surface is oriented exactly at 45 degrees 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, TABLES
140.3-B,C

Fenestration products must meet the prescriptively required maximum U-factor criteria in Tables 140.3-B and 140.3-C of the Energy Standards (Table 3-16) for each climate zone. Most NFRC-rated multi-glazed windows with a low-e coating and a thermally broken frame will comply with the U-factor criterion. See <http://www.nfrc.org>, Certified Product Directory database, or use Equation NA6-1 found in Reference Nonresidential Appendix NA6.

Table 3-16: 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

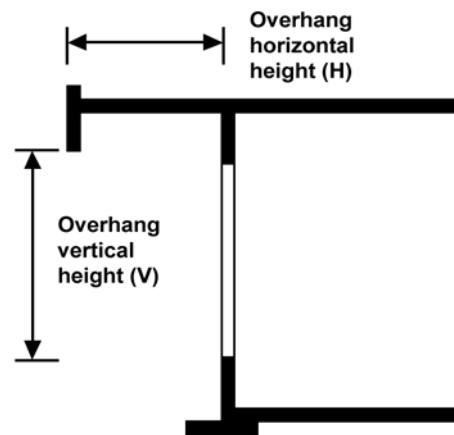
C. SHGC and Overhang Factor

§140.3(a)5C

Relative solar heat gain (RSHGC) allows for an 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 specify the maximum area-weighted average RSHGC, excluding the effects of interior shading. (Table 3-16)

Overhang factors may either be calculated or taken from Table 3-17 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), see 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 comply.

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

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

Where:

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

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

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

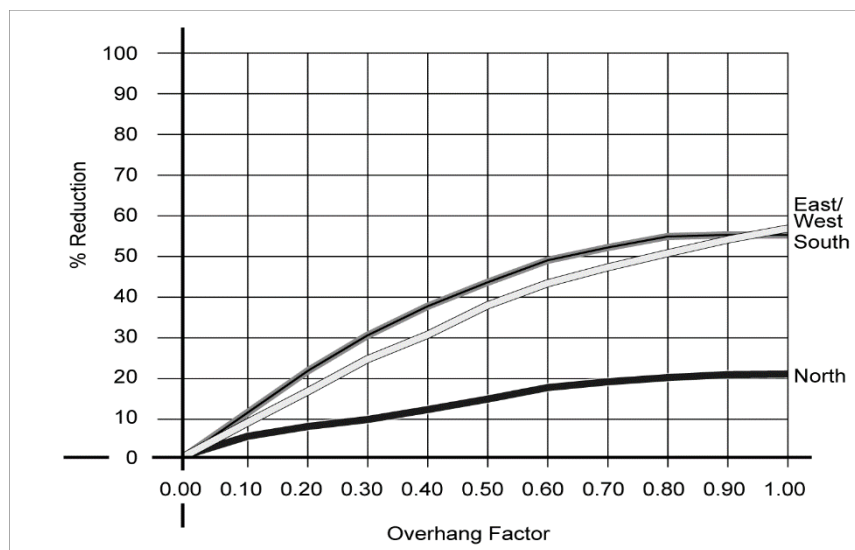
b = 0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east- and west-facing windows

Table 3-17: 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

Any value of H/V greater than 1 has the same overhang factor (for a given orientation) shown in the last row of Table 3-17.

Figure 3-15 illustrates the benefits of overhang factors of the various orientations as a function of H/V. The graph 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.

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 feet out from the plane of the glass ($H = 3$) and is 6 feet above the bottom of the glass ($V = 6$). The overhang extends more than 3 feet beyond each side of the glass, and the top of the window is less than 2 feet 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: $0.63 \times 0.71 = 0.45$.

D. Visible Light Transmittance (VT)**§140.3(a)5D**

The prescriptive requirements of Tables 140.3-B and 140.3-C (Table 3-16) 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. The performance method is discussed in more detail in Chapter 5.

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 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

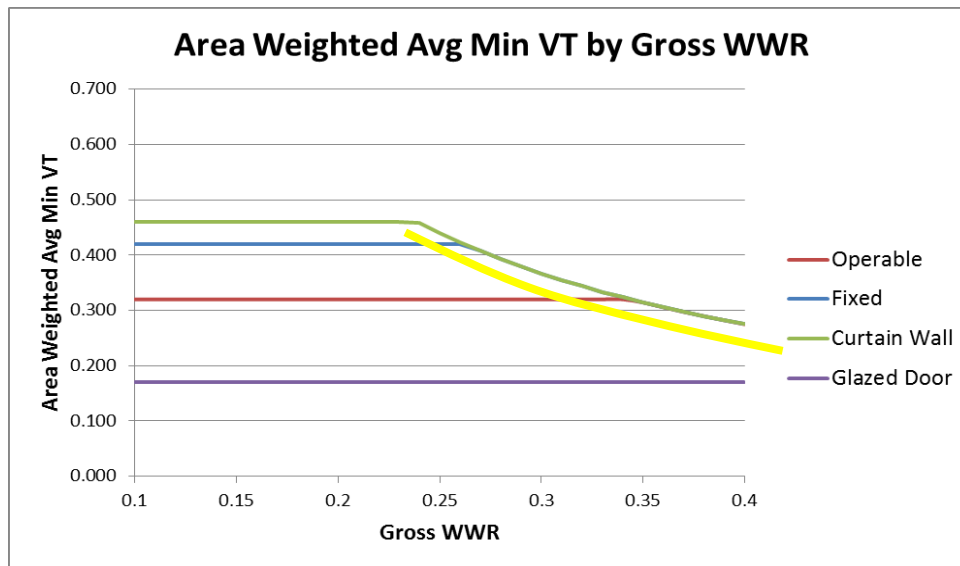
$$VT \geq 0.11 / WWR$$

Where:

VT = the visible transmittance of the framed window

WWR = the gross window-to-wall ratio

The graph in Figure 3-16 shows the allowed area weighted average minimum VT's by gross WWR for four types of windows. 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. All glazing that is not chromatic must separately meet the area-weighted VT prescriptive requirements.

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

Use the formula $VT \geq 0.11 / WWR$, to determine the minimum area weighted average VT for this space,

$VT \geq 0.11 / 0.3 = 0.367$. The area weighted minimum VT we need for this window is 0.367.

$(\text{View window Area} \times \text{View window VT}) + (\text{Clerestory Area} \times \text{Clerestory VT}) / \text{Total Window Area} = 0.367$

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.

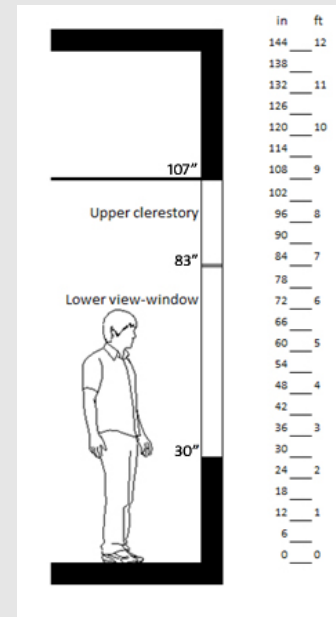
Using a 0.30 VT glazing in the view window then View window VT = 0.30

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

Solve the equation for Clerestory VT: Clerestory VT = 0.515

$(6360 \times 0.367) + (2880 \times VT_{CL}) / 9240$

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



Example 3-15**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:

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

3.3.3.2 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.

Look for NFRC Dynamic Glazing Labels to compare and contrast the energy performance for these products. See Figure 3-17. 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, ($\leftrightarrow$), 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

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

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

1. Optional prescriptive U-factor and SHGC from Tables 140.3-B and 140.3-C
2. Performance approach compliance gives 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

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 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. 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 security films and to reduce ultraviolet (UV) light, which contributes to fading. These 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 secondary.

3. **Metalized** (reflective) films can be metalized through vacuum coating, sputtering, or reactive deposition and may be clear or colored. Metalized films are preferred for 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.

