3 Building Envelope

This chapter describes the requirements for the design of the building envelope for nonresidential buildings. Loads from the building envelope, especially windows, skylights, and roofs are among the most significant loads that affect heating and cooling energy use. The principal components of heating loads are infiltration through the building envelope and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows and doors. Cooling loads, however, are dominated by solar gains through the windows and skylights. Outside air ventilation loads and lighting loads are also quite significant, but these are addressed in the Mechanical Systems and Lighting Systems chapters.

The design of the building envelope is generally the responsibility of an architect, although a contractor, an engineer, or some other person may do it. The designer is responsible for making sure that the building envelope complies with the Standards. Likewise, the building official is responsible for making sure that the building envelope is designed and built in conformance with the Standards. This chapter is written for the designer and the building official, as well as other specialists who participate in the design and construction of the building envelope.

3.1 Overview

The Standards have both mandatory measures and prescriptive requirements that affect the design of the building envelope. These requirements establish a minimum level of performance, which can be exceeded by advanced design options or construction practices. These advanced design options are discussed later in this chapter. Those design options that are recognized for credit in the performance approach are called compliance options. Compliance options have eligibility criteria that must be satisfied before compliance credit is offered.

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

3.1.1 Prescriptive Component Envelope Approach

Standards Table 143-A, B and C

This prescriptive compliance approach consists of meeting specific requirements for each envelope component: roofs and ceilings, exterior roofing products, exterior walls, demising walls, external floors and soffits, windows, and skylights. Each opaque assembly has to meet a minimum insulation level. Each glazing component has to meet insulating and solar heat gain coefficient (SHGC) values, and there is an upper limit on glazing area. If these requirements are met, the building envelope complies with the Standards. See the ENV-2C forms.

The prescriptive requirements (Envelope Component Approach §143) are shown in Standards Table 143-A for nonresidential buildings and Standards Table 143-B for high-rise residential buildings and hotel/motel buildings.

Standards Table 143-C shows climate independent prescriptive envelope criteria for relocatable public school buildings. The prescriptive requirements are the easiest way to comply with the building envelope requirements, but there is little flexibility, since each component of the building envelope must comply with its requirements. If each and every prescriptive requirement is met, the building envelope complies prescriptively with the Standards.

Under the Component Envelope Approach, each of the envelope assemblies (walls, roofs, floors, windows, and skylights) must comply individually with its requirement. If one component of the envelope does not comply, the entire envelope does not comply. The simplicity of this approach means there can be no trade-offs between components. If one or more of the envelope components cannot meet its requirement, the alternative is to use either the Overall Envelope TDV Energy Approach or the Performance Approach, either of which allows tradeoffs between components.

Standards Tables 143-A and 143-B are organized in a similar manner and are climate zones-based. Each climate zone has its own specific prescriptive requirements for roofs and ceilings, exterior roofing products, exterior walls, demising walls, external floors and soffits, windows, and skylights. The top portions of the prescriptive tables have requirements for the opaque portions of the building envelope, including roofing products, walls, and floors. The criteria are given as maximum U-factors; nominal insulation R-value compliance is no longer permitted under the Standards. The U-factor criteria in turn are given for different classes of construction. For walls, U-factor criteria are given for wood framed walls, metal-framed walls, metal building walls, and high and low mass walls and furred walls. For floors, criteria are given for mass floors and other floors.

3.1.2 Prescriptive Overall Envelope TDV Energy Approach

§143(b)

The overall envelope TDV energy approach treats envelope components as a system and offers the ability to make simple trade-offs between envelope components. §143(b) describes the overall envelope TDV energy approach. The overall envelope TDV energy approach allows the performance of some building envelope components to be increased while the performance of others is reduced. For instance, the energy impact of single-paned windows could be offset by additional wall and roof insulation. The overall envelope TDV energy approach combines the heat loss and heat gain equations into a single trade-off equation that calculates the annual TDV energy of space cooling and heating based on the thermal performance of envelope. Trade-offs would be compared using TDV energy instead of source energy, which allows for trade-offs between cooling and heating aspects of the envelope in one equation. The impacts of each building envelope component are estimated by a set of weighting coefficients that are dependent on climate and building type. See the ENV-3C forms.

TDV energy for the proposed building is calculated according to procedures in Reference Nonresidential Appendix NA7. TDV energy of the standard building, which minimally complies with prescriptive requirements, is also calculated. As long as overall envelope TDV energy of the proposed building does not exceed the TDV energy of the standard building, the building is in minimum compliance with the prescriptive requirements.

The overall envelope TDV energy approach permits trade-offs between many building envelope components, but no trade-offs are permitted with the interior lighting system or mechanical systems. The performance approach is required in order to make these trade-offs.

3.1.3 Performance Approach

§141

The performance approach may be used for compliance, or may include lighting and mechanical system compliance when these systems are permitted at the same time. When the performance approach is used for the envelope only, the computer model deals with the energy efficiency of the entire envelope under both heating and cooling conditions. This means that trade-offs can be made among all envelope components. The computer analysis is much more sophisticated and can account for more subtle energy effects due to surface orientation and hourly changes in the outside temperature. If the envelope is combined with other parts of the building for energy compliance, then more trade-offs can be made, such as increasing envelope efficiency in order to allow more lighting power or a less efficient mechanical system. See Chapter 9 for a more complete discussion of the performance approach.

3.1.4 What's New in the 2008 Standards

With the update to the Standards, there were several important changes to the building envelope requirements, as described below:

1. A new section §143(c) reduces the prescriptive area requirement for skylights in **large enclosed spaces** in nonresidential buildings from 25,000 ft² down to 8,000 ft².
2. The building plans must show all **skylit and primary side lit areas** that total more than 2,500 ft² in an enclosed space (room) §131(c)2B&C. This will require coordination between the architect and the lighting designer so the daylit areas are relocated when the location or sizes of windows and skylights change in design iterations.

3. A new prescriptive requirement for **steep-sloped roofing products** (cool roof).
4. **Overall Building Envelope Method -** The overall building envelope method has been revised to combine heating and cooling and to provide simplified trade-offs for roofing alterations.
5. **Site-Built Fenestration - Acceptance Requirements**. The Standards introduce Acceptance Requirements, ENV-2A, for site-built fenestration products.
6. NFRC's new Component Method Approach (CMA) for manufacturers to calculate the U-factor and SHGC through computer simulation. Speeds up the process in acquiring an NFRC label Certificate for site-built fenestration.
7. Default Table 116-A and 116-B now includes Block Glass values.
8. **Insulation Levels -** Revised prescriptive roof, wall, and floor insulation requirements levels in certain climate zones.
9. The **alteration requirements for roofing products** have been changed to clarify that all replacements, recovering or recoating of the exterior surface of existing nonresidential roofs shall meet the requirements of §118(i).

3.2 Fenestration

Windows, glazed doors, and skylights have a large impact on envelope-related 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. Fenestration, orientation, and shading play a major role in the building's energy use and can affect the operation of the HVAC system and the comfort of the occupants.

3.2.1 Mandatory Measures

The mandatory measures for doors, windows, and skylights address the air-tightness of the units and how their U-factor and SHGC are determined. Fenestration products must be labeled with a U-factor and SHGC, and the manufacturer or an independent certifying organization must certify that the product meets the air infiltration requirements of §116(a).

Certification and Labeling

§10-111 and §116
Reference Nonresidential Appendices NA6

The Administrative Regulations §10-111 and §116 require that fenestration products have labels that list the U-factor, the solar heat gain coefficient (SHGC), and the methods used to determine those values. The label must also certify that the fenestration product meets the requirements for air leakage. The air leakage requirements are specified in §116 and limit the infiltration rate to 0.3 cfm/ft² for most products.

Manufactured (Factory-Assembled) Fenestration Label Certificates

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

1. 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). If the manufactured fenestration product is rated using the NFRC Rating Procedure, it must also be permanently labeled in accordance with NFRC procedures.
2. The manufacturer can choose to use §116 default values for U-factors and SHGC. If default values are used, the manufacturer must attach a temporary label meeting specific requirements (permanent labels are not required). Product meets the air infiltration requirements of §116(a)1,
U-factor criteria of §116(a)2, and SHGC criteria of §116(a)3, in the *Building Energy Efficiency Standards for Residential and Nonresidential Buildings.*

Figure 3-1 shows a sample default temporary label. Where possible, it is best to select fenestration that is NFRC-rated, and to do so before completing compliance documents. This enables the use of NFRC-certified data to be used for compliance purposes.

Default Temporary Label

Although there is no exact format for the default temporary label, it must be clearly visible and large enough for the enforcement agency field inspectors to read easily and it must include all information required by the regulations. The suggested label size is 4 in. x 4 in. The label must have the words **"California Energy Commission Default U-factor"** followed by the correct value for that fenestration product from Table 116-A in the Standards and the words **"California Energy Commission Default SHGC"** followed by the correct value from Standards Table 116-B. The U-factor and SHGC default values should be large enough to be visible from 4 ft. For skylights, the label must indicate when the product was rated with a built-in curb.

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. Placing the term "**Meets Thermal-Break Default Criteria"** on the temporary label can do this.

California Energy Commission Default Label	XYZ Manufacturing Co.
Key Features:	Double-pane Operable Metal, Thermal Break Air space 7/16 in. or greater Tinted
California Energy Commission Default U-factor 0.61	**California Energy Commission** Default SHGC 0.53
Product meets the air infiltration requirements of §116(a)1, U-factor criteria of §116(a)2, and SHGC criteria of §116(a)3, 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.	

Figure 3-1– Sample Default Temporary Label

Site-Built Label Certificates

Site-built fenestration is fenestration designed to be field-glazed or field-assembled using specific factory-cut or otherwise factory-formed framing and glazing units that are manufactured with the intention of being assembled at the construction site. Site-built fenestration must either have an NFRC label certificate or use default values. Site-built fenestration may be pre-assembled off-site by the glazing contractor. The glazing contractor may pre-assemble the site-built fenestration. Examples of site-built fenestration include storefront systems, curtain walls, and atrium roof systems. Site-built fenestration in large projects (more than or equal to 10,000 ft² of site-built fenestration area, which includes windows, non-opaque doors, and skylights) must have either a label certificate issued by NFRC that is filed in the contractor's project office during construction and in the building manager's office after construction, or a label certificate issued by the glazing fabricator using California Energy Commission Default U-factor and SHGC. For further discussion of the NFRC's new Component Modeling Approach (CMA), see below.

For site-built fenestration products, the glazing contractor will likely generate the label certificate after the construction project is awarded. For compliance purposes, the designer should select a U-factor and SHGC for the fenestration system that is reasonable and achievable. For site-built fenestration that will be NFRC-certified, the certified data should be modeled for compliance purposes. If the fenestration is not NFRC-certified, the designer should model the appropriate default U-factor and SHGC for the glass and frame type selected from Table 116-A and Table 116-B or the alternative equations for U-factor and SHGC in Reference Nonresidential Appendix NA6. Note that the Reference Nonresidential Appendix NA6 equation for default U-factors and SHGC can only be used in buildings with less than 10,000 ft² of site-built fenestration. Use California Energy Commission's Fenestration Certificate FC-1/FC-2 to document the values for less than 10,000 ft².

For site-built fenestration of 10,000 ft² and greater, which includes windows, non-opaque doors, and skylights, use NFRC-certified products with NFRC Label Certificates or for non NFRC-certified products, use California Energy

Commission default values from Table 116-A for U-factors or Table 116-B for SHGC and use Fenestration Certificate FC-1/FC-2 to document the values.

For site-built fenestration products, a Label Certificate can take the place of the temporary label and the permanent label. For site-built fenestration products that are not rated through the NFRC 100 or 200 procedures, a Default Label Certificate can be provided by the person (e.g., architect, responsible party, glazing contractor, extrusion manufacturer, IG fabricator or glass manufacturer) taking responsibility for fenestration compliance using California Energy Commission's Default Fenestration Label Certificates FC-1/ FC-2 approved by the Energy Commission. See example on page 3-124.

A FC-1/ FC-2 Default Label Certificate should be completed for each product line that results in a different U-factor and SHGC. The Default Label Certificate should state the total amount of this product line throughout the project, the locations in the project where the product line is installed, and the pages in the drawings and fenestration schedule that show this product line. The Default Label Certificate 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 must also be attached to the plans.

The Default Label Certificate may also include the visible (light) transmittance (VT) factor to determine whether daylit area credit may be taken in conjunction with daylighting controls. The person taking responsibility for fenestration compliance can choose to attach Default Temporary Labels to each fenestration product as described in the previous paragraph instead of providing Default Label Certificates for each product line.

NFRC's New Component Modeling Approach (CMA) Product Certification Program and the Energy Standards

The National Fenestration Rating Council ("NFRC") has developed a new commercial certification product program that rates whole fenestration products to include site-built fenestration in accordance with NFRC 100 and NFRC 200. This new approach determines the U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT) of a product faster and more accurately without actual physical laboratory testing in most cases. Such results can be used in a pre-bid report or for other energy performance analysis, and is used for obtaining an NFRC CMA Label Certificate.

Each component that makes up a fenestration product shall have values that are NFRC-approved and maintained by NFRC. NFRC's Approved Component Library Database includes the glazing, spacer and frame components. Each of the components is NFRC certified before they are inputted into the library's database.

The component manufacturers shall have their products approved by NFRC in accordance with the new NFRC 705-2009 Component Modeling Approach Product Certification Program (CMA-PCP). Before the components can be accepted into the Component Library Database they must be first verified by an

Independent Certification and Inspection Agency (IA), which has been licensed by NFRC.

The new NFRC CMA software tool may be used to obtain non-certified performance ratings and will be made available to the public through NFRC.

The calculations can be used in pre-design energy analysis and can also be used as a pre-bid tool. The CMA software tool assembles the chosen components, configures them into a whole fenestration product, and calculates the thermal performance of the whole product. This data can then be exported and used in a pre-bid report or for other energy performance analysis. However, to acquire an NFRC CMA Label Certificate, products must first meet NFRC's CMA Product Certification Program (CMA-PCP) requirements. Further details are available at www.NFRC.org.

Compliance for Specifiers

To comply with NFRC's new CMA approach:

1. The new NFRC-certified software tool will be used to calculate NFRC non-certified product ratings from the Component Library Database. The CMA software will be made available to the public through NFRC to calculate the energy product thermal performance. The resulting report can be used in pre-design energy analysis and can also be used as a pre-bid report;
2. The CMA software tool is designed to put together the chosen components as a whole fenestration product and simulate the thermal performance of the whole product. The software tool prints out a report in which provides the thermal performance of the product. The report can be used in a pre-bid report or for other energy performance analysis. However, the report is not an NFRC-approved label certificate. To acquire an NFRC-approved label certificate, products must first meet NFRC's CMA Product Certification Program (CMA-PCP, NFRC 705-2008) requirements and sign the applicable NFRC license agreement. Further details will be available at www.NFRC.org.

Note: Ensure that all NFRC Certified Label Certificates are registered with project site records for later energy Acceptance verification according to Reference Nonresidential Appendices NA7.

Field-Fabricated Fenestration

Field-fabricated fenestration is not the same as site-built fenestration. Field-fabricated fenestration is a very limited category of fenestration that is made at the construction site out of materials that were not previously formed or cut with the intention of being used to fabricate a fenestration product. No labeling is required for field-fabricated fenestration products. Field-fabricated fenestration and field-fabricated exterior doors may be installed only if the compliance documentation has demonstrated compliance using U-factors from Standards Table 116-A and SHGC values from Standards Table 116-B. The field inspector is responsible for ensuring field-fabricated fenestration meets the specific criteria described in Standards Tables 116-A and 116-B for the U-factor and SHGC used for compliance. Thermal break values do not apply to field-fabricated fenestration products.

Example 3-1

Question

A 150,000 ft² "big box" retail store has 2,000 ft² of site-built vertical fenestration located at the entrance. An operable 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 and SHGC of 0.50 and 0.70?

Answer

One of the following three methods may be used:

1. The site-built fenestration can be rated using NFRC-100 procedures for U-factors and NFRC-200 procedures for SHGC.

2. The second option for determining U-factor and SHGC may be to select from Default Standards Table 116-A and 116-B. From these tables, the U-factor is 0.79 and the SHGC is 0.73.

3. There is a third option for site-built fenestration that is less than 10,000 ft² in a building. In this case, site-built fenestration does not have to be rated through the NFRC 100 and NFRC-200 procedures and may use the default U-factor and SHGC values from equations in Reference Nonresidential Appendix NA6 as described in the following bullets:

- The Alternate U-factor may be calculated from the Reference Nonresidential Appendix NA6, Equation NA6-1, $U_T = C_1 + C_2 X U_C$. From Table NA-1 for metal frame site-built fenestration, C_1= 0.311 and C_2 = 0.872, therefore the overall U-factor is calculated to be 0.75.
- Likewise, the SHGC is determined from the Reference Nonresidential Appendix, NA6, Equation NA6-2, $SHGC_T = 0.08 + 0.86 \times SHGC_C$. Therefore, the SHGC is calculated to be 0.68.

A CEC Default Label Certificate, FC-1/FC-2, should be completed for each fenestration product line unless the responsible party chooses to attach Default Temporary Labels to each fenestration product throughout the building.

Example 3-2

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 gas. Two panes of glazing laminated together do not constitute double-pane glazing.

§116(a)1

Doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-1. For field-fabricated products or an exterior door, the 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 3-1 – Maximum Air Infiltration Rates

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

3.2.2 Window Prescriptive Requirements

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

1. Maximum area total plus west-facing
2. Maximum U-factor
3. Maximum relative solar heat gain

Window Area

§143(a)5.A.

Under the envelope component approach, the total window area may not exceed 40 percent of the gross wall area (encompassing conditioned space) for the building. Likewise, the west-facing window area may not exceed 40 percent of the west gross wall area (encompassing 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.

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

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

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

For glass doors, also use the rough opening area, except where the door glass area is less than 50 percent of the door, in which case the glazing area may be either the entire door area, or the glass area plus two 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. Glazing area in demising walls has no limit and any glazing in demising walls is not counted as part of the exterior wall/window ratio.

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 non-public spaces). The display perimeter is used for a special calculation of window area (§143(a)5A). Demising walls are not counted as part of the display perimeter.

In general, any orientation within 45° of true north, east, south or west will be assigned to that orientation. The orientation can be determined from an accurate site plan. Figure 3-2 indicates how surface orientations are determined and what to do if the surface is oriented exactly at 45° of a cardinal orientation. For example, an east-facing surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

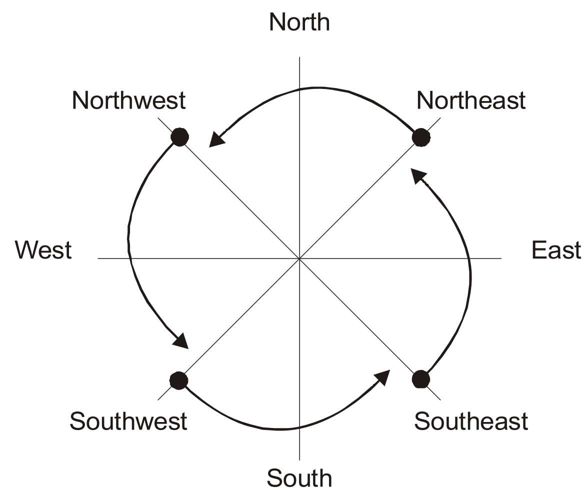


Figure 3-2 – Four Surface Orientations

Window U-factor

§143(a)5B

Each window must meet the required U-factor criteria (see Table 3-2). For nonresidential buildings, the U-factor criterion is 0.47 Btu/h-°F-ft² for the valley, desert and cold climates. The criterion is 0.77 Btu/h-°F-ft² for the middle coast and south coast climates.

In general, an NFRC-rated double-glazed, low-e window with a thermal break frame will comply with the 0.47 criterion, and an NFRC-rated double-glazed, low-e window with a standard frame will comply with the 0.77 criterion; however, other window constructions may comply. See www.NFRC.org, Certified Product Directory database or use Equation NA6-1in Reference Nonresidential Appendix NA6.

Table 3-2 – Window Requirements

		Climate Zones									
Space Type	Criterion	1,16		3-5		6-9		2,10-13		14, 15	
Nonresidential	U-factor	0.47		0.77		0.77		0.47		0.47	
	Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
	0-10% WWR	0.49	0.72	0.61	0.61	0.61	0.61	0.47	0.61	0.46	0.61
	11-20% WWR	0.43	0.49	0.55	0.61	0.61	0.61	0.36	0.51	0.36	0.51
	21-30% WWR	0.43	0.47	0.41	0.61	0.39	0.61	0.36	0.47	0.36	0.47
	31-40% WWR	0.43	0.47	0.41	0.61	0.34	0.61	0.31	0.47	0.31	0.40
Residential High-rise	U-factor	0.47		0.47		0.47		0.47		0.47	
	Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
	0-10% WWR	0.46	0.68	0.41	0.61	0.47	0.61	0.36	0.49	0.36	0.47
	11-20% WWR	0.46	0.68	0.40	0.61	0.40	0.61	0.36	0.49	0.31	0.43
	21-30% WWR	0.36	0.47	0.31	0.61	0.36	0.61	0.31	0.40	0.26	0.43
	31-40% WWR	0.30	0.47	0.26	0.55	0.31	0.61	0.26	0.40	0.26	0.31

Summary from Standards Tables 143-A and 143-B

Window Relative Solar Heat Gain

§143(a)5C

Each window or skylight must meet the required relative solar heat gain (RSHG) (see Table 3-2).

The required value for relative solar heat gain is less stringent (higher) for north-facing windows. Either an RSHG of 0.56 or the "north" value, whichever is greater, may be used for windows in the first floor display perimeter that are prevented from having an overhang because of building code restrictions (such as minimum separation from another building or a property line) (*Exception* to §143(a)5C). The relative solar heat gain criteria also depend on the window-wall ratio, becoming more stringent with larger window areas.

Note also that the RSHG limitation allows credit for window overhangs. In order to get credit for an overhang, it must extend beyond both sides of the window jamb by a distance equal to the overhang projection (§143(a)5Cii). This would occur naturally with a continuous eave overhang but may require special attention in some designs. See Section 3.2.6 for more information on RSHG.

3.2.3 Skylight Prescriptive Envelope Requirements

As with windows, there are three aspects of the envelope component approach for skylights:

1. Maximum area
2. Maximum U-factor
3. Maximum solar heat gain coefficient

Table 3-3 – Skylight Requirements

			Climate Zones				
			1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	U-factor	Glass w/Curb	1.11	1.11	1.11	1.11	1.11
		Glass w/o Curb	0.68	0.82	0.82	0.68	0.68
		Plastic	1.04	1.11	1.11	1.11	1.11
	SHGC Glass	0-2% SRR	N/R	0.57	0.57	0.46	0.46
		2.1-5% SRR	0.N/R	0.40	0.40	0.36	0.36
	SHGC Plastic	0-2% SRR	0.69	0.69	0.69	0.69	0.69
		2.1-5% SRR	0.57	0.57	0.57	0.57	0.57
Residential High-rise	U-factor	Glass w/Curb	1.11	1.11	1.11	1.11	1.11
		Glass w/o Curb	0.68	0.82	0.82	0.68	0.68
		Plastic	1.11	1.11	1.11	1.11	1.11
	SHGC Glass	0-2% SRR	0.46	0.57	0.57	0.46	0.46
		2.1-5% SRR	0.36	0.32	0.40	0.32	0.31
	SHGC Plastic	0-2% SRR	0.69,0.57	0.57	0.57	0.57	0.57
		2.1-5% SRR	0.55	0.39	0.57	0.34	0.27

Excerpt from Standards Tables 143-A and 143-B, Skylight Roof Ratio, SRR.

Skylight Area

§143(a)6A.

The area limit for skylights is 5 percent of the gross exterior roof area or skylight roof ratio (SRR). This effectively prevents large skylights under the envelope component approach. The limit increases to 10 percent for buildings with an atrium over 55 ft high (see Reference Joint Appendix JAI definition). The 55ft height is also the height limitation at which the California Building Code requires a mechanical smoke-control system for such atriums (CBC Sec. 909). This means that the 10 percent skylight allowance is not allowed for atriums unless they also meet this smoke control requirement. All skylights must meet the maximum U-factor criteria.

There are two ways that skylights can be mounted into a roof system, either flush-mounted or curb-mounted. In order to create a positive water flow around them, skylights are often mounted on "curbs" set above the roof plane. These curbs, rising 6 to 12 inches (15 to 30 centimeters) above the roof, create additional heat loss surfaces, right where the warmest air of the building tends to collect.

Skylight area of unit skylights is the area of the rough opening of a skylight. The rough framed opening is used in the NFRC U-factor ratings (NFRC U-factor ratings for manufactured skylights with integrated curbs include glazing, framing, and the curb) procedure; it is also the basis of the default U-factors in Reference Nonresidential Appendix NA6. For skylights, the U-factor represents the heat loss per unit of rough framed opening (the denominator). However, the heat loss (the numerator) includes losses through the glazing, the frame, and the part of the curb that is integral with the skylight and included in the skylight test. Portions of roof that serve as curbs that mount the skylight above the level of the roof (see Figure 3-3) are part of the opaque building envelope.

Site-built monumental or architectural skylights that are 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 and are treated differently. In such 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 (i.e., could be flat pyramid, bubble, barrel vault, or other three-dimensional shape). For special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5 Section 5.2.1 of this manual.

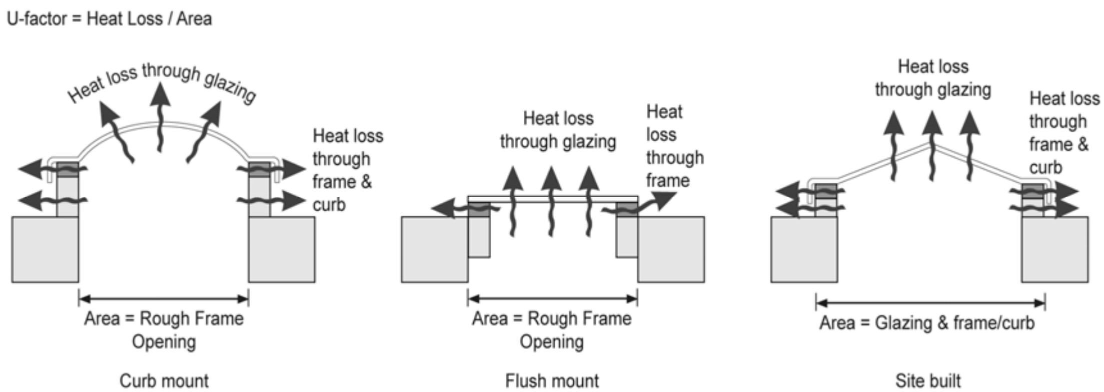


Figure 3-3 – Skylight Area

When skylights are specified, the designer must also calculate the skylit daylight area. If the total of the skylit daylight areas in a room exceed 2,500 ft², the skylit daylight area must be drawn on the plans. See Figure 3-5 below for an example of the skylit daylight area. See Section 5.2 of this manual for a detailed discussion of the daylight areas.

Skylight U-factor

§143(a)6B

For skylights, the U-factor and solar heat gain coefficient (SHGC) criteria is different, depending on whether the skylight glazing material is plastic or glass. For glass skylights, the U-factor criteria depend on whether or not the skylight is intended to be mounted on a curb. It is assumed that all plastic skylights are mounted on a curb. See Standards Tables 143-A, 143-B, and 143-C for U-factor requirements. As discussed above, the U-factor for skylights includes heat losses through the glazing, the frame and the integral curb (when one exists). In many cases, an NFRC rating does not exist for projecting plastic skylights. In this case, the designer can make use of the default fenestration U-factors in Standards Table 116-A.

If a glass skylight is installed and it is not possible to determine whether the skylight was rated with a curb, compliance shall be determined by assuming that the skylight must meet the requirements for skylights with a curb. All plastic skylight types are assumed to meet the requirements for plastic skylights with a curb.

Skylight SHGC

§143(a)6C

Skylights are regulated only for SHGC, not RSHG, because skylights cannot have overhangs. The SHGC criteria vary with the skylight to roof ratio (SRR). Two ranges are represented in the Standards: up to and including 2 percent of the exterior roof, and greater than 2 percent but less than or equal to 5 percent. See Standards Tables 143-A, 143-B, and 143-C for SHGC requirements. The designer can make use of default solar heat gain coefficients in Standards Table 116-B or use the Nonresidential Reference Appendix NA6 if less than 10,000 ft².

3.2.4 Daylighting Prescriptive Requirements for Skylights in Large Enclosed Spaces

§143(c)

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

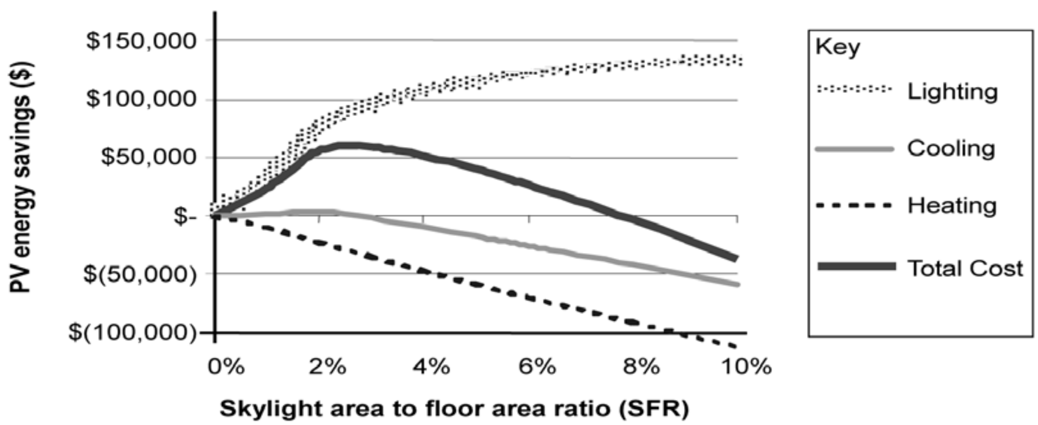


Figure 3-4 – Present Value Savings of Skylight 50,000 ft² Warehouse in Sacramento

Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required in enclosed spaces (rooms) that are larger than 8,000 ft², directly under a roof and have ceiling heights greater than 15 ft., and have lighting power densities greater than 0.5 W/ft². The demanding lighting control needs in auditoriums, churches, museums and movie theaters, and the need to minimize heat gains through the roofs of refrigerated warehouses, render these few occupancies exempt from the skylight requirement. Gymnasiums do not qualify for this exemption unless there is a stage or there is a determination that this space will be used to hold theatrical events.

Since skylights with controls reduce electric lighting, they are prescriptively required on all nonresidential occupancies that meet the above criteria, whether the space is conditioned or unconditioned. Single-glazed skylights are sufficient for unconditioned buildings such as unconditioned warehouses. Skylights over conditioned spaces must meet the U-factor and SHGC requirements in §143(a).

3.2.5 Minimum Skylight Area for Large Enclosed Spaces

§143(c)

Minimum skylight area for large enclosed spaces with three or fewer stories applies to low-rise conditioned or unconditioned enclosed spaces that meet the following conditions:

1. In climate zones 2 through 15
2. A room that is greater than 8,000 ft²
3. Directly under a roof
4. Ceiling heights greater than 15 ft
5. A lighting power density for general lighting equal to or greater than 0.5 w/ft²

A. Daylit Area

§143(c)1

At least one half of the floor area shall be in the skylit area under skylights and the skylit are shall be shown on the building plans.

Skylit area is defined in §131(c)1D.

B. Minimum Skylight Area or Effective Aperture

§143(c)2

Areas that are skylit shall have a minimum skylight area to skylit area ratio of at least 3.3 percent or minimum skylight effective aperture of at least 1.1 percent. The skylit effective aperture shall be determined as specified in Equation 3-1.