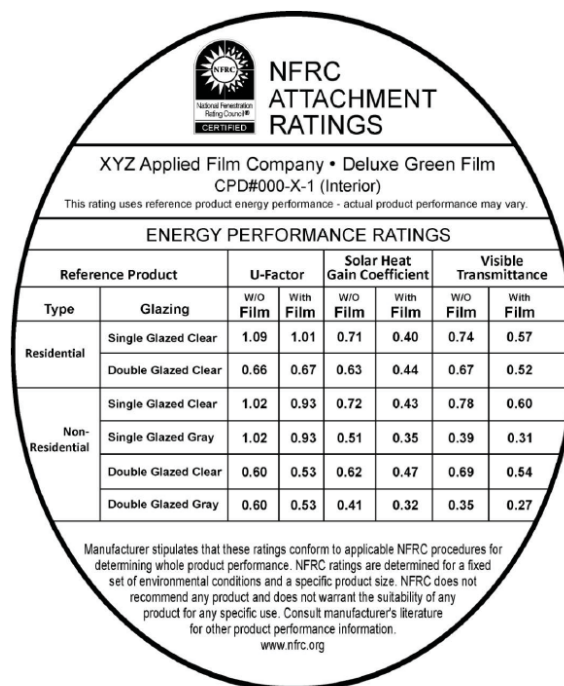
Look for the NFRC-certified attachment ratings energy-performance label, which helps consumers understand the contrast in energy performance of window films. An example of a window film energy performance label is shown on Figure 3-18.

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 15-year or longer warranty.

Figure 3-18: Window Film Energy Performance Label



3.3.4 Skylights

Skylights can be either flush-mounted or curb-mounted into a roof system. 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.

3.3.4.1 Skylight Mandatory Measures

§10-111, §110.6, §110.7

Skylights must meet all mandatory requirements for fenestration in §10-111, §110.6 and §110.7. Either the prescriptive or performance approach may be used.

When skylights are specified, the designer must show the skylit daylight zones on the building plans. There are mandatory requirements for lighting controls related to daylighting. See Section 3.3.3. Automatic daylighting controls are required when the installed power in the daylight zones of a room is greater than 120W. See Chapter 5 of this manual for a detailed discussion of the daylight zones.

3.3.4.2 Skylight Prescriptive Requirements

§140.3(a)6

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 3-18: 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 Reference Joint Appendix 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, called the skylight roof ratio (SRR). The limit increases to 10 percent for

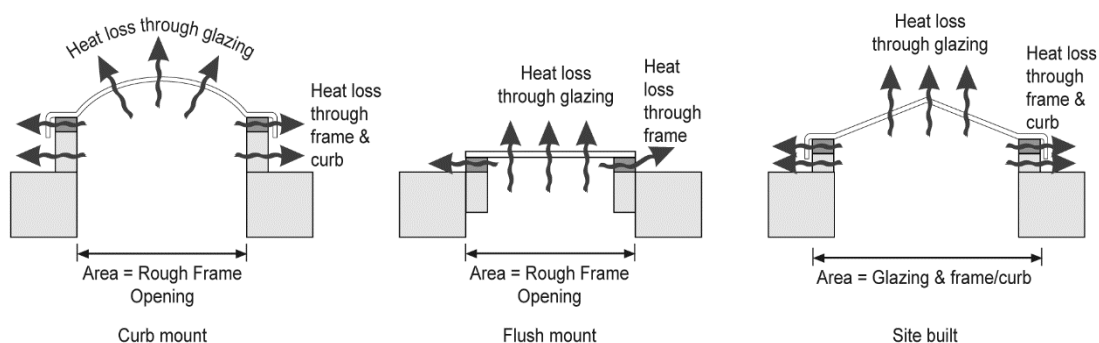
buildings with an atrium more than 55 ft high. The 55-ft height is the threshold at which the California Building Code requires a mechanical smoke-control system for atriums (CBC Sec. 909). This means that the 10 percent SRR is not allowed for atriums unless they also meet the smoke control requirement.

Site-built monumental or architectural skylights equipped with integral built-in or site-built curbs (not part of the roof construction) are often used for atrium roofs, malls, and other applications that need large skylights. In these cases, the skylight area is the surface area of the glazing and frame/curb, *not the area of the rough-framed opening*. Regardless of the geometry of the skylight (flat pyramid, bubble, barrel vault, or other three-dimensional shape), what matters is the anticipated heat exchanged through the glazing area. For special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5.

§140.3(c)4 requires that the skylight area be at least 3 percent of the floor area (not accounting for obstructions), or that the total of the skylight area multiplied by 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 skylit 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

U-factor = Heat Loss / 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 use 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. (Table 3-18)

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 3-18). The designer can use 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 200 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 Tables 140.3-B, C, and D (Table 3-18). There are exceptions for chromogenic glazing.

E. Daylighting

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.

Mandatory Daylighting Controls

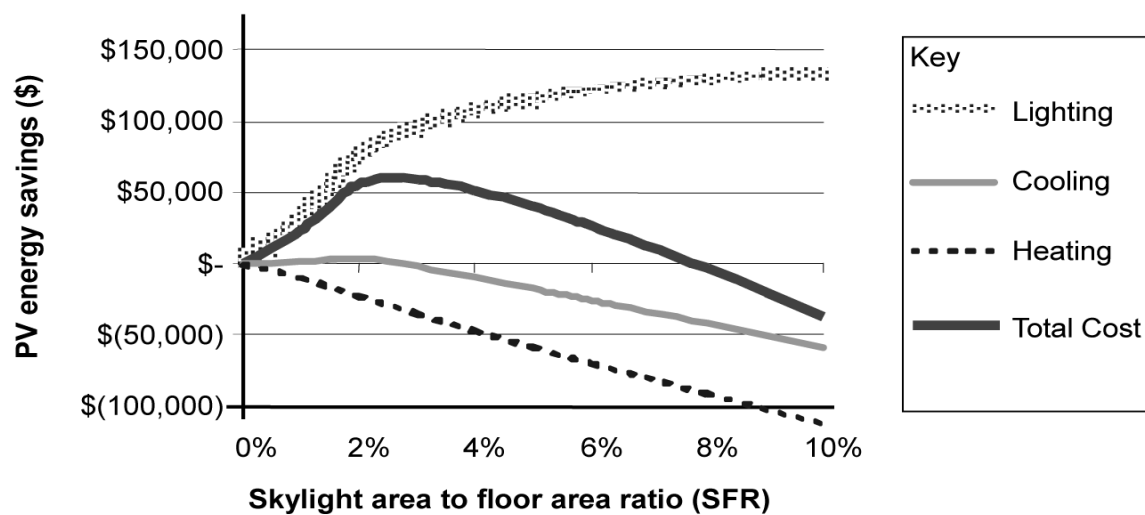
§130.1(d)

Electric lighting in skylight daylit zones shall meet the mandatory control requirements in §130.1(d). Obstructions are ignored for evaluating the architectural area served by skylights. For controlling lighting, consider the area shaded that is behind permanent obstructions that are greater than half the ceiling height. Those luminaires behind tall obstructions are not part of the skylit daylit area and not controlled by automatic daylighting controls.

Minimum Daylighting Prescriptive Requirements in Large Enclosed Spaces

§140.3(c)

Sizing is important; since too little skylight area has insufficient light available to turn off electric lighting; where 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 Climate Zone 12

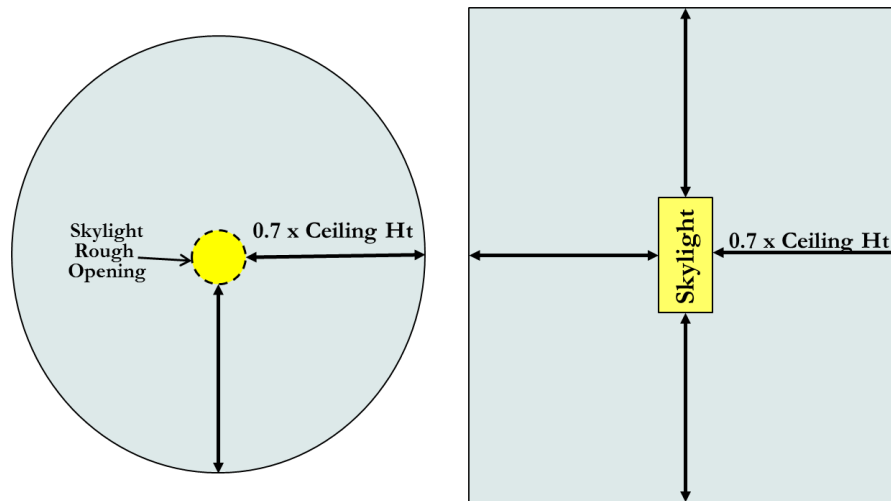
Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required in enclosed spaces (rooms):