Equation 3-1 (Standards Equation 146-C) – Effective Aperture of Skylights

$$\text{Skylit EA} = \frac{0.85 \text{ x} \sum \text{Skylight Area x VT x Well Efficiency}}{\text{Daylit Area Under Skylights}}$$

Skylit EA is the product of the well efficiency (WE), the transmittance of the glazing and accessories (Glazing VT), an 85 percent dirt factor and the skylight area to daylit area ratio. The Glazing VT is the product of the visible light transmittance of the skylight glazing and all components in the light well that might reduce light transmission such as louvers, diffusers, etc. The visible light transmittance of movable accessories (such as louvers, shades, etc.) is rated in the full open position. For more details on how to calculate Skylit EA, refer to Chapter 5 of this manual.

Though §143(c)1 requires that at least half of the floor space be daylit and that the ratio of skylight area to skylit area be 3.3 percent, there are maximum skylight area requirements whenever the skylights are above conditioned spaces. §143(a)6 limits skylight area to 5 percent of the gross roof area in most cases and to 10 percent of the roof area for atria over 55 ft.

C. Skylight Characteristics

§143(c)3

Skylights installed to comply with the minimum skylight area for large enclosed spaces shall:

1. 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.
2. If the space is conditioned, meet the requirements in §143(a)6 or §143(b). In general, these requirements require the use of double-glazed skylights. When the skylights are above unconditioned spaces, there is no limitation placed on skylight area or its U-factor or SHGC.

If the space is unconditioned, single-glazed skylights will comply with the code requirements as long as they are sufficiently diffusing (i.e. the glazing or diffuser material has a haze rating greater 90 percent). Products that have such a rating include prismatic diffusers, laminated glass with diffusing interlayer's, pigmented plastics, etc. The purpose of this requirement is to assure the light is diffused over all sun angles.

Other methods of diffusion that result in sufficient diffusion of light over the course of 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 of a diffuse surface prior to entering the space over all sun angles encountered during the course of a year. This alternative method of diffusion would have to be documented by the designer and approved by the code authority in your jurisdiction.

D. Controls

§143(c)4

Electric lighting in the daylit area shall meet the mandatory control requirements in §131(c)2. These control requirements include controlling at least 50 percent of the general lighting in the skylit daylight areas separately from other lighting in the enclosed space, controlling luminaires in primary sidelit areas separately from skylit areas, in addition to other lighting control requirements. See Section 5.2.1 for more information about lighting control requirements and for more information about daylighting control requirements.

E. Exceptions

The following spaces are not required to have a minimum skylight area:

1. Auditoriums, churches, movie theaters, museums, and refrigerated warehouses
2. Buildings with unfinished interiors, future enclosed spaces where it is planned to have ≤ 8,000 ft² of floor area, or ceiling heights ≤ 15 ft, based on proposed future interior wall and ceiling locations as delineated in the plans. This exception shall not apply to these future enclosed spaces when interior walls and ceilings are installed for the first time, the enclosed space floor area is > 8,000 ft², and the ceiling height > 15 ft [See §149(b)1M]. This exception shall not be used for S-1 or S-2 (storage), or for F-1 or F-2 (factory) occupancies.

3. Enclosed spaces having a designed general lighting system with a lighting power density < 0.5 W/ft².

When skylights are prescriptively required by §143(c), at least one half of the floor area in the enclosed space must be in the “daylit area.” New in 2008 , trade-offs are allowed between skylights and windows as long as the minimum daylit area threshold (50 percent of eligible enclosed space area) is met. There are specific definitions and geometries for daylit areas under skylights and those near windows. It is allowed to have a combination of windows and skylights as long as there is no double-counting of the overlapping daylit areas when meeting the 50 percent space area threshold. Definitions of the daylit area under skylights and near windows are explained in Section 5.2.1 of this manual.

Designing with Skylights to Meet §143(c) Requirements

The skylight area must be a minimum fraction of the daylit area or minimum skylight aperture, and the skylights must be diffusing (haze rating greater than 90 percent). The purpose of this haze requirement for skylight glazing is to assure the light is diffused over all sun angles. Other methods of diffusion that result in sufficient diffusion of light over the course of the entire year would also be acceptable in lieu of using diffusing glazing. Acceptable alternatives are baffles or reflecting surfaces that ensure that direct beam light is reflected off a diffuse (matte) surface prior to entering the space for all sun angles encountered during the course of a year. This alternative method of diffusion would have to be documented by the designer and approved by the code authority in your jurisdiction. To determine the number and spacing of skylights that are required to meet the “daylit area under skylights” requirements, the effect of the skylight spacing, size of skylights, and interaction with other building components must be determined. These parameters are described in “daylit area under skylights” as defined in §131(c) of the Mandatory Requirements for Lighting Systems. Refer to Section 5.2.1 as it describes the daylit area and the mandatory electric lighting controls for the daylit area.

As ceiling heights increase, the daylit area under a skylight increases. To maintain the minimum skylight area to daylit floor area ratio, one must either increase the skylight size or increase overlap between daylit areas (space skylights closer together).

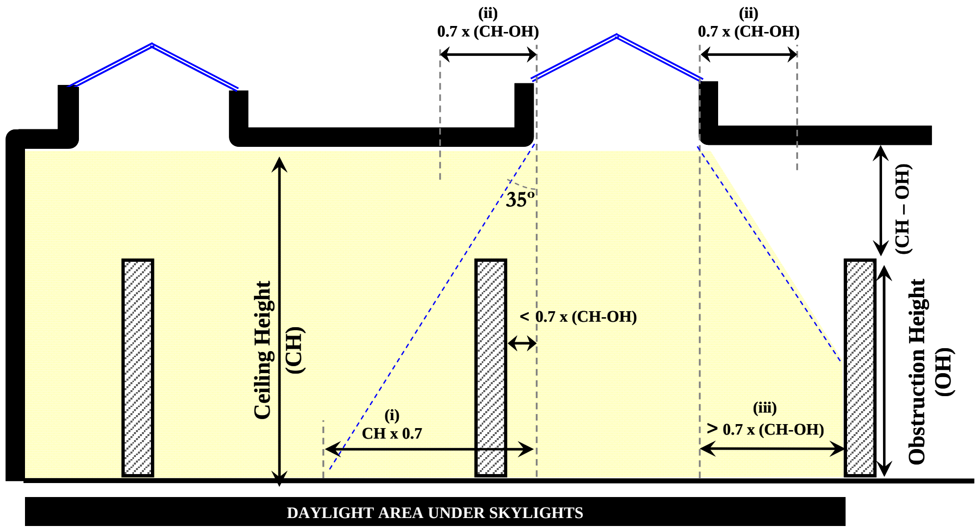


Figure 3-5 – Daylit Area under Skylights

For good uniformity of illumination, the daylit areas under skylights should overlap. In the case of multiple skylights in a space, the skylight area to daylight area ratio will be the total skylight area (number of skylights times the area per skylight) to the total daylit area under skylights (often the area of the entire space).

While §143(a)6A caps the skylit area to 5 percent of the gross exterior roof area, §143(c)2 also requires that the total skylight area be a minimum of 3.3 percent of the daylit area under skylights (explained in Section 5.2.1 of this manual). §143(c)2 also requires that the skylights have an effective aperture of at least 1.1 percent.

The skylight effective aperture (as defined in Standards Equation 146-C in §146(a)2Eiii) is a measure of the skylight system's transmittance including light loss due to dirt, transmittance of glazing, transmittance of louvers, diffuser or other light controlling elements, and transmittance of the light well (well efficiency). See Chapter 5 of this manual for more information on how to calculate effective aperture for skylights.

It should be noted that the skylight requirements in the Standards specify the minimum amount of skylight area needed to meet code; you can install more skylight area. In some cases, additional energy savings from lighting can be realized by increasing the skylight area. However, too much skylight area will result in increased mechanical loads that may outweigh the electric light savings (see Figure 3-6). The optimal skylight area can be calculated by some building energy simulation programs (EnergyPro, DOE-2, EnergyPlus, TRNSYS, SkyCalc, etc.) that perform an hourly annual calculation of both the electric lighting and HVAC impacts of skylights. Contact the energy efficiency program staff at your local energy provider for more information on how your skylight system can be optimized for energy savings.

When skylights are used to save energy by displacing electric lighting, they must be diffusing so that the light is spread broadly illuminating a relatively wide area around the skylight and so that excessive glare is avoided. When either the skylight glazing or the diffuser or lens on the light well is measured according to ASTM D1003[1] and has a haze

[1] ASTM D1003-00 Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics. American Society for Testing and Materials, West Conshohocken, PA

rating greater than 90 percent, the skylight system is deemed to be "diffusing" and complies with the haze value requirement of §143(c)3. For any skylight you are considering for compliance with §143(c), contact the skylight manufacturer and ask for documentation of the haze rating of the skylight glazing. Almost all diffusing skylights comply with this requirement. Clear or bronze skylights usually do not comply and must have a separate diffuser with a haze rating of greater than 90 percent to make the skylight system comply.

Any skylight system that is used to comply with §143(c) invokes the mandatory control requirements in §131(c)2 for automatic lighting controls in the daylit area under skylights. When the total daylit area under skylights exceeds 2,500 ft², the general lighting must be controlled by an automatic multi-level daylighting control or a multi-level astronomical time switch. See Chapter 5 in this manual for a detailed discussion of these mandatory controls.

The requirements of §143(c) apply to new large open spaces such as warehouses and medium to large retail. These requirements also apply when a large space such as a warehouse is conditioned for the first time or when the lighting system is installed for the first time §149(b)1F. Thus when applying for a permit for a warehouse or other large nonpartitioned structure without submitting a lighting plan, one should determine in advance its final use, as installing skylights while the shell is being constructed is less expensive then retrofitting them later.

Substituting Skylights with Windows to Meet §143(c) Requirements

The Standards allow the daylighting area requirements for spaces affected by §143(c) to be fulfilled by using a combination of skylights and windows. One may choose to provide all daylighting through windows alone, skylights alone or a combination of both.

It is important to note that the Standards prohibit double-counting of daylit areas that may be served by multiple skylights or windows due to close spacing of the skylights or windows.

The example in Figure 3-6 below shows a space with daylighting provided through two skylights in the roof and one window mounted high on the external wall. The primary sidelit daylight area can only be used to satisfy part of §143(c), if the primary sidelit effective aperture is greater than 10 percent.

The EA for primary sidelit area is a product of the window area, the VT of the window and the primary sidelit daylit area.

Equation 3-2 (Standards Equation 146-A) – Effective Aperture of the Primary Sidelit Area

$$\text{Primary Sidelit Effective Aperture} = \frac{\sum \text{Window Area x VT}}{\text{Primary Sidelit Daylit Area}}$$

Where:

Window Area = rough opening of windows adjacent to the sidelit area, ft²

Window VT = visible light transmittance of window as reported by the window manufacturer, no units

See Chapter 5 for more details on how to calculate the primary sidelit effective aperture and a detailed definition of the primary sidelit daylight area.

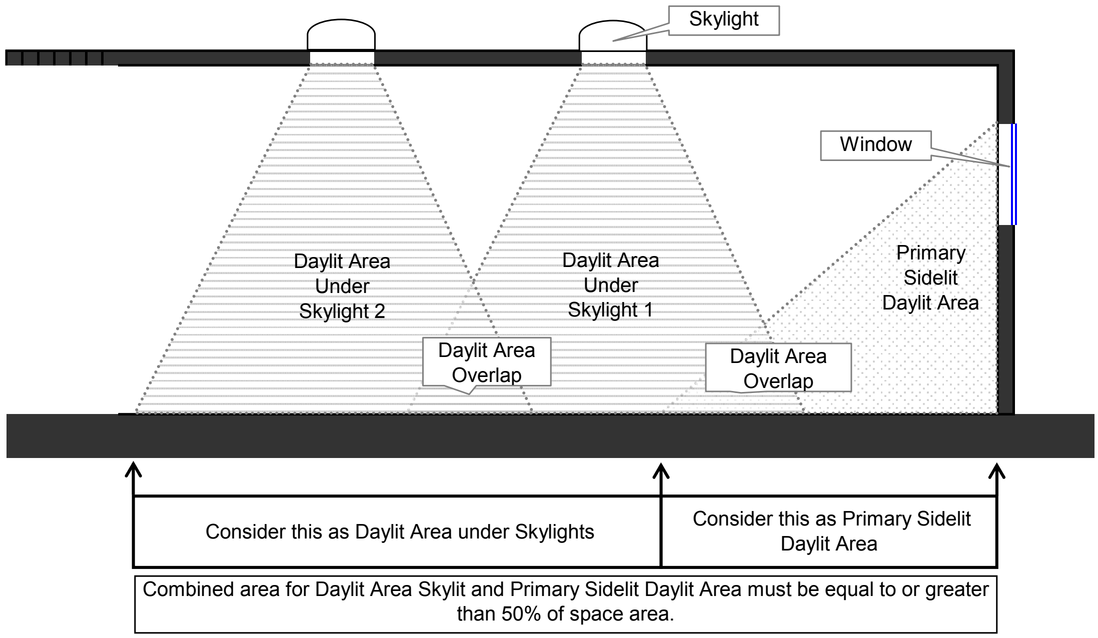


Figure 3-6 – Daylit Area Tradeoff between Skylights and Windows

In order to calculate the total daylit area in this scenario, the following logic must be used:

1. Calculate the Primary Sidelit Daylit Area near the window as explained in Chapter 5 of this manual.
2. If the Primary Sidelit Daylit Area thus calculated is greater than 50 percent of the total floor area of the space, there is no need for additional windows or skylights to meet the requirements of §143(c)
3. If the Primary Sidelit Daylit Area is less than 50 percent of the floor area of the space, skylights need to be added in order to reach the 50 percent space area threshold.
4. Calculate Daylit Area under Skylights as explained in Chapter 5 of this manual.
5. Subtract any overlaps in daylit areas due to multiple skylights or due to windows and skylights spaced close to each other.
6. Add the net Daylit Area under Skylights (minus the overlaps) to the Primary Sidelit Daylit Area to get the Total Daylit Area in space.
7. As long as the Total Daylit Area in space is equal to or greater than 50 percent of the floor area of the space, the requirements of §143(c) are met.

It is important to note that any skylights used to achieve the required Total Daylit Area must meet all applicable requirements for Diffusion, U-Factor and SHGC as defined in §143(c)3.

Any windows used to achieve the required Total Daylit Area must meet appropriate requirements of §143(A)5The general lighting in the space must also meet the lighting controls requirements in §131(b) and §131(c)2, as explained in Chapter 5 of this manual.

Example 3-3

Question

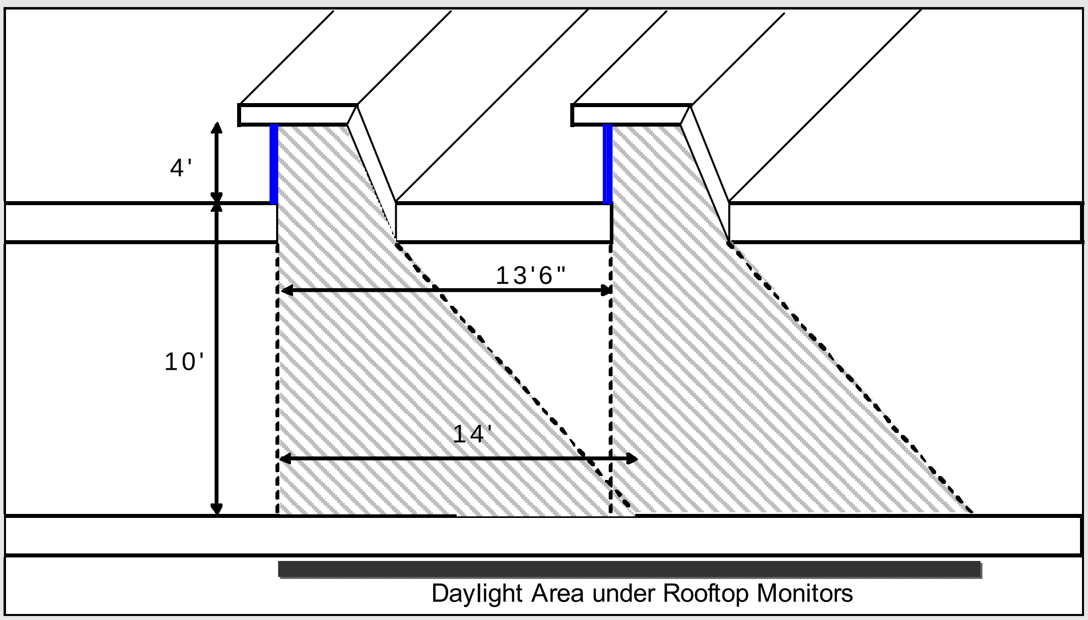
Are rooftop monitors considered to be windows or skylights?