- Larger than 5,000 ft².
- Directly under a roof.
- Ceiling heights greater than 15 ft.
- 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, an area in plain 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 3-20), or
2. A primary sidelit daylit zone, an area in plain 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 3-20: Area Within 0.7 Times Ceiling Height of Rough Opening of Circular Skylight and Rectangular Skylight

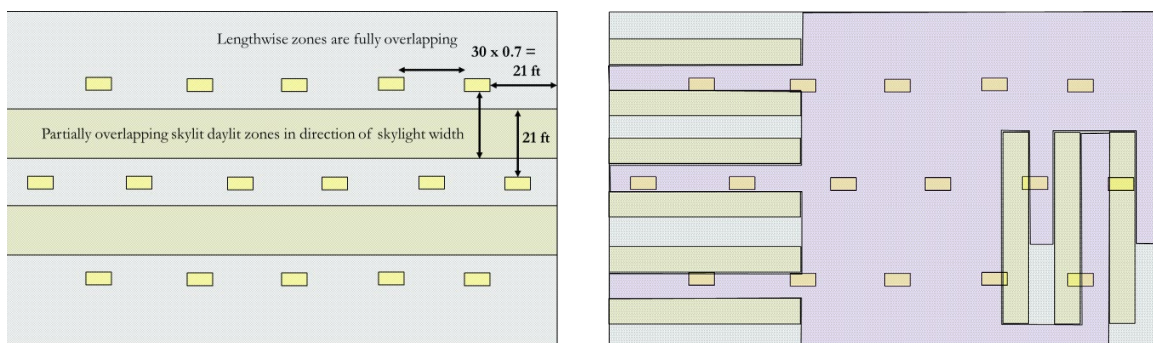


The shape of the skylit daylit zone will be similar in shape to the rough opening of the skylight (Figure 3-20).

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 3-21: 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 3-21, 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:

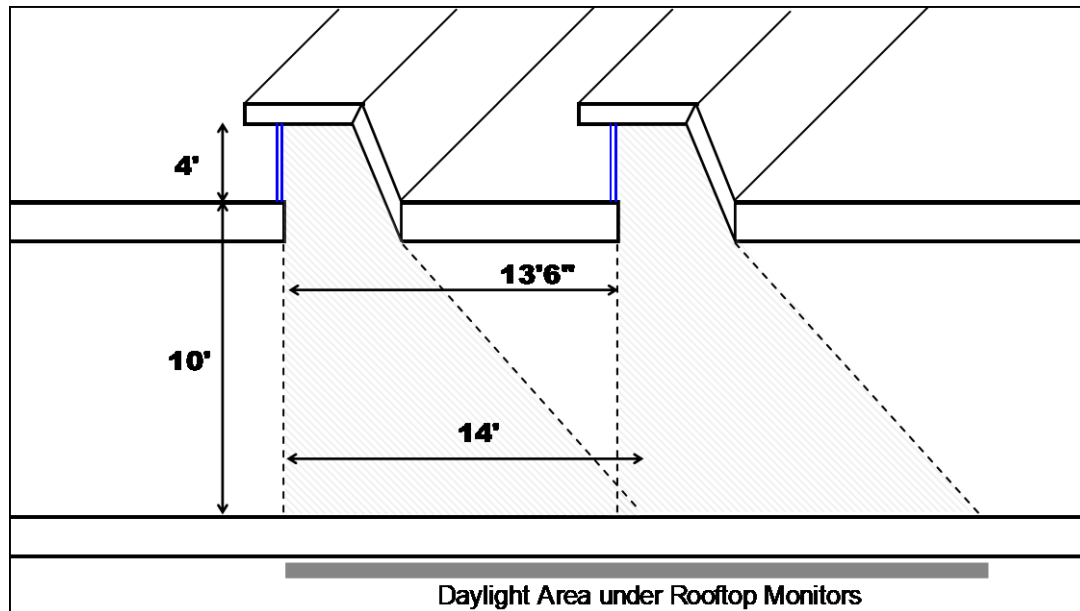
- 1. Auditoriums, churches, museums and movie theaters due to the demanding lighting control needs.*
- 2. Refrigerated warehouses to minimize heat gains.*

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 3-22: Daylight Area Under Rooftop Monitors (Primary Sidelit Daylit Zone)

G. Exceptions for Shading

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 site⁴, hand calculation tools such as the sun path calculator⁵, and computer-aided design software tools that automate this calculation.

3.3.4.3 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.

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>

Example 3-16**Question:**

What is the maximum spacing and recommended range for skylights in a 40,000 ft² 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:

$$\text{Maximum skylight spacing} = 1.4 \times \text{Ceiling Height} + \text{Skylight width}$$

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 $1.4 \times 30 = 42$ 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 $(32 \times 32) = 1,024$ 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:

$$(0.64 \times 32 / 0.02) = 1,024 \text{ sf.}$$

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.

3.3.4.4 Glazing Material and Diffusers**§140.3(a)6E, TABLE 140.3-B,C**

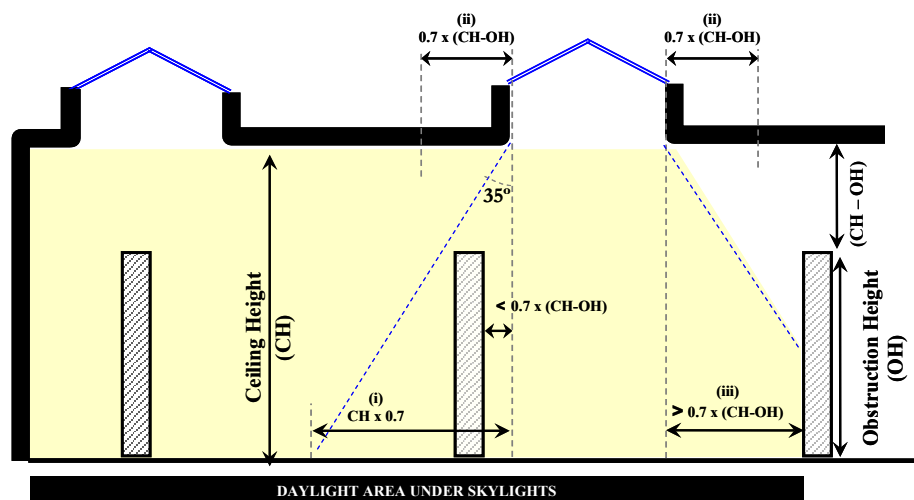
Skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 (notwithstanding its scope) or other test method approved by the Energy Commission.

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 Energy Standards require 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 the glazing or diffuser material has a haze rating greater 90 percent and the visible transmittance meets 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 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 need to be documented by the designer and approved by the code authority in your jurisdiction.

Figure 3-23: Daylit Area Under Skylights



3.3.5 Daylighting Design Power Adjustment Factors (PAFs)

Certain design features and technologies have the capacity to increase the daylighting potential of spaces. Some of these design features and technologies may be used in conjunction with automatic daylighting controls to receive PAFs from Table 140.6-A, or as a performance compliance option (PCO) in the performance method.

A thorough daylighting analysis should be performed to ensure the avoidance of glare issues when including daylighting features in the design. An example where caution should be taken is specularly reflective (e.g. polished or mirror-finished) horizontal slats. These slats may redirect direct beam sunlight causing uncomfortable glare. This is not the only consideration when designing daylighting

features. Daylighting analysis should be performed on a space-by-space, project-by-project basis.

Throughout all phases of the project, the envelope and lighting designers will need to coordinate closely to ensure that the requirements are met for their respective disciplines. Even if the envelope (e.g. horizontal slats) portion of the requirements meets all the envelope requirements, installing daylighting controls that do not meet the daylighting controls requirements will result in a loss of the PAF or PCO. Chapter 5, Section 5.5.1 gives guidance on the daylighting controls requirements.

3.3.5.1 Clerestory Fenestration

§140.3(d)1

Clerestory windows may be used in conjunction with automatic daylighting controls to receive a prescriptive PAF. Clerestory windows increase the head height of windows and therefore increase the depth and width of the primary and secondary daylit zones for a space.

As with all vertical fenestration installed in a building, clerestory windows must meet the vertical fenestration requirements.

A. Qualifying Fenestration Area

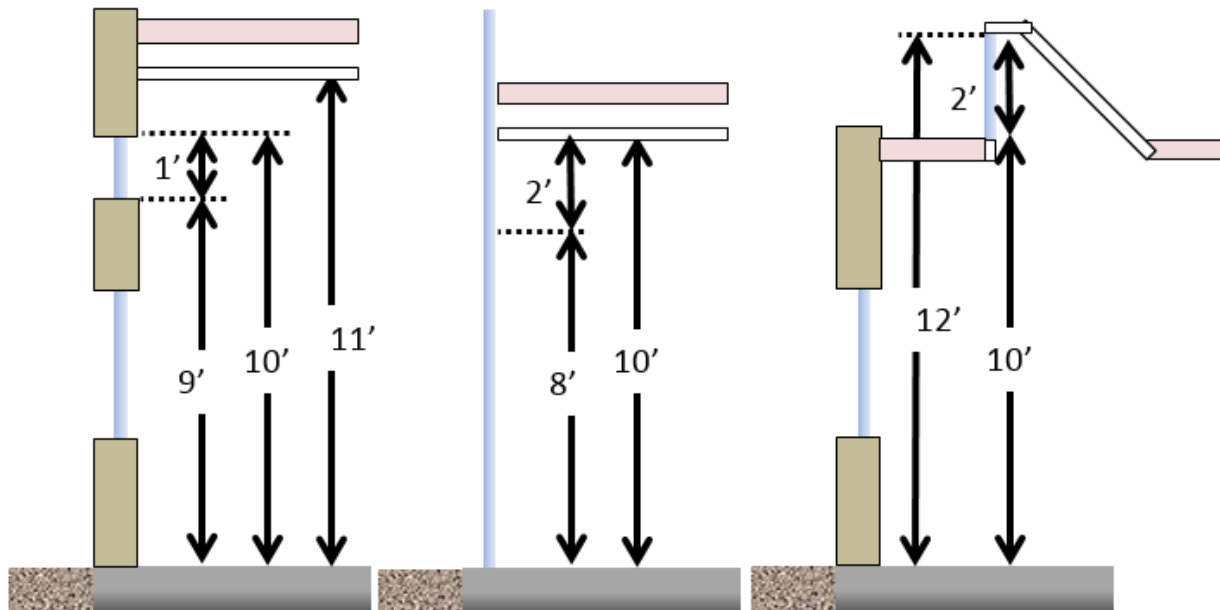
Any portion of vertical fenestration area 8 feet or higher above the finished floor of a space is considered a clerestory window. Note that a rooftop monitor (see Figure 3-22) qualifies as a clerestory window.

B. Orientation

For the PAF, the clerestory windows must be installed on east-, west- or south-facing facades.

C. Head Height and Window Height

For the PAF, clerestory windows must have a head height at least 10 feet above the finished floor of the space onto which the clerestory window is installed. The clerestory window height must be at least 10 percent of its head height. Examples are given in Figure 3-24.

Figure 3-24: Prescriptive PAF Clerestory Window Examples

D. Shading

Blinds or shading may not be installed at the time of inspection. However, if blinds or shading are installed at the time of inspection, then the blinds or shading which covers the clerestory window must be shown to be controlled separately from shading serving other vertical fenestration.

3.3.5.2 Interior and Exterior Horizontal Slats

§140.3(d)2

Horizontal slats on exterior or interior of windows may be used in conjunction with automatic daylighting controls to receive a prescriptive PAF or as a PCO in the performance method. Exterior horizontal slats may be preferable in a design to reduce solar gains whereas interior horizontal slats may be preferable considering wind loads, thermal bridging, passive solar heating, or vandalism.

A. Adjacency and Window-to-Wall Ratio (WWR)

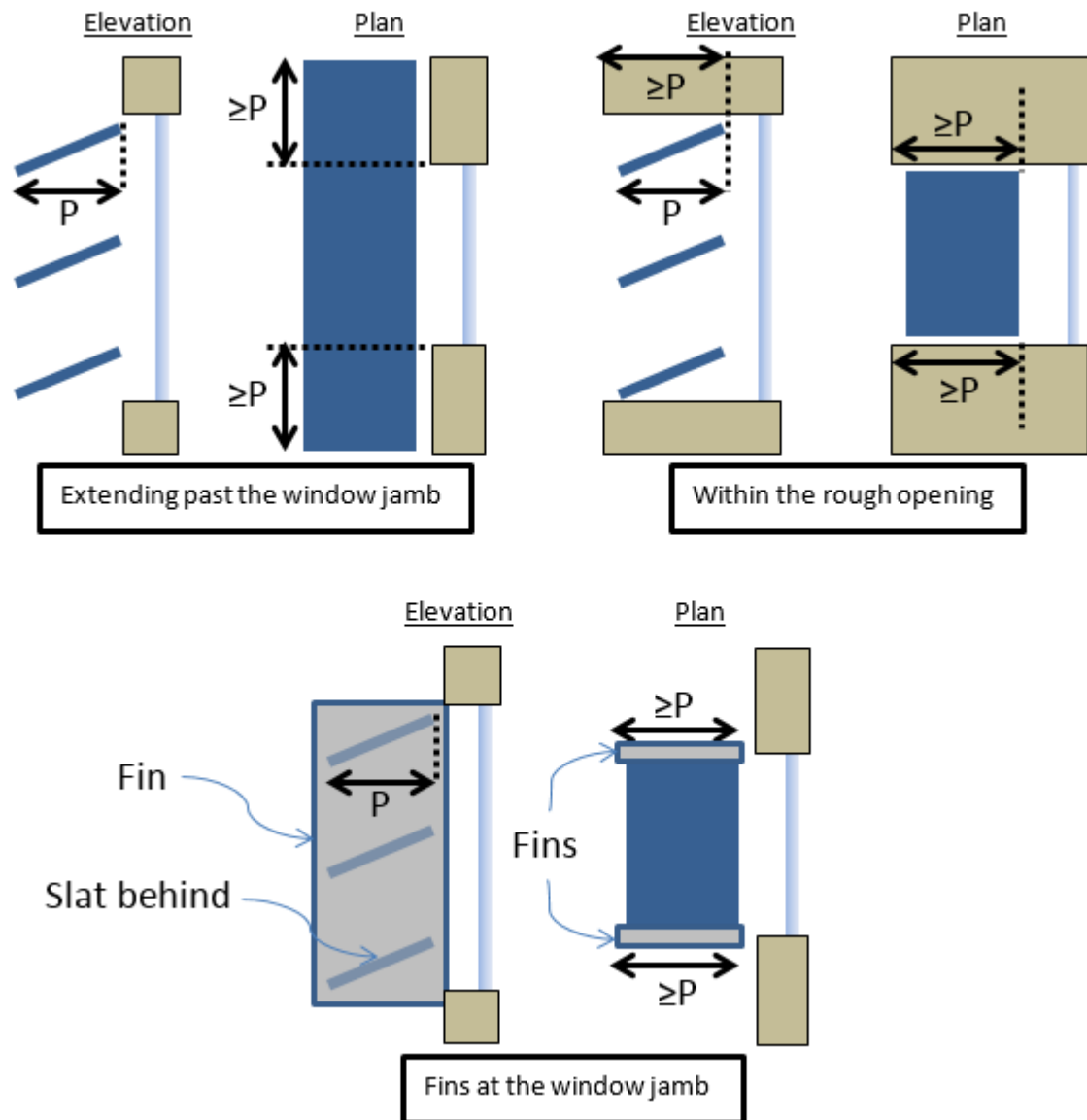
For the PAF, horizontal slats must be installed adjacent to (in front or behind) vertical fenestration. They must also extend the entire height of the window, and the WWR must be between 20 percent and 30 percent. The horizontal slats must be mounted on windows on east- and west-facing facades.

B. Side-Shading

Horizontal slats must block direct beam sunlight at their side edges. At sharp horizontal angles to the window (i.e. high and low relative azimuths), direct beam sunlight still passes through horizontal slats if they are only as wide as the window. Similar to overhangs, slats must extend on either side of the window at least as far as their horizontal projection.

Alternatively, the horizontal slats can be located entirely within the reveal for the window or have fins on either side from top to bottom. Diagrams of qualifying side-shading configurations are given in Figure 3-25.