Answer

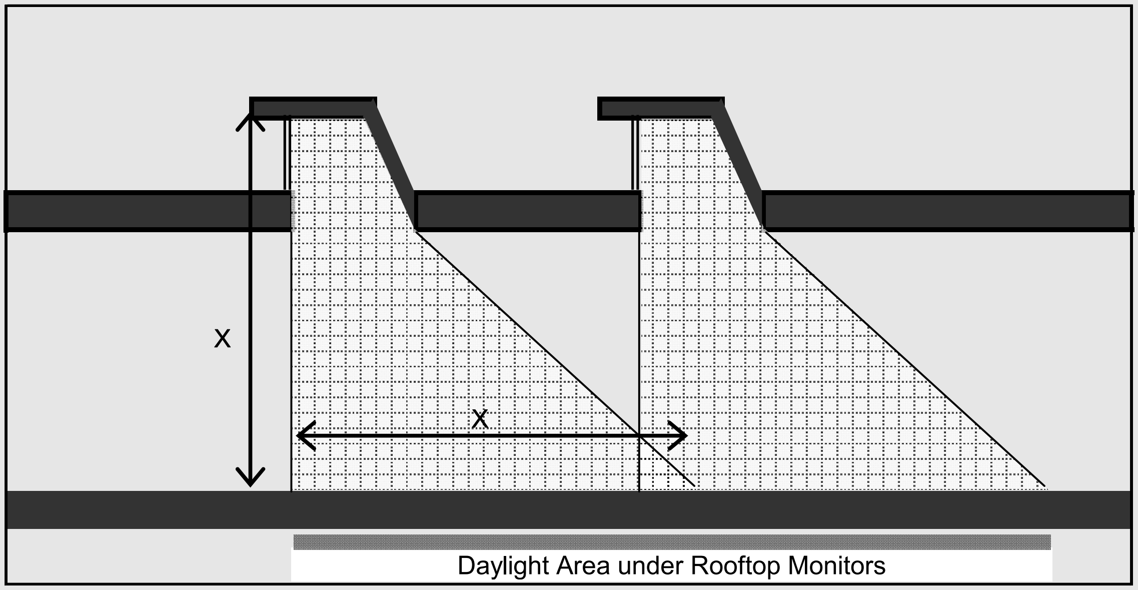
Standards currently define skylights as glazing having a slope less than 60 degrees from the horizontal with conditioned or unconditioned space below. Since rooftop monitors have a slope greater than 60 degrees, they are therefore considered to be windows. To qualify for power adjustment factors (PAF), rooftop monitors must comply with the automatic control requirements for windows.

The daylit area by windows is calculated as if they were in an exterior wall. The daylit area extends 2 ft on either side of the monitor window and one window head height perpendicular into the room or to the closest partition that is greater than 5 ft tall. The figure below shows a section view of the daylit area under rooftop monitors.

Section view of daylit area under rooftop monitors



Section view of daylit area under rooftop monitors



3.2.6 Determining Fenestration U-factors

§116 and §141(c)4D

The U-factor for a fenestration product describes the rate of heat flow through the entire unit, not just the glass or plastic glazing material. The U-factor includes the heat flow effects of the glass, the frame, and the edge-of-glass conditions (there also may be spacers, sealants and other elements that affect heat conduction). For skylights mounted on a curb that is part of the roof construction, the total heat flow considered in determining the U-factor includes losses through the frame, glazing and other components, but not through the curb that is part of the roof construction.

Standards Tables 143-A, 143-B, and 143-C, lists skylight product that includes a curb, and the effects of this curb are included in the product U-factor rating. This curb included in the product rating is separate from the curb that is a part of the roof construction. For projecting windows (greenhouse windows), the total heat flow includes the side panels, base and roof of the projecting window assembly. However, the area used to determine the U-factor for skylights and projecting windows is the rough-framed opening. Using the rough-framed opening eases the process of making load calculations and verifying compliance, since the rough-framed opening is easier to calculate than the actual surface area of the projecting window or skylight.

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

Table 3-4 Shows acceptable procedures for determining fenestration U-factors for four classes of fenestration; manufactured windows, manufactured skylights, site-built fenestration, and field-fabricated fenestration.

Table 3-4 – Acceptable Methods for Determining U-factors

Fenestration Class				
U-factor Determination Method	**Manufactured Windows**	**Manufactured Skylights**	**Site-Built Fenestration**	**Field-Fabricated Fenestration**
NFRC 100	✓	✓	✓	
Default U-factors from Standards Table 116-A	✓	✓	✓	✓
Alternate Default U-factor equation from Reference Nonresidential Appendix NA61,2		✓	✓	
Note 1: The default U-factors from Nonresidential Reference NonresidentialAppendixNA6may also be used for site-built skylights. *Note 2: The default U-factors from Reference Joint Appendix NA6 may be used only for site-built fenestration in buildings having less than 10,000 ft² of site-built fenestration area.*				

The preferred methods for determining fenestration U-factor are those in NFRC 100 for manufactured windows and for site-built fenestration. For manufactured windows, the default U-factors in Standards Table 116-A (reproduced in Table 3-5 below) must be used if NFRC-determined U-factors are not available. These U-factors represent the high side of the range of possible values, thereby encouraging designers to obtain ratings through NFRC procedures, when they are available.

NFRC U-factors are becoming more common for skylights; increasingly, more manufacturers are getting NFRC labels for their skylights, including tubular skylights (which includes U-factor), and SHGC. If NFRC data is not available, the Alternative Default U-factor equation from Reference Nonresidential Appendix NA6, Equation NA6-1 may be used for skylights. This equation is derived from NFRC-100 and represent average typical values, as opposed to the values published in Table 116-A in the Standards that are on the high side of the range of typical values.

The recommended method for determining the U-factor of site-built fenestration systems (curtain walls and storefront systems) is the NFRC 100 procedure. This requires that site-build fenestration, including curtain walls, go through the NFRC process for obtaining label certificates for site-built products. If the building has less than 10,000 ft² of site-built fenestration area, which includes windows, non-opaque doors, and skylights, then U-factors used for compliance for site-built products may instead be calculated from Equation NA6-1 from the Reference Nonresidential Appendix NA6, or Standards default values from Table 116-A.

For buildings with more than 10,000 ft² of site-built fenestration area, there are two compliance choices with regard to U-factor and labeling of site-built fenestration:

1. Go through the NFRC process and obtain a label certificate. This is the option described in §10-111(a)1A.
2. Provide a default label certificate using the default U-factors from Standards Table 116-A. This option results in very conservative U-factors.

Field-Fabricated Fenestration Product or Exterior Door

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

For field-fabricated fenestration, the U-factor and solar heat gain coefficient are default values (see Standards Tables 116-A and 116-B).

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

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

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

Table 3-5 – Standards Table 116-A Default Fenestration Product U-Factors

FRAME TYPE[1,2]	PRODUCT TYPE	SINGLE PANE U-FACTOR	DOUBLE-PANE U-FACTOR	GLASS BLOCK U-FACTOR1
Metal	Operable	1.28	0.79	0.87
Metal	Fixed	1.19	0.71	0.72
Metal	Greenhouse/garden window	2.26	1.40	N/A
Metal	Doors	1.25	0.77	N/A
Metal	Skylight	1.98	1.3	N/A
Metal, Thermal Break	Operable	N/A	0.66	N/A
Metal, Thermal Break	Fixed	N/A	0.55	N/A
Metal, Thermal Break	Greenhouse/garden window	N/A	1.12	N/A
Metal, Thermal Break	Doors	N/A	0.59	N/A
Metal, Thermal Break	Skylight	N/A	1.11	N/A
Nonmetal	Operable	0.99	0.58	0.60
Nonmetal	Fixed	1.04	0.55	0.57
Nonmetal	Doors	0.99	0.53	N/A
Nonmetal	Greenhouse/garden windows	1.94	1.06	N/A
Nonmetal	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.

3.2.7 Determining Relative Solar Heat Gain

§143(a)5C

Relative solar heat gain (RSHG) is essentially the same as SHGC, except for the external shading correction. It is calculated by multiplying the SHGC of the fenestration product by an overhang factor. If an overhang does not exist, then the overhang factor is 1.0.

Overhang factors may either be calculated (see Figure 3-7) or taken from Table 3-6 below and depend upon the ratio of the overhang horizontal length (H) and the overhang vertical height (V). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing, as shown in Figure 3-7. An overhang factor may be used if the overhang extends beyond both sides of the window jamb a distance equal to the overhang projection [§143(a)5Cii]. The overhang projection is equal to the overhang length (H) as shown in Figure 3-7. If the overhang is continuous along the side of a building, this restriction will usually be met. If there are overhangs for individual windows, each must be shown to extend far enough from each side of the window.

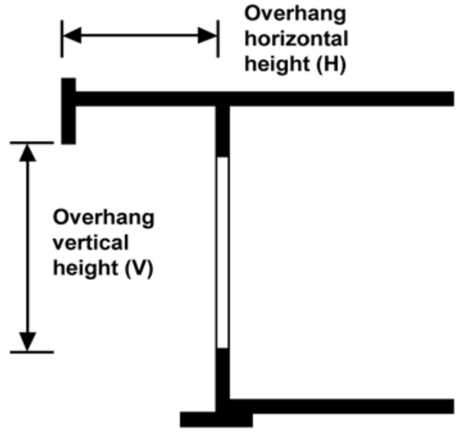


Figure 3-7– Overhang Dimensions

Equation 3-3 – Relative Solar Heat Gain

RSHG = $SHGC_{win}$ x OHF

Where

RSHG = Relative solar heat gain.

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

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

Where:

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

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

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

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

Table 3-6 – Overhang Factors

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

To use Table 3-6, measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cut-off point of the overhang (V). Then calculate H/V. Enter the table at that point. If the calculated H/V falls between two values in the Table 3-6, choose the next higher value to the calculated H/V value from the Table. Move across to the column that corresponds to the orientation of the window and find the overhang factor. Note that any value of H/V greater than one has the same overhang factor (for a given orientation) shown in the last row of the table.

Figure 3-8 graphs the overhang factors of the various orientations as a function of H/V. It shows that overhangs have only a minor effect on the north (maximum reduction in SHGC is only about 20 percent). East, west and south overhangs can achieve reductions of 55–60 percent. The benefits of the overhang level off as the overhang becomes large. (*Note:* this graph is presented only to illustrate the benefits of overhangs.)

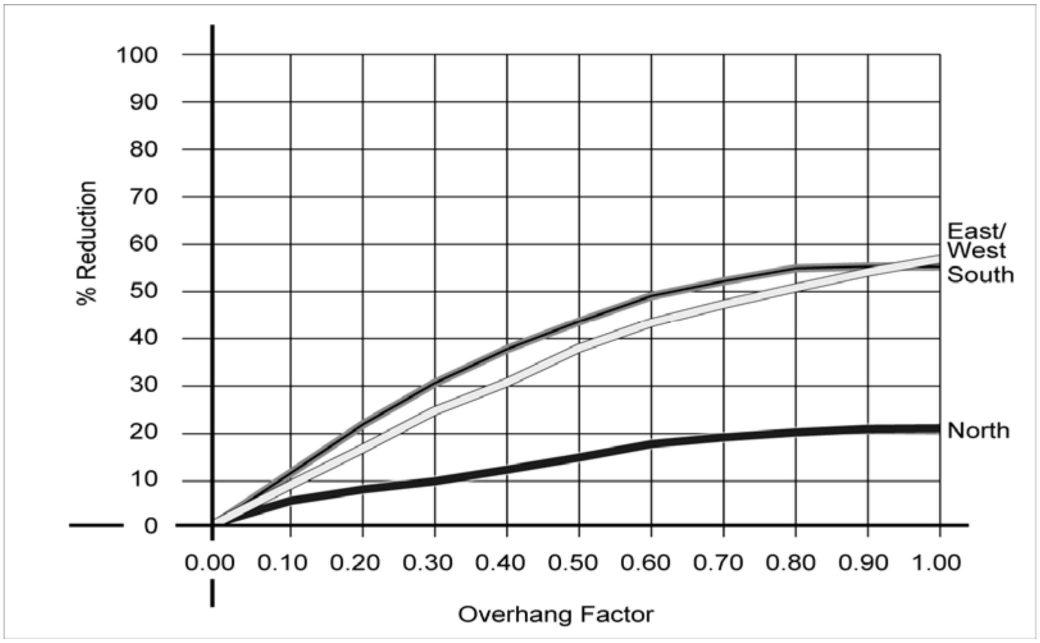


Figure 3-8 – Graph of Overhang Factors

Example 3-4

Question

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

Answer

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

3.2.8 Determining Solar Heat Gain Coefficients

§141(c)5

The solar heat gain coefficient (SHGC) is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. The lower the SHGC, the less solar heat gain. For SHGC measurements, the solar radiant energy includes infrared, visible light and ultraviolet. A low SHGC reduces solar heat gains, thereby reducing the amount of air conditioning energy needed to maintain comfort in the building. A low SHGC may also increase the amount of heat needed to maintain comfort in the winter. The technical definition of SHGC is the ratio of solar energy entering the window (or fenestration product) to the amount that is incident on the outside of the window. As with U-factors, the window frame, sash and other opaque components, and type of glazing affect SHGC.

There are four acceptable methods for determining SHGC for use with the Standards (see Table 3-8). The preferred methods are two NFRC procedures:

1. NFRC 200 for manufactured fenestration, which includes manufactured skylights; and NFRC 100 for site-built fenestration, which includes site-built skylights. The NFRC standard for rating the SHGC of tubular daylighting devices (TDDs or tubular skylights) is appropriate only for attic configurations where the insulation layer is directly on top of the ceiling.
2. For spaces with insulated roofs, use the NFRC or default rating of the top dome only.
3. A third method is to use the SHGC Defaults from Standards Table 116-B or (see Table 3-7). These values are on the high side and do not account for special coatings and other technologies that may be part of a proposed fenestration product.

Table 3-7 – Standards Table 116-B Default Fenestration Product SHGC

FRAME TYPE	PRODUCT	GLAZING	TOTAL WINDOW SHGC		
			SINGLE PANE	DOUBLE-PANE	GLASS BLOCK[1]
Metal	Operable	Clear	080	0.70	0.70
	Fixed	Clear	08.	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
1. Translucent or Transparent panels shall use glass block values.					

The fourth method, applicable only to skylights and site-built fenestration in buildings with less than 10,000 ft² of site-built fenestration, is to use Equation NA6-2 in the Reference Nonresidential Appendix NA6. This equation calculates an overall SHGC for the fenestration ($SHGC_t$) assuming a default framing factor and using the center-of-glass SHGC value ($SHGC_c$) for the glazing from the manufacturer's literature.

Note: Buildings that have 10,000 ft² or more of site-built fenestration cannot use the Alternative Default Fenestration Procedure, Equation NA6-1 or NA6-2.

Windows are not allowed SHGC credit for any interior shading such as draperies or blinds. Only exterior shading devices such as shade screens permanently attached to the building or structural components of the building can be modeled through performance standards compliance. Manually operable shading devices cannot be modeled. Only overhangs can be credited using the relative solar heat gain procedure for prescriptive compliance.

Table 3-8 – Methods for Determining SHGC

SHGC Determination Method	Manufactured Windows	Manufactured Skylights	Site-Built Fenestration	Field-Fabricated Fenestration
NFRC 200	✓	✓ (Note 2)		
NFRC 100			✓	
Default SHGC values from Standards Table 116-B)	✓	✓	✓	✓
SHGC alternative procedure from Reference Nonresidential Appendix NA6, Equation NA6-2		✓	✓(Note 1)	

Note 1: The SHGC procedure defined in Reference Nonresidential AppendixNA6 may be used only for site-built fenestration in buildings that have less than 10,000 ft² of site-built fenestration area. Site-built fenestration includes site-built skylights.

Note 2: Tubular Daylight Device SHGC rating is appropriate only for insulated ceilings.

3.2.9 Determining Visible Transmittance (VT)

Visible Transmittance (VT) is a property of glazing materials that has a varying relationship to SHGC. VT is the ratio of light that passes through the glazing material to the light that is incident on the outside of the glazing. Light is the portion of solar energy that is visible to the human eye. VT is an important characteristic of glazing materials, because it affects the amount of daylight that enters the space and how well views through windows are rendered. Glazing materials with a very low VT have little daylighting benefit and views appear dark, even on bright days. The ideal glazing material for most of California's summer climates would have a high VT and a low SHGC. Such a glazing material would allow 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 20 percent or so higher than the SHGC. Higher VT can result in energy savings in lighting systems. The value of VT for a given material is found in the manufacturer's literature.

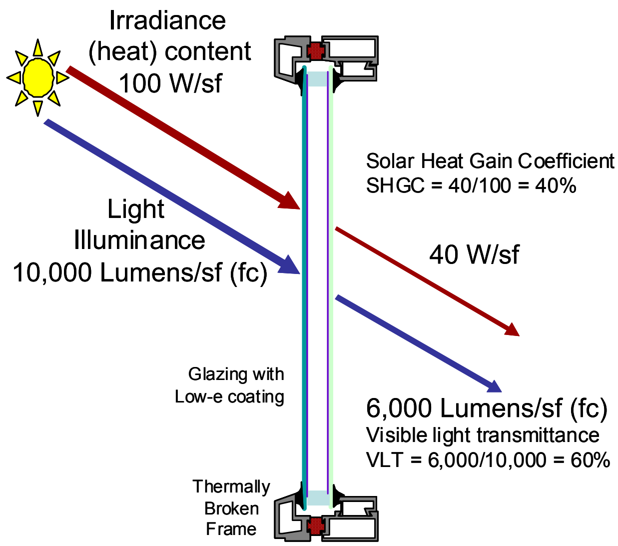


Figure 3-9 – Visible Light Transmittance

The visible light transmittance is used in the calculation of the effective aperture of daylighting systems and daylighting control power adjustment factors. This is discussed in more detail in Chapter 5 of this manual.

3.2.10 Site-Built Fenestration Roles and Responsibilities

§116, §10-111

Manufactured fenestration products are factory-assembled as a unit, and the manufacturer is able to assume the burden of testing and labeling. However, with site-built fenestration, multiple parties are responsible. Architects and/or engineers design the basic glazing system by specifying the components, the geometry of the components, and sometimes, the method of assembly. An extrusion manufacturer provides the mullions and frames that support the glazing and is responsible for thermal breaks. 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. A glazing contractor (usually a subcontractor to the general contractor) puts the system together at the construction site or their 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.

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 Section 3.2.1.

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

It is not necessary to complete the NFRC testing and labeling prior to completing the compliance documentation and filing the building permit application. However, plans examiners should verify that the fenestration performance shown in the plans and specifications and used in the compliance calculations is "reasonable" and achievable. This requires some judgment and knowledge on the part of the plans examiner. Generally, designers will know the type of glass that they plan to use and whether or not the frame has a thermal break or is thermally improved. This information is adequate to consult the default values for U-factor and SHGC in Nonresidential Reference Nonresidential Appendix NA6. If the values used for compliance are within 5 percent of the Reference Nonresidential Appendix NA6 values, then the values may be considered reasonable for plan check. If the compliance values are outside the 5 percent range, the plans examiner should request information from the designers to justify the proposed values.

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

Example 3-5

Question

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

Answer

The default U-factor for this glazing combination from Nonresidential Reference Appendix NA6 is 0.59. The proposed factor of 0.57 is within 5 percent and should be considered reasonable.

Example 3-6

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 re-installed (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 6000 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 §116(a)1 applies in this case (this exception applies to fenestration products removed and reinstalled as part of a building alteration or addition).

3. Use either NFRC Label Certificate or use Table 116-A default values; applies in this case as 24,000 ft² (more than the threshold value of 10,000 ft²) of new fenestration is being installed.

4. Since the site-built fenestration area is less than 10,000 ft², use either NFRC label certificate, the applicable default U-factor and SHGC set forth in Nonresidential Reference Appendix NA6, or California Energy Commission default values.

3.3 Opaque Envelope Insulation

The requirements for opaque surfaces include both mandatory measures and prescriptive requirements.

Sloping surfaces are considered either a wall or a roof, depending on their slope (see Figure 3-10). If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including the windows in walls and any skylights in roofs.

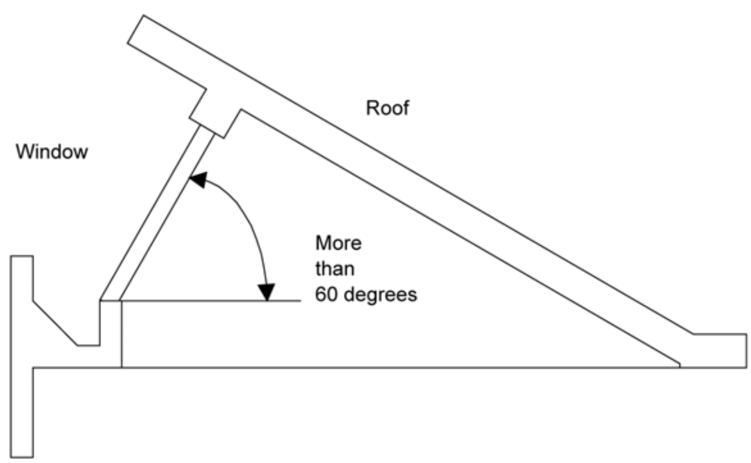


Figure 3-10 – Slope of a Wall or Window (Roof or Skylight slope is less than 60°)

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

3.3.1 Mandatory Measures

Certification of Insulation Materials

§118(a)

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

Manufacturers must certify that insulating materials comply with *California Quality Standards for Insulating Materials* (CCR, Title 24, Part 12, Chapters 12-13), which ensure that insulation sold or installed in the state performs according to stated R-values and meets minimum quality, health, and safety standards. Builders may not install insulating materials, unless the product has been certified by the Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Material* to verify the certification of the insulating material. The Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Joint Appendix JA4; only U-factors may be used to demonstrate compliance. The stated R-values for insulation are nominal values and cannot be used for compliance purposes; the U-factors represent the actual thermal conductance of the assembly, including air film coefficients and all layers used to construct the assembly. If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation Program, at (916) 574-2041.

Urea Formaldehyde Foam Insulation

§118(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.

Flamespread Rating

§118(c)

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

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

Insulation Over T-bar Ceilings

§118(e)

Insulation installed on the top of suspended (T-bar) ceilings with removable ceiling panels may not be used to comply with the Standards unless the installation meets the criteria described in the *Exception* to §118(e)3 below. Insulation may be installed in this location for other purposes such as for sound control, but it will have no value in terms of meeting roof/ceiling insulation requirements of the Standards.

Acceptable insulation installations include placing the insulation in direct contact with a continuous roof or ceiling that is sealed to limit infiltration and exfiltration as specified in §117; including but not limited to placing insulation either above or below the roof deck or on top of a drywall ceiling.

When insulation is installed at the roof in nonresidential buildings, the space between the ceiling and the roof is considered to be either directly or indirectly conditioned space. This space must not include fixed vents or openings to the outdoors or to unconditioned spaces. This space must not be considered an attic for the purposes of complying with 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 §118(e)3: When there are conditioned spaces with a combined floor area no greater than 2,000 ft² 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 ft, 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.

U-factors for this exception are found in Reference Joint Appendix JA4, Table 4.2.8.

Demising Walls

§118(f)

Demising walls separating conditioned space from enclosed unconditioned space must be insulated with a minimum of R-13 insulation if the wall is a wood or metal framed assembly. This requirement applies to buildings meeting compliance under the prescriptive or performance approach. This requirement assures at least some insulation in a wall where an adjoining space may remain unconditioned indefinitely. Demising walls that are constructed of brick, concrete masonry units, or solid concrete are not required to be insulated.

Insulation Requirements for Heated Slab Floors

§118(g)

Heated slab-on-grade floors must be insulated according to the requirements in Table 118-A of the Standards. The top of the insulation must be protected with a rigid plate to prevent intrusion of insects into the building foundation.

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

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

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

Wet Insulation Systems

§118(h)

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

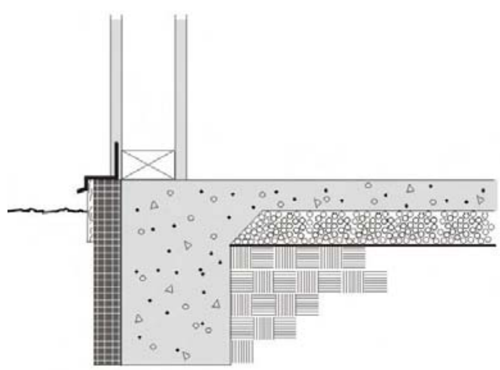


Figure 3-11 – Perimeter slab insulation

3.3.2 Prescriptive Insulation Requirements

The prescriptive requirements include minimum insulation levels for roofs/ceilings, walls, and floors. The requirements are expressed as a maximum U-factor. The U-factor criterion are given for different classes of construction such as wood framed, metal framed, metal building, and mass assembles. The assembly U-factor and descriptions of a particular roof/ceiling, wall or floor can be found in the appropriate tables listed in Reference Joint Appendix JA4. The reason U-factors are used instead of R-values is because the U-factor is the overall coefficient of thermal transmittance for a construction assembly whereas the R-value is the nominal measure of the thermal insulation of a building envelope component. When an assembly of the proposed building does not precisely match one of the choices in Reference Joint Appendix JA4, choose the best match which captures (a) the overall type of assembly (e.g., masonry, wood frame, metal frame); and (b) an insulation level in the Reference Joint Appendix JA4 assembly which is the same or less than the proposed assembly.

The criteria also vary by climate zone and occupancy type. Standards Table 143-A has the criteria for nonresidential buildings, including relocatable public school buildings where manufacturer certifies the use in a specified climate zones. Standards Table 143-B has the criteria for high-rise residential buildings and hotel/motel guest rooms. The latter is more stringent because the buildings are assumed to be heated and cooled continuously. Standards Table 143-C has criteria for relocatable public school buildings where the manufacturer certifies the use in all climate zones; these criteria are not climate dependent, since manufacturers often do not know who will buy their product and which climate zone it will be located to. The nonresidential and residential criteria are expressed for the 16 climate zones described in the overview section of this chapter.

Exterior Roofs and Ceilings

§143(a)1B and §143(a)1C

Under the prescriptive requirements, exterior roofs or ceilings 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 (see Table 3-9). 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. The Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Joint Appendix JA4; only U-factors may be used to demonstrate compliance.

Table 3-9 – Roof/Ceiling U-Factor Requirements

Summary from Standards Tables 143-A, 143-B and 143-C

Building Type		1	2	3	4	5	6	7	8
Nonresidential	Metal Bldg	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood-framing & Other framing type	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067
I High-rise Residential	Metal Bldg	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood-framing & Other framing type	0.034	0.028	0.039	0.028	0.039	0.039	0.039	0.028
Relocatable Public School Buildings	Metal Bldg	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
	Wood-framing & Other framing type	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039

Building Type		9	10	11	12	13	14	15	16
Nonresidential	Metal Bldg	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood-framing& Other framing type	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
High-rise Residential	Metal Bldg	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood-framing & Other framing type	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Relocatable Public School Buildings	Metal Bldg	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
	Wood-framing & Other framing type	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039

Figure 3-12 shows acceptable means of meeting the U-factor criteria for metal roofs. For screw down metal roofs with no thermal blocks, continuous insulation will be required to meet the U-factor requirement.

The mandatory measures prohibit insulation from being installed directly over suspended ceilings (see previous section), except for limited circumstances.

The U-factor must be selected from Reference Joint Appendix JA4.

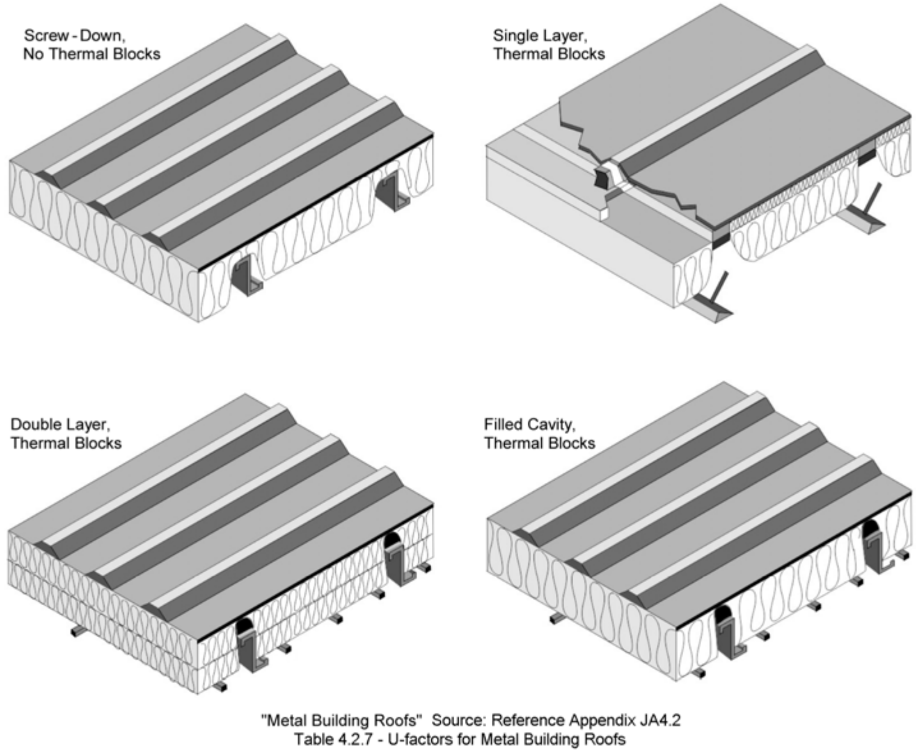


Figure 3-12 – Acceptable Metal-to-Metal Roof Constructions

Exterior Walls

§143(a)2

Under the prescriptive requirements, exterior walls must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential, high-rise residential buildings and relocatable public school buildings (in Table 3-10 below). The U-factor for exterior walls from Reference Joint Appendix JA4 must be used to determine compliance with the maximum assembly U-factor requirements. The Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Joint Appendix JA4; only U-factors may be used to demonstrate compliance.