Figure 3-25 Qualifying Horizontal Side-Shading



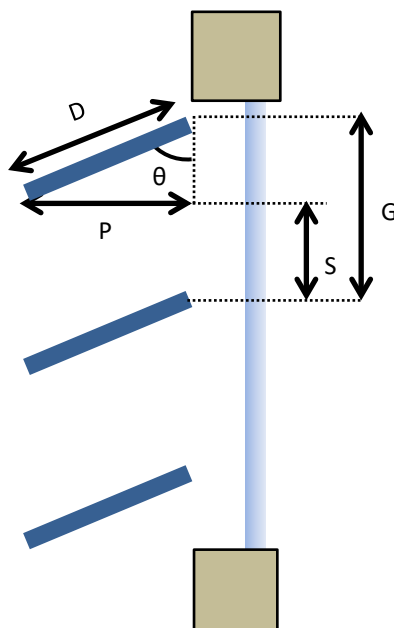
C. Projection Factor

Horizontal slats must shade direct beam sunlight from above. They may be level or slope downwards when looking out the window (i.e. exterior horizontal slats slope downwards from fenestration while interior horizontal slats slope upwards from fenestration).

Projection factor is the ratio of the effective horizontal depth to the effective vertical spacing of a shading surface.

For the PAF, the projection factor must be at least 2.0 and no greater than 3.0. The projection factor is calculated per Equation 140.3-D. Horizontal slat angle, depth, gap and corresponding spacing and horizontal projection are illustrated in Figure 3-26. The spacing and horizontal projection must be documented in the construction documents.

Figure 3-27 Projection Factor for Horizontal Slats



$$\text{Projection Factor} = \frac{P}{S} = \frac{D \times \sin(\theta)}{G - D \times \cos(\theta)}$$

P = Projection, S = Spacing, θ = Angle, G = Gap, D = Depth

D. Distance Factor

If objects exterior to the building are tall enough, they will shade the building's fenestration. In some cases, they may shade enough such that adding horizontal slats to the project adds no benefit. For this reason, horizontal slat installations must also have a minimum distance factor to ensure that any nearby tall objects are far away enough to not cast a substantial shadow on the fenestration. An object casting a shadow can be all or part of an existing structure or natural object such as a chimney on an otherwise flat roof, a decorative feature of a roofline, or even any particular point along a flat roofline, a place on a hilly landscape, a tree on that landscape, or a particular branch on that tree. All of these objects must be evaluated to see if they meet the minimum distance factor requirement.

Distance factor is calculated using the projection factor, the elevation of the window sill, and the distance and elevation of the top of obstructions within view of the window. To determine the lowest distance factor for the window, all obstructions within view of the window must be considered. This includes building self-shading from walls within view of the window. Distance factor is calculated

using Equation 140.3-D. For the PAF, the distance factor must be at least 0.3. Example 3-17 shows how to calculate distance factor.

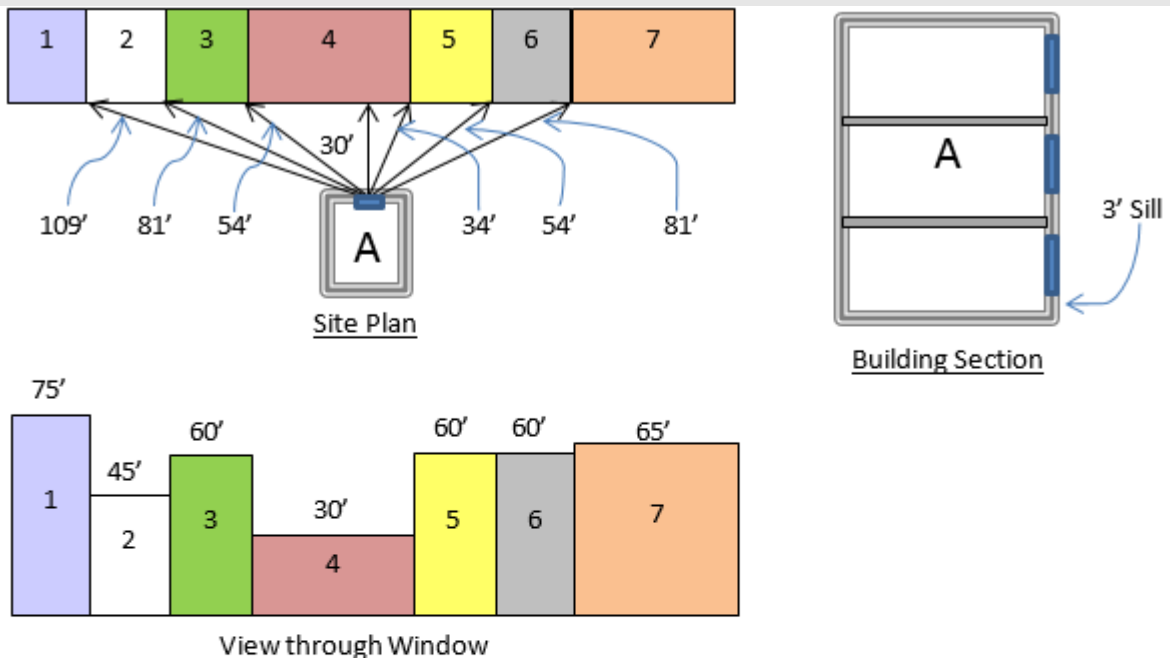
Note that for calculating distance factor, the shape of the obstruction is not accounted for. This is accurate for a situation where the relative heights of obstructions are similar, such as a street with an ordinance on height limit, but it actually may not be relevant if the obstruction does not cast much of a shadow (e.g. a radio tower on a hill).

In these cases, the project may instead demonstrate to the enforcement agency that the fenestration is shaded for less than a certain number of daytime hours between 8 a.m. and 5 p.m. For the PAF, the minimum number of shaded hours is 500. Section 3.3.4.2G shows how to demonstrate shaded hours.

Example 3-17

Question

Building "A" in the diagram below faces east and has a window on the first floor with a sill height of three feet. There are seven buildings within view of this window with the distances and elevations as given in the figures. Can the designer use horizontal slats with a projection factor of 3.0 on this window to receive a PAF?



Building	Distance [ft]	Elevation [ft]	Distance Factor
1	109	75	0.50
2	81	45	0.64
3	54	60	0.32
4	30	30	0.37
5	34	60	0.20
6	54	60	0.32
7	81	65	0.44

Answer:

No. Building 5 is too close compared to its height.

Equation 140.3-D for distance factor is applied to each of the seven buildings within view of building A. For these buildings, the elevations are the same all along their flat rooftops. So, the objects which might not comply with the minimum distance factor requirement correspond to each of the buildings' rooflines. If we examine the closest point for the rooflines, we will be assured that they will not shade as much or more than the horizontal slats are intended to. The closest point for these rooflines are the sides of the buildings to the side of building A's view (namely, buildings 1-3 and 5-7) and the distance directly across for buildings in front of building A (i.e., building 4). In the case of building 5, this distance factor is

$$\text{Distance Factor} = \frac{D}{H_{AS} * \text{Projection Factor}} = \frac{34}{(60 - 3) * 3.0} = 0.2 < 0.3 \text{ (Minimum Distance Factor)}$$

This is lower than the minimum distance factor, so horizontal slats with a projection factor of 3.0 can't be used for the PAF credit.

What can the designer do? The designer may select a lower projection factor or may choose to only use horizontal slats on the 2nd and higher floors of the building which have higher sill elevations.

E. Reflectance and Transmittance

The visible reflectance of horizontal slats must be tested as specified in ASTM E903. Certain coatings for horizontal slats have already been tested per ASTM E903 and can be researched to avoid re-testing. For the PAF, the visible reflectance must be at least 0.50.

If slats are opaque, then they do not require visible transmittance testing. But if they are not opaque, they must be tested as specified in ASTM E1175 and have a visible transmittance of 0.03 or less.

F. Mounting and Adjustability

Horizontal slats must be permanently mounted and not adjustable by occupants or facilities personnel. Horizontal slats are intended to be fixed and unmoving. Venetian blinds do not qualify for the PAF or a performance compliance option. Fasteners such as bolts, welds, and rivets are examples of fasteners that may be used to meet this requirement as long as they impede the movement of the horizontal slats and the horizontal slat assembly as a whole.

G. Labeling

A factory installed label must be permanently affixed and prominently located on an attachment point of the device to the building envelope. This label spells out that removal of the horizontal slats will trigger re-submittal of compliance documentation to the enforcement agency. If the horizontal slat assembly is removed, the building owners will again need to prove that the building still meets the requirements of Title 24, Part 6 with the slats removed.