For metal framed walls with batt insulation between framing section, continuous insulation may need to be added to meet the U-factor requirements of the 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 3-10 – Wall U-Factor Requirements

Building Type		1	2	3	4	5	6	7	8
Non-residential	Metal Bldg	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
	Metal-Frame	0.098	0.062	0.082	0.062	0.062	0.098	0.098	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	0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102
Residential High-rise	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
	Metal-Frame	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
	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 School Buildings	Wood-Frame	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
	Metal-Frame	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Metal Bldg	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Mass Light – 7.0≤ HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Other	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Building Type		9	10	11	12	13	14	15	16
Non-residential	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal-Frame	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Mass Light	0.44	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Frame	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
Residential High-rise	Metal Bldg	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
	Metal-Frame	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
	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 School Buildings	Wood-Frame	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
	Metal-Frame	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Metal Bldg	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Mass Light – 7.0≤ HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Other	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Reference Joint Appendix JA4. There are seven classes of wall constructions: wood frame, metal frame, metal building walls, medium mass, high mass, furred walls, and others see (Figure 3-14A). The “other” category is used for any wall type that does not fit into one of the other seven wall classes. The following provides additional information about each type of wall:

1. **Wood framed walls -** As defined by the 2007 California Building Code, Type IV buildings typically have wood framed walls. Framing members typically consist of 2x4 or 2x6 framing members spaced at 24 in. or 16 in. OC. Composite framing members and engineered wood products also qualify as wood framed walls if the framing members are non-metallic. 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. See Opaque Surface Details on ENV-2C Page 2 of 4.
2. **Metal framed walls -** Many nonresidential buildings and high-rise residential buildings require non-combustible 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. From Reference Joint Appendix JA4, Table 4.3.3 has data for metal framed walls. See Opaque Surface Details on ENV-2C Page 2 of 4.
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 buildings walls is to drape the insulation over the horizontal framing members and to compress the insulation when the metal exterior panel is installed. Table 4.3.9 from Reference Joint Appendix JA4 has data for metal building walls. See Opaque Surface Details on ENV-2C Page 2 of 4.
4. **Low-mass walls -** Low-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. See Opaque Surface Details on ENV-2C Page 2 of 4.
5. **High-mass walls -** Have an HC equal to or greater than 15.0 Btu/°F-ft². See Reference Joint Appendix JA4 for HC data on mass walls.

6. **Furred walls -** Are a specialty wall commonly applied to a mass wall type. See figure 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 Reference Joint Appendix JA4 Table 4.3.13 and calculated using either Equation 4-1 or 4-4 from the JA4. The Final Assembly U-factor will be inserted in Column L in the **Mass and Furring Strips Construction Table for Mass Walls** section found on Page 2 of the ENV-2C form.

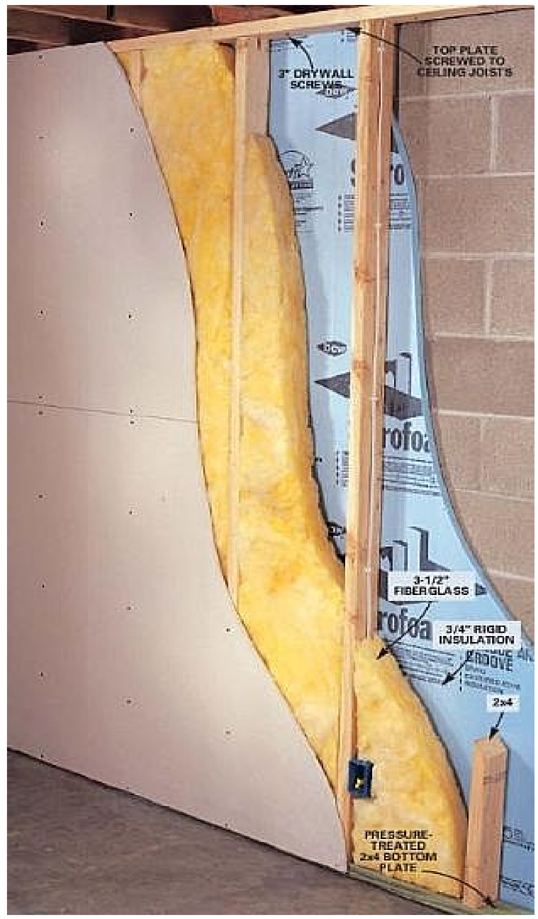


Figure 3-13 – Brick wall with furring details

7. **Spandrel panels and glass curtain walls.** See Reference Joint Appendix JA4, Table 4.3.8 for U-factor data. See Opaque Surface Details on ENV-2C Page 2 of 4.

The **heat capacity** is the amount of heat required to raise the temperature of the material by one degree F. By storing heat, materials with a high heat capacity, or thermal mass, have a tendency to dampen temperature swings throughout the day. For this reason, U-factor criteria are less stringent for mass walls than for framed construction.

Continuous Insulation

For some climate zones, mass walls require continuous insulation to meet the 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.

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

Example 3-7

Question

An 8 inches (20 cm) medium-weight concrete block wall with uninsulated cores has 1 inch (25 mm) thick exterior polystyrene 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:

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

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 Joint Appendix JA4.

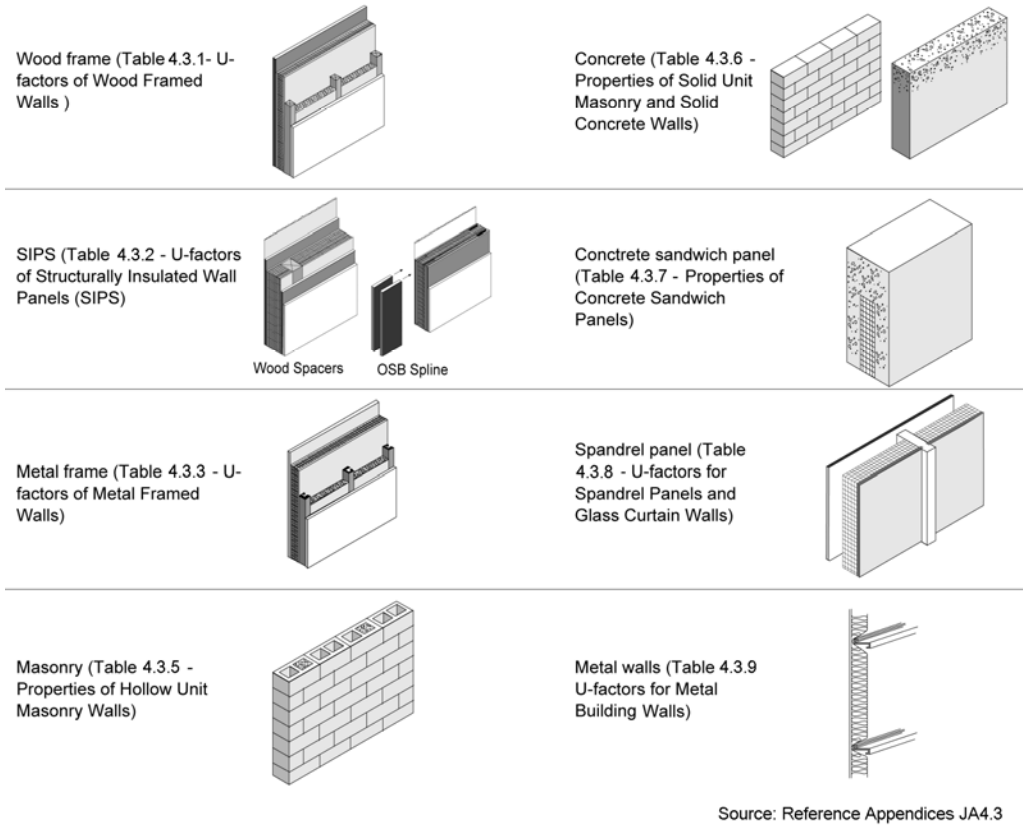


Figure 3-14A – Classes of Wall Constructions.

Demising Walls

§118(f), §143(a)3 and Exception to §143(a)5A

Demising walls, separating conditioned space from enclosed unconditioned space, must be insulated with a minimum of R-13 insulation if the wall is a framed assembly. If it is not a framed assembly, then no insulation is required. This applies only to the opaque portion of the wall.

The rationale for insulating demising walls is that the space on the other side may remain unconditioned indefinitely. For example, the first tenant in a warehouse building cannot know whether the future neighbor will use the adjoining space as unheated warehouse space or as an office. This requirement assures at least some insulation in the wall.

Exterior Floors and Soffits

§143(a)4

Under the prescriptive requirements, exterior floors and insulated soffits must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential, high-rise residential buildings and relocatable public school buildings in Table 3-11 below. 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 Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Joint Appendix JA4; only U-factors may be used to demonstrate compliance. 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 Standards.

The U-factor criteria depend on whether the floor is a mass floor or not. A mass floor is one constructed of concrete and for which the HC is greater than or equal to 7.0 Btu/°F-ft².

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

Building Type		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
Residential High-rise	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 School Buildings	Wood-Framed and Other	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048

Building Type		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
Residential High-rise	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 School Buildings	Wood- Framed and other	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048

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 and for which the heat capacity is 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 the desert and mountain 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 also Figure 3-15.

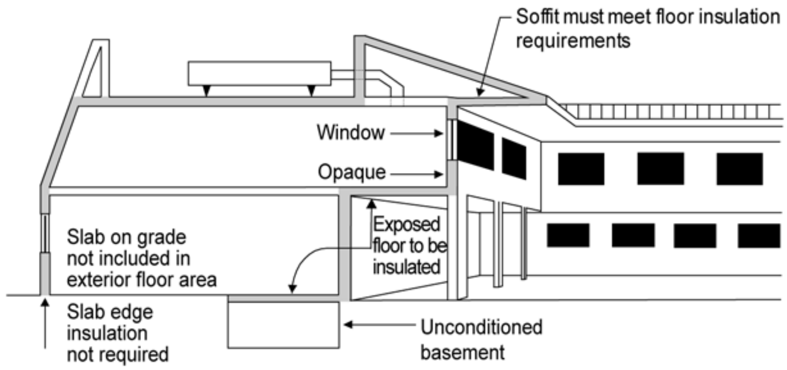


Figure 3-15 – Requirements for Floor/Soffit Surfaces

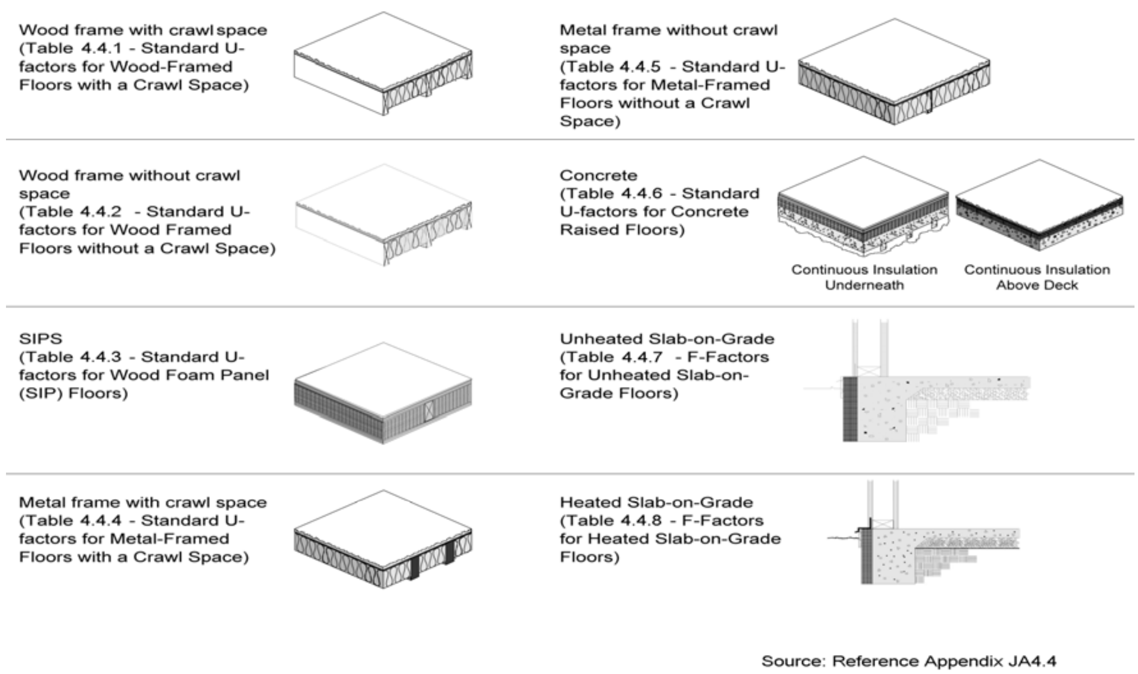


Figure 3-16 – Classes of Floor Constructions

Exterior Doors

§143(a)7

The Standards provide new prescriptive requirements for exterior doors. The Standards establish U-factor requirements for swinging and non-swinging doors. A maximum U-factor of 0.70 is allowed for swinging doors. For non-swinging doors the criteria depends on the climate zone as shown in the Table 3-12 below.

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

Table 3-12 from Reference Joint Appendix JA4 has U-factors for exterior doors.

Table 3-12 – Door Requirements Summary from Standards Tables 143-A and 143-B

Building Type	**Door Type**	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
Residential High-rise	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 School Buildings	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**	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
Residential High-rise	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 School Buildings	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

Additions and Alterations

§149

In general, additions and alterations to the building envelope must meet the prescriptive insulation requirements in §149 or comply with the performance compliance approach. Note that §149(b)2 lists prescriptive requirements for alterations; this means that the altered component must have a U-factor within limits defined in Tables 143-A and 143-B of the Standards. Additions to an existing building must comply with insulation requirements of §149(a).

Roofing Alterations

§149(b)1B For reroofing, when low-sloped roofs are exposed to the roof deck, the exposed area must be insulated to levels specified in Standards Table 149-A. For nonresidential buildings, this level is R-8 continuous insulation in climate zones 1 and 3 through 9 and R-14 continuous insulation in climate zones 2 and 10 through 16. Several exceptions are provided:

1. No additional insulation is required if the roof is already insulated to a minimum level of R-7.
2. If mechanical equipment is located on the roof and it 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 (20 cm) from the roof membrane surface to the top of the base flashing.
3. If adding the required insulation will reduce the base flashing height to less than 8 inches (20 cm) at penthouse or parapet walls, the insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (20 cm) from the roof membrane surface to the top of the base flashing.
4. Tapered insulation may be used which has a thermal resistance less than that prescribed in Standards Table 149-A at the drains and other low points, provided that the insulation thickness is increased at high points, so that the average thermal resistance equals or exceeds the level specified in Standards Table 149-A.

Refer to Section 3.4 to learn what roofing product requirements apply to additions and alterations.

3.4 Roofing Products (Cool Roofs)

Projects complying with the prescriptive approach must meet the requirements of §143(a)1 for roofing products (cool roofs). All cool roofs for which compliance credit is taken, regardless of compliance approach, must meet the requirements of §118(i). Cool roofs with high solar reflectance and thermal emittance are referred to as “cool roofs”, which refers to an outer layer or exterior surface of a roof. As the term implies, the temperature of a cool roof is lower on hot sunny days than for a conventional roof, reducing cooling loads and the energy required to provide air conditioning.

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

There are several ways to achieve the thermal emittance and solar reflectance required under the prescriptive approach. One method is to use a single-ply roofing membrane with high emittance properties as an integral part of the material. Another approach is to apply a coating to the surface of a conventional roof membrane; for example, modified bitumen or a mineral cap sheet. Metal roofs using an industrial grade coating may have high reflectance and high emittance.

3.4.1 Mandatory Measures

The mandatory measures require that roofing products be tested and labeled by the Cool Roof Rating Council (CRRC) and that liquid-applied products meet minimum standards for performance and durability per §118(i)4. Note that installing cool roofs is *not* a mandatory measure. To receive compliance credit, roofing product's reflectance and thermal emittance must be tested and certified according to CRRC procedures. If a CRRC rating is not obtained for roofing products, default values for reflectance and emittance must be used.

Rating and Labeling

§10-113

When cool roof is installed to meet the prescriptive requirement or are used for compliance credit, the products must be tested and labeled by the Cool Roof Rating Council (CRRC) as specified in §10-113. 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.

Figure 3-17 provides an example of an approved CRRC product label.

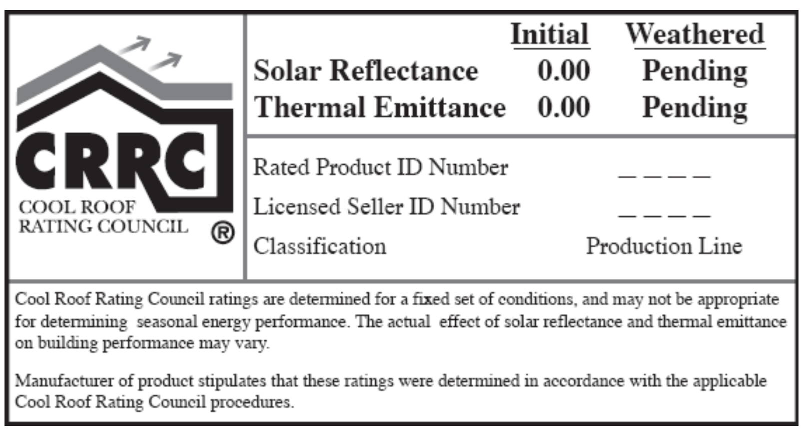


Figure 3-17 – Sample CRRC Product label and information

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

§118(i)1,2, and 3

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

- Initial solar reflectance
- 3-year aged reflectance

All Standards requirements are based on the 3-year aged reflectance. However, if the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the equation below can be used until the aged rated value for the reflectance is posted in the directory.

Aged $\text{Reflectance}_{\text{calculated}}=(0.2+0.7[\rho_{\text{initial}} - 0.2])$

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

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

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

Solar Reflectance Index (SRI) is a new concept in the Standards. The temperature of a surface depends on the solar radiation incident, surface's reflectance, and emittance. The SRI measures the relative steady-state surface temperature of a surface with respect to standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient condition. A calculator has been produced by the staff at Lawrence Berkeley National Laboratory, which calculates the SRI by designating the Solar Reflectance and Thermal emittance of the desired roofing material. The calculator can be found at http://www.energy.ca.gov/title24/2008standards. SRI calculations must be based on moderate wind velocity of 2-6 meters per second. To calculate the SRI, the 3-year aged value of the roofing product must be used. By using the SRI calculator a cool roof may comply with an emittance lower than 0.85, as long as the aged reflectance is higher and visa versa.

Performance Requirements for Field Applied Liquid Coatings

§118(i)4, Table 118-B

There are a number of qualifying liquid products, including elastomeric coatings and white acrylic coatings. The Standards specify minimum performance and durability requirements for field-applied liquid coatings. Please note that these requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail below.

Aluminum-Pigmented Asphalt Roof Coatings

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

This class of field-applied liquid coatings shall be applied across the entire surface of the roof and meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied on. Also, the aluminum-pigmented asphalt roof coatings shall be manufactured in accordance with ASTM D2824[2]. Standard Specification for Aluminum-Pigmented Asphalt Roof Coatings, Nonfibered, Asbestos Fibered, and Fibered without Asbestos that is suitable for application to roofing or masonry surfaces by brush or spray. Use ASTM D6848, Standard Specification for Aluminum Pigmented Emulsified Asphalt used as a Protective Coating for Roofing; installed in accordance with ASTM D3805[3], Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

Cement-Based Roof Coatings

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

Cement-based coatings shall be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the manufacturer. Also, cement-based coatings shall be manufactured to contain no less than 20 percent Portland

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

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

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

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

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

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

Cement and meet the requirements of ASTM D822[4],ASTM C1583 and ASTM D5870.

Other Field-Applied Liquid Coatings

Other field-applied liquid coatings include elastomeric and acrylic-based coatings. These coatings must be applied across the entire surface of the roof surface to meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. The field-applied liquid coatings must be tested to meet a number of performance and durability requirements as specified in Table 118-B of the Standards.

3.4.2 Roofing Products Prescriptive Requirements

§143(a)1A

The prescriptive requirements call for roofing products meeting the solar reflectance and thermal emittance in both low-sloped and steep-sloped applications for nonresidential buildings. A low-sloped roof is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizon), while a steep-sloped roof is a surface with a pitch greater than 2:12 (9.5 degrees from the horizon). The prescriptive requirements for cool roofs under the Standards are now climate zone-dependent and the aged solar reflectance and thermal emittance criteria depend on the type of roofing material being used. A qualifying roofing product must have an aged solar reflectance and thermal emittance greater than or equal to that the values indicated in Table 3-13 for the nonresidential buildings, including relocatable public school buildings where manufacturer certifies use only for specific climate zones. Table 3-14 is for high-rise residential buildings and hotel/motel guest rooms and Table 3-15 is for relocatable public school buildings where manufacturer certifies use in all climate zones.

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

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

Table 3-13 – 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	NR	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	NR
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	NR
		SRI	NR	64	64	64	64	64	64	64	64	64	64	64	64	64	64	NR
	Steep Sloped (less than 5 lb/ft^2)	Aged Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	NR	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Steep Sloped (5 lb/ft^2 or more)	Aged Reflectance	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Table 3-14 – Prescriptive Criteria for Roofing Products for High-rise Residential Buildings and Guest Rooms of Hotel/Motel Buildings

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

Table 3-15 – 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	0.55/0.75
SRI	64
Steep-Sloped – Less than 5 lb/ft^2	0.20/0.75
SRI	16
5 lb/ft^2 or more	0.15/0.75
SRI	10

If the aged value for the Reflectance is not available in the CRRC's Rated Product Directory, then the equation in Section 3.4.1 can be used until the aged rated value for the reflectance is posted in the directory.

There are four exceptions to the minimum prescriptive requirements for solar reflectance and thermal emittance or the SRI:

1. Wood-framed roof assemblies in climate zones 3 and 5 are exempt if the roof assembly has a U-factor of 0.039 or lower.
2. Metal framed roofs in climate zones 3 and 5 are also exempted if the roof assembly has a U-factor 0.048 or lower.
3. Roof area covered by building-integrated photovoltaic panels and building integrated solar thermal panels is not required to meet the cool roof requirements.
4. If the roof construction has a thermal mass over the roof membrane with a weight of at least 25 lb/ft², it does not need to meet the above requirement.

Example 3-8

Question

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

Answer

The answer depends on the compliance approach you chose. For prescriptive compliance, compliance with solar reflectance and thermal emittance, or SRI is required where indicated in Standards Tables 143-A, B, and C. 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, mechanical, and lighting systems.

Example 3-9

Question

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

Answer

It depends on the compliance approach you are using. If you are using the prescriptive envelope component approach, the answer is yes; the roof must be certified and labeled by CRRC for nonresidential roofs. On the other hand, if you are using prescriptive overall envelope TDV energy approach or the performance approach to receive compliance credit, you can either obtain a CRRC certification, OR use a default reflectance of 0.10. Note that 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. Also note that the default reflectance for asphalt roofs is different than tile and metal roofing products; see Example 3-15.

Example 3-10

Question

When re-roofing with gravel, must the roof meet reflectance and emittance requirements of the Standards? Is CRRC certification required?

Answer

Not necessarily. Roof recoverings allowed by the California Building Code do not have to meet the reflectance and emittance requirements, and a CRRC certification is not required, if ALL of the following are true:

1. The existing roof is a rock or gravel surface;
2. The new roof is a rock or gravel surface;
3. There is no removal of existing layers of roof coverings;
4. There is no recoating with a liquid-applied coating; and
5. There is no installation of recover board, rigid insulation, or other substrate.

Example 3-11

Question

Why is there a different requirement in the different climate zones for the aged solar reflectance and SRI requirements between roofing products with density less than 5 lb/ft^2 versus more than 5 lb/ft^2 ?

Answer

Roofing products with less density perform differently compared to the higher density materials, which have a tendency to retain some gained heat. For this reason the performance characteristics of the two different densities were evaluated separately for each climate zone.

Example 3-12

Question

How do I know if my roofing material is weighs less than 5 lb/ft^2?

Answer

Roofing products which are less than 5 lb/ft^2 are usually asphalt shingles and metal roofing products. Products that weigh 5 lb/ft^2 or more are usually concrete and clay tile and slate roofing products. Check the product literature or contact the roofing product manufacturer to obtain the weight of the desired roofing product.

Example 3-13

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

Only CRRC ratings from the product directory list can be used to establish cool roof product qualification for Standards compliance. The CRRC process requires use of a CRRC-accredited laboratory [under most circumstances, an "Accredited Independent Testing Laboratory (AITL) defined by the CRRC program]. Any testing laboratory can become an AITL by following the CRRC accreditation process and satisfying the requirements. The roster of CRRC-accredited laboratories is posted on the CRRC website (http://www.coolroofs.org).

Example 3-14

Question

The aged reflectance for the material I want to use for my roof is currently not available in the CRRC Rated Product Directory. Can I use the initial reflectance that is listed?

Answer

Yes. You have to use the equation $0.2+0.7[\rho_{initial} - 0.2]$) where ($\rho_{initial}$ = Initial Reflectance listed in the CRRC Rated Product Directory) to calculate the aged reflectance value until the aged value is available in the directory at some future time.

Example 3-15

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 their Rated Product Directory can be used to the Standards. CRRC currently is the only organization which have met the criteria set in §10-113.

Example 3-16

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 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 Standards for field-applied coatings.

Example 3-17

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 US or (510) 482-4420, ext. 215 or email info@coolroofs.org. In addition, CRRC publishes the procedures in "CRRC-1 Program Manual," available for free on http://www.coolroofs.org or by calling the CRRC. However, working with CRRC staff is strongly recommended.

Example 3-18

Question

I understand reflectance, but what is emittance?

Answer

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

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

Example 3-19

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 §143(c), the skylight requirements. Building envelope (other than skylight requirements) and mechanical requirements do not apply to unconditioned buildings.

Example 3-20

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 §143(a)1Ai and ii?

Answer

Yes, but, if your building is in climate zones 1 or 16 you would not be required to do the low-sloped reflective roof. However, you would have a requirement for the steep-sloped roofs in climate zones 2-16 for low density steep-sloped material and in all climate zones for high density steep-sloped materials.

Example 3-21

Question

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

Answer

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

Under *Exception* 4 to §143(a)1Ai, if a garden roof has a dry unit weight of 25 lb/ft² then the garden roof is equivalent to cool roof.

3.5 Infiltration and Air Leakage

§117

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

No special construction requirements are necessary for suspended (T-bar) ceilings, provided they meet the requirements of §118(e). See Section 3.3.1. Standard construction is adequate for meeting the infiltration/exfiltration requirements.

3.6 Relocatable Public School Buildings

Standards Table 143-C

Reference Nonresidential Appendix NA4

Public school building design is defined by two prescriptive requirements (listed in Tables 143-A and 143-C of the Standards) covering climate-specific relocatable public school buildings as well as relocatable public school buildings that can be installed in any climate. Building envelopes must meet the prescriptive requirements in §143. For additional design requirements, refer to §143 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, each model using the same proposed design energy features rotated through 12 different orientations and different climate zones (Reference Nonresidential Appendix NA4). Also see §141(d) and §149(b)2. Note. If prescriptive method is used for all climate zones compliance, then all the requirements of Table 143-C must be met; for climate zone specific prescriptive compliance, the relocatable classrooms must comply with the requirements of Table 143-A.

Performance Approach

§141(d) Performance
Reference Nonresidential Appendix NA4

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 143-C. When the manufacturer/builder certifies that the relocatable building is manufactured for use in specific climate zones and that the relocatable building cannot be lawfully used in other climate zones, the energy budget must be met for each climate zone that the manufacturer/building certifies, assuming the prescriptive envelope criteria in Table 143-A, including the non-north window RSHG and skylight SHGC requirements for each climate zone. 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 §143(a)8.

Manufacturers may certify the relocatable classrooms for multiple orientations or for compliance for all climate zones statewide. Since relocatable public school buildings could be positioned in any orientation, it is necessary to perform compliance calculations for multiple orientations. Each model with the same proposed design energy features shall be rotated through 12 different orientations: either in climate zones 14, 15 and 16 for relocatables showing statewide compliance; or, in the specific climate zones that the manufacturer proposes for the relocatable be allowed to be installed (i.e., the building with the same proposed design energy features), the relocatable model is rotated in 30 degree increments. The relocatable model shall comply in each case. Approved compliance software programs shall automate the rotation of the building and reporting of the compliance results to insure it is done correctly and uniformly and to avoid unnecessary documentation.

3.7 Overall Envelope TDV Energy Approach

§143(b)

The overall envelope TDV energy approach offers greater design flexibility. It allows the designer to make trade-offs between many of the building envelope components. For example, if a designer finds it difficult to insulate the walls to a level adequate for meeting the wall component U-factor requirement, then the insulation level in a roof or floor or the performance of a window component could be increased to offset the under-insulated wall. The same holds true for glazing. If a designer wants to put clear, west-facing glass to enhance the display of merchandise in a show window, it would be possible to use lower SHGC glazing on the other orientations to make up for the increased SHGC on the west.

The overall envelope approach estimates the time dependent valued (TDV) energy associated with the building envelope, and in doing so, accounts for both overall heat loss and overall heat gain. The TDV energy impact distributed to each building component (floor, wall, window, skylight, door or roof) is estimated using a weighting coefficient that is dependent on both the climate zone and occupancy type (nonresidential, high-rise residential or retail) and orientation. The procedure also accounts for the effect of the roof's solar reflectance and thermal emittance on TDV energy use.

A standard design value and a proposed design value are calculated for TDV energy use. The standard design building complies with the exact requirements of the prescriptive approach. The requirements are more stringent in more extreme climate zones than in mild climate zones. The standard values are compared to the proposed values calculated from the actual envelope design. If the proposed value does not exceed the standard value, then the overall building envelope requirements are met.

While the overall envelope approach increases design flexibility, this comes at the expense of the complexity of the calculations. There is an Envelope TDV Energy Trade-off spreadsheet tool (see Section 3.7.1) available on the California Energy Commission website which can perform this calculation. In addition, one or more state-approved compliance software programs (see Chapter 9) are capable of performing the Overall Envelope TDV energy calculation as well.

3.7.1 Overall Envelope TDV Energy Approach Overview

There are two parts to the Overall Envelope TDV energy approach calculation. The first is to calculate the standard TDV energy use. The second is to calculate the proposed TDV energy use, which is compared to the standard to show that it does not exceed the standard TDV energy budget.

The envelope trade-off procedure has been revised. Previously, heat loss and heat gain rates were calculated separately and compared to the standard design values. For the current Standards, the building Overall Envelope TDV Energy Approach, which accounts for both heat loss and heat gain, is calculated. The TDV energy impact of each building envelope component (i.e., wall, roof, floor) is estimated by applying a weighting coefficient that is both climate- and occupancy-dependent. The weighting coefficients allow for trade-offs between envelope components. Weighting coefficients are also developed to account for effects of window and skylight glazing, and roof solar reflectance and thermal emittance. The overall envelope trade-off procedure is documented in Reference Nonresidential Appendix NA5.

The Overall Envelope computer spreadsheet tool helps calculate the TDV energy of the proposed and standard design buildings from user inputs. See Figure 3-16 below. The user selects the construction assembly from a drop-down list, and the tool automatically looks up the required U-factors and SHGCs for the standard design, looks up weighting coefficients and performs the calculations.

The U-factor for opaque building elements is determined by choosing a construction from the appropriate table in Reference Joint Appendices JA4. The U-factor, SHGC and visible transmittance (VT) for windows and skylights are taken from NFRC rating values or defaults from Table 116-A or 116-B of the Standards.

The following table below summarizes the information that is required for each envelope component.

Table 3-16 – Required Information for Building Envelope Components

	Floor	Wall	Window	Skylight	Door	Roof
Area, ft²	X	X	X	X	X	X
U-factor*	X	X	X	X	X	X
SHGC*			X	X		
VT*			X	X		
Orientation		X	X		X	
Projection Factor			X			
Reflectance						X
Emittance						X
Slope (Steep or low-sloped)						X

These are automatically determined when the construction is selected.

A sample trade-off calculation worksheet is shown below. The fields highlighted in yellow are those that must be filled in by the user.