Specifically, the label must state:

"NOTICE: Removal of this device will require re-submittal of compliance documentation to the enforcement agency responsible for compliance with California Title 24, Part 6."

3.3.5.3 Interior and Exterior Light Shelves

§140.3(d)3

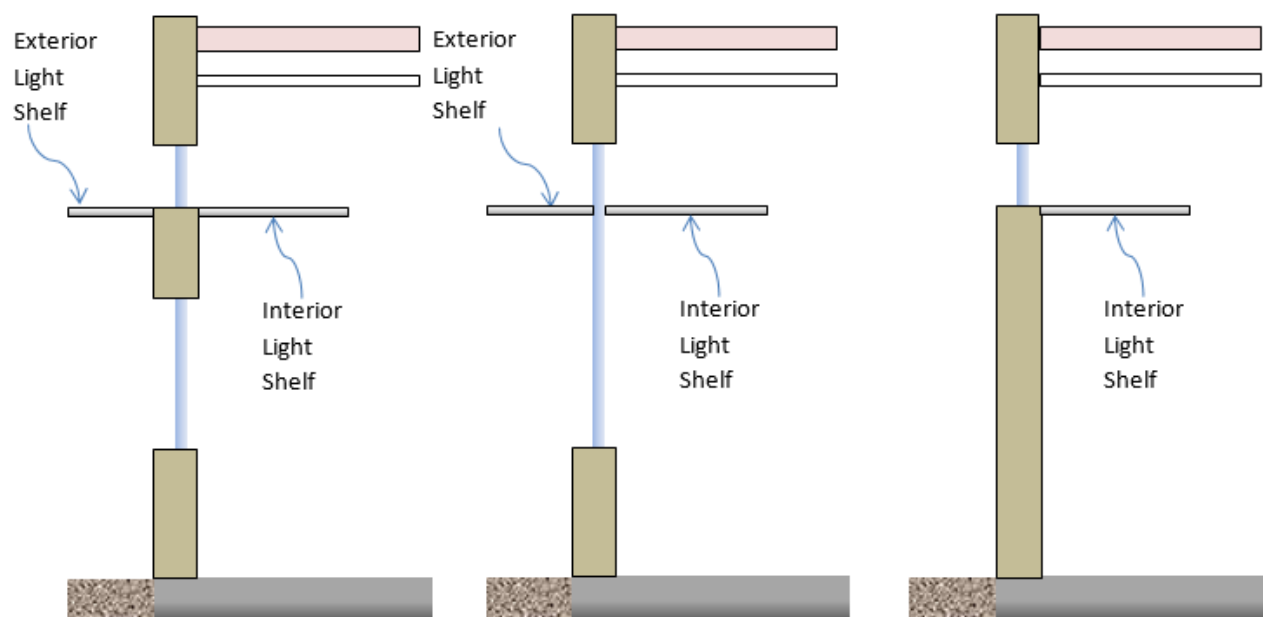
Interior light shelves combined with exterior light shelves on clerestory windows can be used in conjunction with automatic daylighting controls to receive a PAF. Light shelves block and redirect direct sun beam onto the ceiling of a space then reflect it downward into the space.

One pitfall of interior light shelves is the tendency for occupants to place objects on top of them, effectively using them as shelving. Thoughts should be put into the design of interior light shelves so as to discourage their use in this manner.

A. Exterior Light Shelf Exception and RHSGC

An exterior light shelf also acts as an overhang, blocking direct sun beam through any window area below the clerestory window (the “view window” area). Thus, it may take the overhang SHGC credit. If there is no view window area below the light shelf, then an exterior light shelf may still be installed but it is not required. Diagrams of qualifying interior and exterior light shelf configurations are given in Figure 3-27.

Figure 3-27 Qualifying Interior and Exterior Light Shelves Combinations



B. Clerestory

Light shelves must be installed adjacent to a clerestory window that meets the requirements discussed in the Clerestory Fenestration section. In addition, interior light shelves depend on a ceiling to reflect daylight. So, the clerestory window’s head must be no greater than one foot below a finished ceiling.

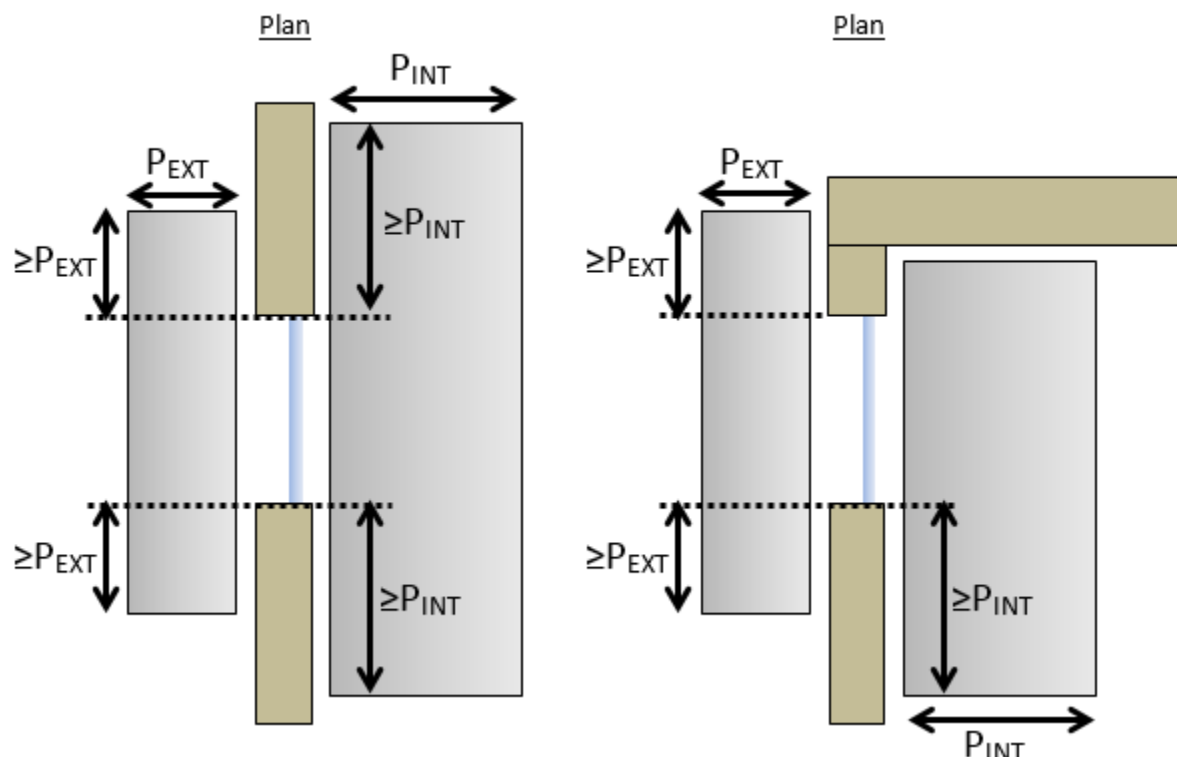
C. Window-to-Wall Ratio (WWR) and Orientation

For the PAF, the WWR must be greater than 30 percent. The light shelves must be mounted on windows on south-facing facades.

D. Side-Shading

Light shelves must block direct beam sunlight at their side edges. At sharp horizontal angles to the window (i.e. high and low relative azimuths), direct beam sunlight still passes through horizontal slats if they are only as wide as the window. Similar to overhangs, light shelves must extend on either side of the window at least as far as their horizontal projection. An example of a qualifying side-shading configuration is given in Figure 3-28.

Figure 3-28 Qualifying Light Shelf Side-Shading Example

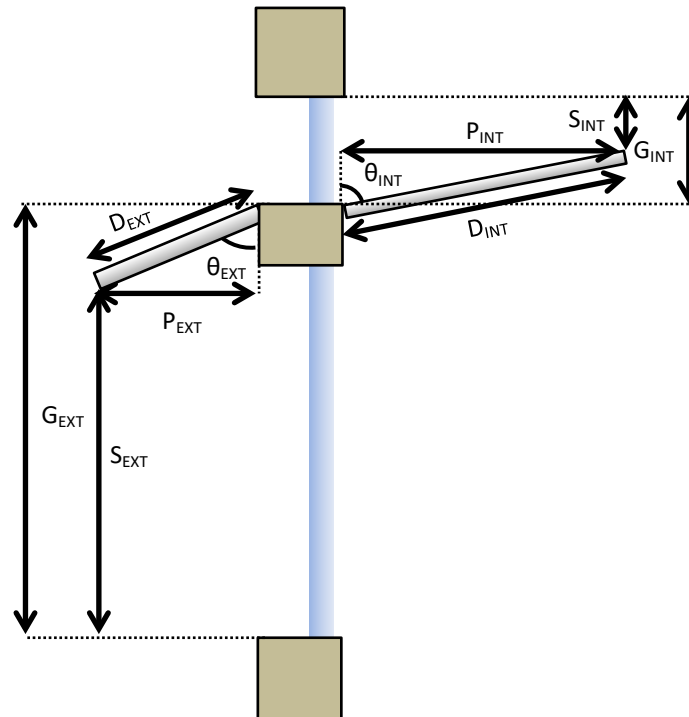


E. Projection Factor

Light shelves must shade direct beam sunlight from above. They may be level or slope downwards when looking out the window (i.e. exterior light shelves slope downwards from fenestration while interior light shelves slope upwards from fenestration). The slopes of interior light shelves should not be too steeply or they may block the daylight reflected off of the ceiling, thus reducing the daylighting benefits.

Projection factor is the ratio of the effective horizontal depth to effective vertical spacing of a shading surface. The projection factor is calculated per Equation 140.3-D. For a PAF, the interior light shelf projection factor must be at least 1.0 and not greater than 2.0. The exterior light shelf projection factor must be at least 0.25 and not greater than 1.25.

Light shelf angle, depth, gap, and corresponding spacing and horizontal projection are illustrated in Figure 3-29. The light shelf spacing and horizontal projections must be documented in the construction documents.

Figure 3-29 Projection Factor for Light Shelves

$$\text{Projection Factor} = \frac{P}{S} = \frac{D \times \sin(\theta)}{G - D \times \cos(\theta)}$$

P = Projection, S = Spacing, θ = Angle, G = Gap, D = Depth

F. Distance Factor

The requirements and procedures for distance factor are the same as those for horizontal slats as given in the Horizontal Slats section. For the light shelf PAF, the minimum shaded hours are 750.

G. Reflectance

The visible reflectance of the top surface of light shelves must be tested as specified in ASTM E903. If the exterior light shelf is greater than two feet below the clerestory sill, then the top surface of the exterior light shelf needs not be reflective. Certain coatings for light shelves have already been tested per ASTM E903 and can be researched to avoid re-testing.

For the PAF, the visible reflectance must be at least 0.50.

3.4 Relocatable Public School Buildings

§140.3, Table 140.3-D, *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 eight different orientations either in climate zones 14, 15 or 16, or the specific climate zones in which the relocatable building is installed. Also see §140.3(a)8 and §141.0(b)2.

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.

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.

3.5 Performance Approach

§140.1

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. A discussion on the performance approach, and fixed and restricted inputs, is included in Chapter 11. 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 Compliance Modeling

3.5.1.1 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 Joint 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.

3.5.1.2 Opaque Surfaces

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:

- Surface areas by opaque surface type.
- Surface orientation and slope.
- 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 represents insulation, framing, homogenous construction material, or a combination of framing and cavity insulation.
- Surface absorptance = $1 - \text{solar reflectance}$. 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 3.2.4.

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.

3.5.1.3 Fenestration

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

- 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.
- 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.
- 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 200 ft².
- 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 200 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.
- Visual Transmittance

3.5.1.4 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).

3.5.1.5 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 Joint 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

§141.0

The Energy Standards offer prescriptive approaches and a performance approach to additions and alterations, but they do not apply to repairs. See §141.0(a) and §100.1(b) for detailed definitions.

- A. Addition** is a change to an existing building that increases conditioned floor area and volume. 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. 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 performance 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.

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 using 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 of §110.6, §110.7, and §110.8 as well.

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 per Table 3-19:

Table 3-19 Wall Insulation for Alterations

Wall Assembly Type	Minimum R-value	Maximum U-factor
Metal buildings	R-13	0.113
Metal-framed walls	R-13	0.217
Wood-framed walls and others	R-11	0.110
Spandrel panel and curtain walls	R-4	0.280

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

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.

Table 3-20 Floor Insulation for Alterations

Floor Assembly Type	Minimum R-value	Maximum U-factor
Raised framed floors	R-11	0.071
Raised mass floors in high rise, hotel and motel	R-6	0.111

Raised mass floors in all other occupancies - No minimum U-factor is required.

3.6.2 Prescriptive Requirements

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

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, §110.7 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 3-21) 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 3-21: 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 3-18

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 to fenestration products removed and reinstalled as part of a building alteration or addition.
3. Use either NFRC label certificate or use Tables 110.6-A and 110.6-B default values; applies in this case as 24,000 ft² of new fenestration is being installed.
4. Since the site-built fenestration area is less than 200 ft², use either the NFRC label certificate, the applicable default U-factor or SHGC set forth in Reference Nonresidential Appendix NA6, or default values from Tables 110.6-A and 110.6-B.

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 50 percent or more of the existing roof area or when more than 2,000 ft² of the roof is being altered, (whichever is less) the requirements apply. When a small repair is made, these requirements do not apply. For example, the requirements for roof insulation would not be triggered if the existing roof surface were overlaid instead of replaced.

These requirements 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 insulation recover boards.

Roof Insulation

When a roof is exposed to the roof deck or recover boards, and the 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 3-22).

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 Joint 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 3-22: 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.

Exceptions to §141.0(b)2Biii:

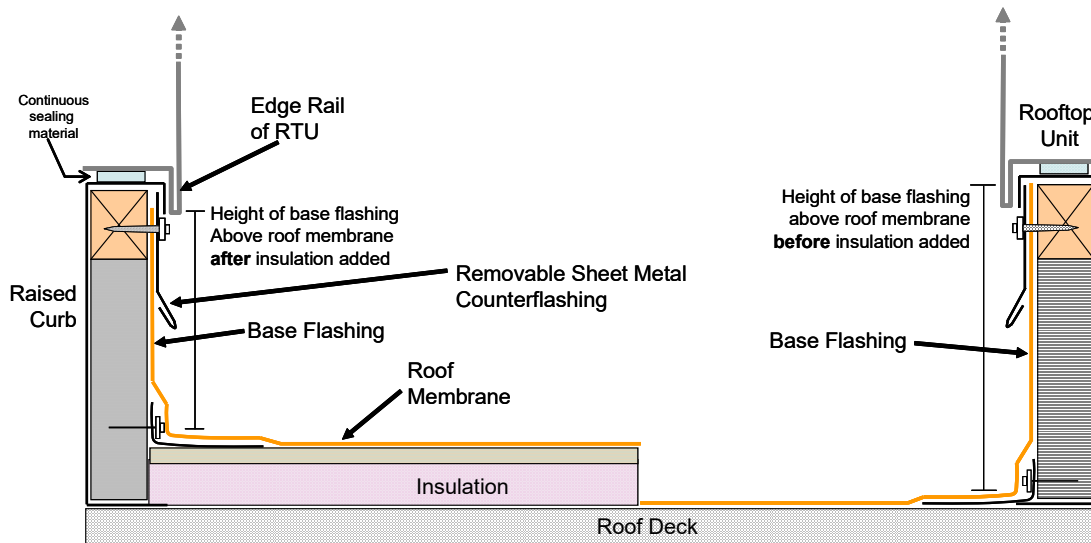
- No additional insulation is required if the roof is already insulated to a minimum level of R-7.
- If mechanical equipment is located on the roof will not be disconnected and lifted as part of the roof replacement, insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (203 mm) from the roof membrane surface to the top of the base flashing.
- 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. These conditions must be met:
 - The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material.
 - 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.
 - 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.

- 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.
- 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.

When insulation is added on top of a roof, the elevation of the roof membrane is increased. When insulation is added to a roof and the curb height (counterflashing for walls) is unchanged (Figure 3-30), 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.

When adding insulation on top of a formerly uninsulated or underinsulated roof, 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, 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 3-30: Base Flashing on Rooftop Unit Curb Detail

Roof Products

§141.0(b)2B

1. Thermal Emittance and Solar Reflectance Prescriptive Requirements

For nonresidential buildings, the prescriptive requirements for roofing products are:

- 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.

Exception for nonresidential buildings: an aged solar reflectance less than 0.63 is allowed, provided that additional insulation is installed. (Table 3-23)

For high-rise residential buildings and hotels and motels, the prescriptive requirements for roofing products are:

- 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.

Exceptions for high-rise residential buildings and hotels and motels:

- 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.

- 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.

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. Table 141.0-B (Table 3-23) shows the overall roof U-factors trade-off requirements, by climate zones.

Table 3-23: 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

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 3-19

Question:

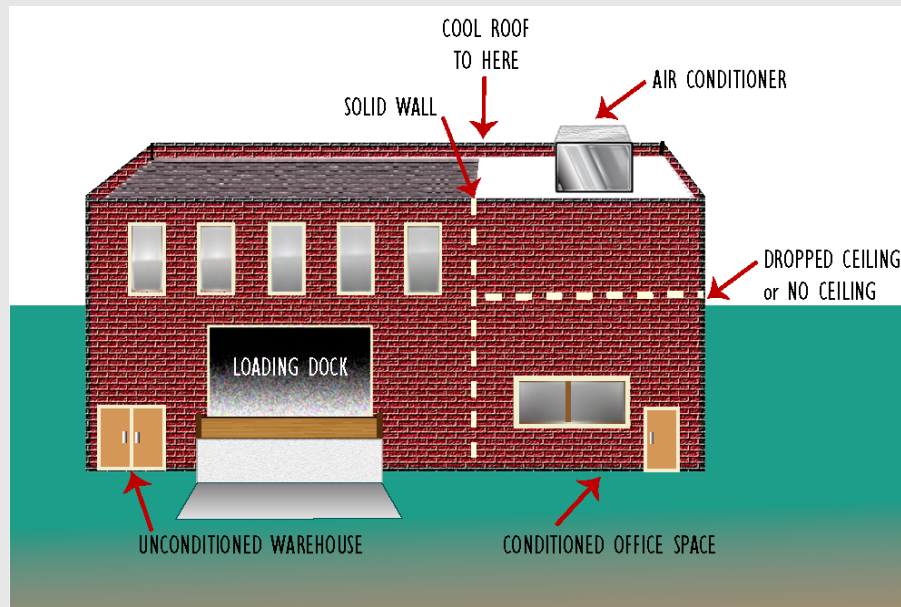
What are the Energy Standards requirements for cool roofs when reroofing a low-sloped roof on an unconditioned warehouse containing conditioned office space?

Answer:

Scenario 1.

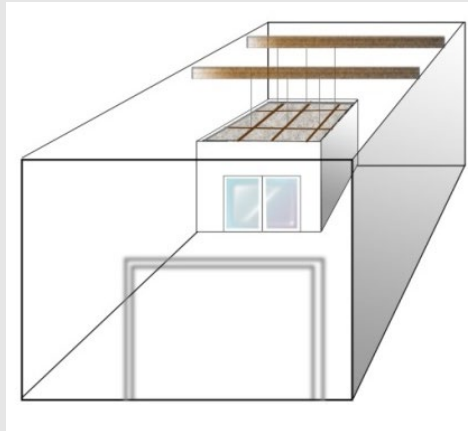
There is either directly or indirectly conditioned space under the roof. The cool roof requirements apply to just the portion(s) of the warehouse roof over the conditioned space(s). The rest of the roof (over unconditioned warehouse space) is not required to be a cool roof.

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. 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 3-20

Question:

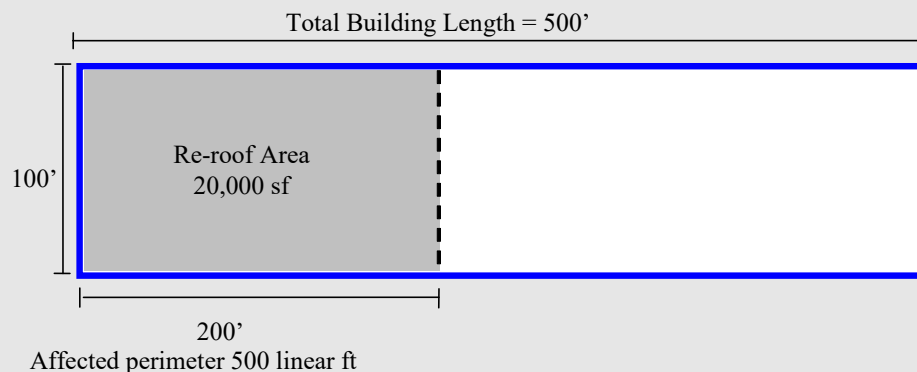
I have a barrel roof on nonresidential conditioned building that needs to be reroofed. Must I follow the Energy Standards roofing product requirement?

Answer:

Yes, the roof would need to meet the aged solar reflectance and thermal emittance for a steep-sloped roof. Although a barrel roof has both low-sloped and steep-sloped roofing areas, the continuous gradual slope change allows the steep-sloped section of the roof to be seen from ground level. Barrel roofs only need to meet the steep-sloped requirement for the entire roof area.

**Example 3-21****Question 1:**

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?

**Answer 1:**

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. The roof does not have any insulation and, therefore, is required to add insulation. 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.

The ratio of the replaced roof to the affected wall area is $20,000 \text{ ft}^2 / 500 \text{ linear ft} = 40:1$. 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 higher up on the wall. Alternatively, the installer may ask for the roofing manufacturer to provide a variance in the warranty 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 meet the U-factor.

Question 2:

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

Answer 2:

Yes. San Francisco (as shown in Reference Joint Appendix JA2) is in Climate Zone 3. Per 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.

For nonresidential buildings in Climate Zone 3, the ratio is 100:1. The ratio of the replaced roof to the affected wall area is $20,000 \text{ ft}^2 / 500 \text{ linear ft} = 40:1$. 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.

Example 3-22**Question 1:**

A nonresidential building is having 5,000 ft^2 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?

Answer 1:

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.

Question 2:

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

Answer 2:

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 3-23

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. There are no exceptions for skylights. Removing a unit skylight and increasing its curb height is substantially less effort than that for space-conditioning equipment.

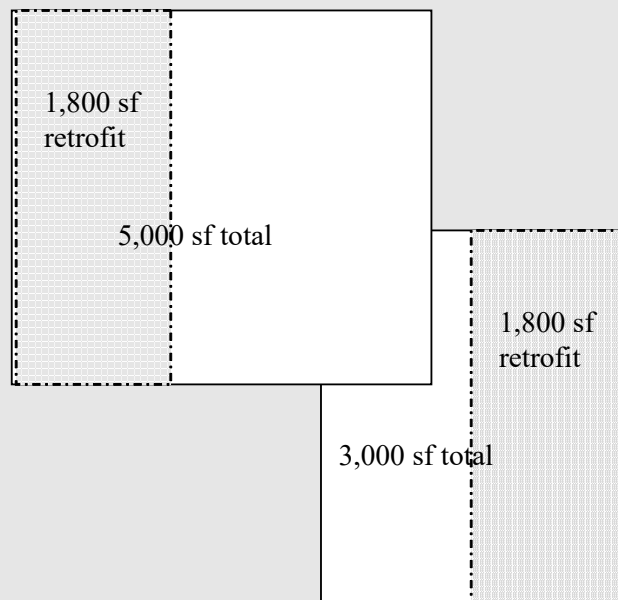
Example 3-24

Question 1:

A building has low-sloped roofs at two elevations. 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 1:

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.



Question 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 be a cool roof and have insulation installed?

Answer 2:

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 3-25

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:

Question 1: 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?

Answer 1:

No. The unit with the 9-inch base flashing was disconnected and lifted and thus it does not qualify for the exception to §141.0(b)2Biii. As much as 6 inches or more of insulation can be added 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. The full R-14 insulation would be required.

Question 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 2:

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. Only 1 inch (2.5 cm) of insulation can be added before the base flashing height would be reduced below 8 inches (20 cm) on the unlifted rooftop unit with a 9-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). Only 1 inch (2.5 cm) of additional insulation is required since 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.

Question 3:

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

Answer 3:

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 3-26

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 exceptions in 140.3(a)Ai?

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 3-27**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 3-28**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 3-29**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.

1. To make an insulation/reflectance trade-off under the prescriptive approach, using Table 141.0-B. 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. Consult Section 4.2 (Roofs and Ceilings) of Reference Joint 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/title24/2019standards/>. 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 3-30**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

3.6.3.1 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.

3.6.3.2 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 one of these:

- 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).

- 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 3-24: 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