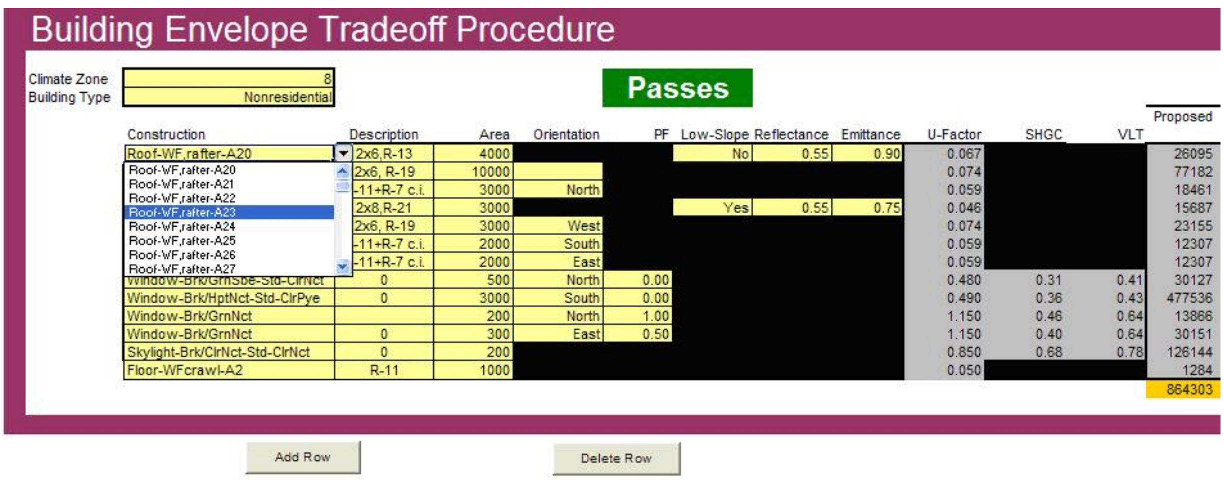


Figure 3-18 –Envelope Tradeoff Spreadsheet Tool

First, the user selects the climate zone and the occupancy type (either nonresidential, high-rise residential or retail). Nonresidential occupancy applies to office buildings and buildings that are typically occupied during office hours.

For each floor, wall, window, skylight, roof and door:

Step 1: Select the construction from the drop-down list. The selections for walls, roofs and doors are named so that the user can match the construction name to a selection from Reference Joint Appendix JA4. For instance, the selection *Roof-WF, rafter-A20* corresponds to table entry A20 in the wood-framed rafter roofs table, Table 4.2.1 of JA4. The entry *Wall-CMU-A9* corresponds to table entry A9 in the concrete masonry unit wall table, Table 4.3.5 of JA4. The selection automatically determines the U-factor.

The assembly selected for windows or skylights determines the U-factor, Solar Heat Gain Coefficient (SHGC) and visible transmittance (VT). The assembly selected also determines the weighting coefficient that is used. Separate weighting coefficients exist for light vs. mass construction. For fenestration, separate weighting coefficients are provided for each orientation.

The window and skylight constructions are named according to a convention that indicates the number of panes, spacing and coatings. In Figure 3-17, the following code indicates a double-paned window with standard spacing and a pyrolitic low-e coating on the interior pane. The assembly is housed in a metal frame with a thermal break.

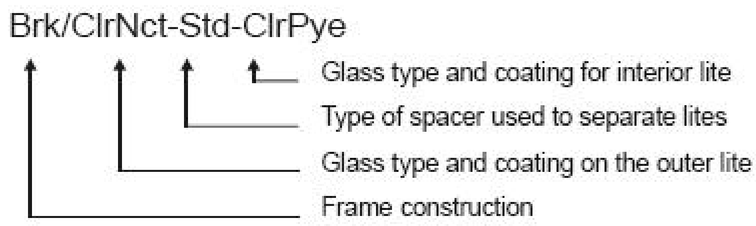


Figure 3-19 – Window and Skylight Construction Naming

The glass types, frame types and coatings are listed in the table below.

Table 3-17 Glazing Code Definitions

Item	Code	Description
Glass Products	Clr	Standard 6mm thick clear glass
	Grn	Standard green 6mm thick tinted glass
	Hpt	High performance tinted 6mm thick glass such as Azurlite or Evergreen
Frame Types	Mtl	Standard metal frame without a thermal break
	Brk	Metal frame with a thermal break
	Vnl	Vinyl or wood frame
Spacers	Std	Standard spacer
	Ins	Insulating spacer
Coatings	Nct	No Coating
	Mpr	Medium performance reflective coating. This is a durable coating that can be used on single glazing, but is less reflective than LOF eclipse or PPG solarcool.
	Pye	Pyrolitic low-e coating similar to LOF Energy Advantage. This is a hard low-e coating that has an assembly on the order of 0.20.
	Spe	Standard sputter low-e coating. This coating is offered by many manufacturers and has an emissivity on the order of 0.10.
	Sbe	SunBelt low-e coating. This has similar emissivity as the Spe product, but a lower SHGC. An example is Guardian's NU-40 coatings.
	Sue	Super low-e coating. This is an advanced coating that has an emissivity below 0.04. It also has a lower SHGC.
Suspended Film	HtMr22	These are Heat Mirror suspended films with varying transmission. The 22 in the code is the light transmission of the film.

The construction schedule contains a limited number of pre-defined window assemblies. To define a new window assembly, go to the *Schedule* tab of the spreadsheet tool and select the *Add Row* button to add a new window assembly.

Step 2: Enter the Area in square feet. For walls, enter the net wall area excluding doors and windows. For roofs, enter the net roof area excluding skylights.

Step 3: For walls, windows or doors, enter the orientation (north, south, east, or west).

Step 4: For windows, enter the projection factor (PF) if an overhang is present. This is defined as the ratio of the horizontal projection out from the wall to the vertical height difference between the top of the window and the bottom of the overhang. If no overhang is present, a value of 0 is used. A maximum value of 1 is permitted for this field.

Step 5: For roofs, select *yes/no* in the low-sloped field to indicate whether the roof is low-sloped (a rise-run equal to or less than 2:12) or steep-sloped (a rise-run greater than 2:12). Also, enter the aged solar reflectance and thermal emittance values from CRRC 's rated products directory.

If the aged solar reflectance is not given but the initial solar reflectance is given in the CRRC's rated products directory, then the aged solar reflectance can be calculated by using the equation below:

$\rho_{Raged} = 0.2 + 0.7 [\rho_{Riprop} – 0.2]$

Where ρ_{Riprop} = the initial solar reflectance from CRRC's rated product directory.

If the initial solar reflectance is not known, a default aged solar reflectance of 0.1 is assumed. If thermal emittance is not known, a default of 0.75 is assumed.

Steps 1 through 5 are repeated for each building element. The user can enter as many building components as needed to define all walls, windows, skylights, doors, and roofs. The user can click the *Add Row* button if additional entries are needed. To remove an entry, select a construction entry and click the *Delete Row* button.

The program automatically calculates the contribution of TDV energy from each component for the proposed design and standard design and displays the difference. The program also adjusts the standard design window area size: if the proposed design window-wall ratio (WWR) exceeds prescriptive limits.

If the TDV energy of the proposed design is less than or equal to the TDV energy of the standard design, the building meets compliance. If it fails, the performance approach can be used to demonstrate compliance by trading off building envelope performance with other measures such as HVAC equipment efficiency. The following sections provide calculation details for a manual calculation of TDV energy use.

The spreadsheet contains a number of pre-defined construction assemblies from Reference Joint Appendix JA4. The user can define additional assemblies by adding them to the construction schedule. See Figure 3-18 below. The new assemblies can then be referenced in the user interface. To define a new assembly, select the Schedule tab and click on the *Add Row* button. Enter the assembly name in column C, and select the construction type (i.e roof) in column D. In the next column, select the table from Reference Joint Appendix JA4. Enter the U-factor in column I, and for fenestration enter the SHGC and VT in columns J and K. For mass walls or floors, enter the heat capacity in column L. If fields are not required for an assembly, they are grayed out.

B	C	D	E	F

Constructions Schedule

Add Row Delete Row

User Name	Type	Joint Appendix Table	Criteria Code
Roof-WF,rafter-A18	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A19	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A20	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A21	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A22	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A23	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A24	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A25	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A26	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A27	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-A28	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-F18	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-WF,rafter-H18	Roof	Table 4.2.2 – U-factors of Wood Framed Rafter Roofs	Roof, Light_Other
Roof-SIP-A1	Roof	Table 4.2.3 – U-factors of Structurally Insulated Panels (SIPS) Roof/Ceilings	Roof, Light_Other
Roof-SIP-A2	Roof	Table 4.2.3 – U-factors of Structurally Insulated Panels (SIPS) Roof/Ceilings	Roof, Light_Other
Roof-SIP-A3	Roof	Table 4.2.3 – U-factors of Structurally Insulated Panels (SIPS) Roof/Ceilings	Roof, Light_Other
Roof-SIP-A4	Roof	Table 4.2.3 – U-factors of Structurally Insulated Panels (SIPS) Roof/Ceilings	Roof, Light_Other
Roof-Metal,rafter-A16	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A17	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A18	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A19	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A20	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A21	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A23	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Metal,rafter-A25	Roof	Table 4.2.5 – U-factors of Metal Framed Rafter Roofs	Roof, Light_Other
Roof-Span Deck-A1	Roof	Table 4.2.6 – U-factors for Span Deck and Concrete Roofs	Roof, Mass
Roof-Span Deck-A2	Roof	Table 4.2.6 – U-factors for Span Deck and Concrete Roofs	Roof, Mass

Figure 3-18 – Construction Schedule

Example 3-22

Question

A building has a 6 inches medium weight concrete masonry unit wall with partially-grouted cells and a 1.5 inches thick interior furring space with wood strips and R-5 insulation. How can a new construction assembly be defined?

Answer

From Table 4.3.5 of Reference Joint Appendix JA4, the CMU has a U-factor of 0.58 and a heat capacity of 8.4. The effective R-value of the interior furring space from Table 4.3.13 of JA4 is 4.4. The U-factor of the entire assembly is calculated from Equation 4-1 in Reference Joint Appendix JA4:

$$U_{With.Cont.Insul} = 1 / (1/_{UCol.A} + R_{Cont.Insul})$$

$$U = 1 / (1/0.58 + 4.4) = 0.163$$

The new assembly is defined in the schedule tab of the Overall Envelope Spreadsheet Tool. Define the name of the assembly in column C, select Wall in column D, select Table 4.3.5 in column E, enter the U-factor of 0.163 in column I, and enter the heat capacity of 8.4 in column L. The assembly can now be referenced on the main User Interface tab of the spreadsheet tool.

3.7.2 TDV Energy of the Standard Building – Calculation Details

The TDV energy of the standard building is calculated according to Equation NA5-1 in Reference Nonresidential Appendix NA5. For each building envelope component (floor, wall, door, window, skylight, and roof), the U-factor from the prescriptive requirements (Standards Tables 143-A and 143-B) is used. For windows, the prescriptive relative solar heat gain (RSHG) requirement, which is based on the window-wall ratio, is used.

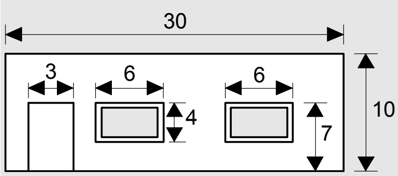
Step 1 – Set Opaque Areas to Match Proposed Design

For opaque building elements, the area of each component of the standard building is equal to the component area of the proposed building. The wall area is the net wall area excluding doors and windows, and the roof area excludes area from skylights. The window-wall ratio (WWR) is the total window area in the gross exterior walls, divided by the gross exterior wall area.

Example 3-23

Question

How is exterior wall area calculated for the following wall (dimensions in ft)?



Answer

The gross exterior wall area is 30 ft x 10ft = 300 ft². The door area is 3 ft x 7 ft = 21 ft². The window areas are 6 ft x 4 ft = 24 ft² each, or a total of 48 ft². The exterior wall area is the gross minus doors and windows, or 300 ft² - 21 ft² - 48 ft² = 231 ft².

Step 2 – Adjust Fenestration Areas if Necessary

In most cases, the window areas of the standard design building match those of the proposed design. However, the Standards have additional limitations on the maximum allowable window area. The window area for the standard building is adjusted if the total window area exceeds limits defined in §143(a)5A. Window area adjustment is required for either of the following conditions:

- Window-wall ratio is greater than 40 percent, or
- West wall window area exceeds the maximum allowable limit.

If either of these conditions is met, an adjusted window area is used to calculate the standard building energy use.

The first adjustment is for buildings with very large window area. If the actual window wall ratio is greater than 40 percent, then an area equal to 40 percent of the gross wall area is used to calculate the standard energy use. Alternatively, for buildings with substantial display perimeter areas (see Section 3.2), an area equal to 6 ft high by the length of the display perimeter is calculated. If this value is greater than 40 percent of the gross exterior wall area, then it is used in the standard energy use calculation.

The second limitation is on west window wall area. The maximum allowable west window area is the greater of 40 percent of the west exterior wall area or 6 times the west display perimeter. If the west window area of the proposed building exceeds this limit, the west window area for the standard design is set to the maximum allowed area.

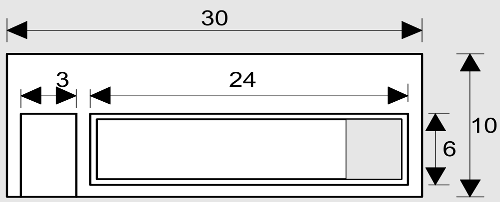
If *both* of the conditions above apply, then two separate adjustments are made. First, the window area for each of the north, east, south and west orientations is scaled down proportionate to the window area on that orientation. For example, if the total window area on all orientations is 45 percent of the exterior wall area for all orientations, the standard window area for each orientation is multiplied by the factor 0.4/0.45, or 0.889. This maintains the same fraction of window area on each orientation (see example below). Then, the west wall window area is checked to see if it still exceeds the greater of 6 times of the display perimeter or 40 percent of the gross west wall area. If it does, it is scaled down so that the west window area does not exceed the prescriptive limit. If either of these adjustments is made to the standard window area, the exterior wall area is also adjusted so that the gross exterior wall area for each orientation matches the proposed design.

Skylights are treated similarly. The actual skylight area or the rough opening area will be used to calculate the standard energy use. If the skylight is site-built and its shape is three-dimensional , then the area is the actual surface area, not the opening area. If the skylight area is larger than 5 percent of the gross exterior roof area (roof doors not included for the standard building), then an area equal to 5 percent of the roof area is used. Alternatively, if the building has an atrium over 55 ft high, then the allowance for skylights is increased to 10 percent (or the actual skylight area if less than 10 percent of the gross roof area).

Example 3-24

Question

What is the window-wall ratio (WWR) for the following west-facing wall (dimensions in ft)? How is the standard design window and wall area adjusted under the overall envelope approach?



Answer

The gross exterior wall area is 30 ft x 10 ft = 300 ft². The window area is 24 ft x 6 ft = 144 ft². The WWR is 144/300 = 0.48, or 48 percent. The exterior wall area is 300 ft^2 - 144 ft^2 = 156 ft². The window area must be adjusted downward to 40 percent of the gross exterior wall area, or 0.40 x 300 ft^2 = 120 ft². This is a window area reduction of 144 ft^2-120 ft^2 = 24 ft². The exterior wall area must be increased by the same amount to 156 ft^2+ 24 ft^2 = 180 ft² (as shown by shaded area in sketch above).

Example 3-25

Question

The building has a west-facing wall with the dimensions shown in the example above. The north-east and south-facing walls have identical dimensions (30 ft width by 10 ft height). The south-facing wall has a window area of 100 ft². The east and north walls have window areas of 148 ft² each. What window area adjustment is required, if any, to the standard design?

Answer

The building gross exterior wall area is 1200 ft². The total window area is 144 ft + 100ft + 148 ft + 148 ft = 540 ft². The building WWR is 540/1200 = 0.45, or 45 percent. The window areas need adjustment.

The first step is to adjust all window areas downwards in proportion to the 40 percent WWR prescriptive requirement.

West Wall: 144 ft x 0.4/0.45 = 128 ft²

North, east walls: 148 ft x 0.4/0.45 = 131.56 ft²

South wall: 100 ft x 0.4/0.45 = 88.89 ft²

Next, check the window wall ratio of the adjusted west window. WWR = 128 / 300 = 0.427. Since the WWR still exceeds 40 percent, it is adjusted downwards to be 40 percent of the gross wall area, or 120 ft².

As a check, the sum of the adjusted window areas should not exceed the maximum allowed window area: 120 ft + 131.56 ft + 131.56 ft + 88.89 ft = 472 ft², which does not exceed 40 percent of the wall area (480 ft²). Note that the south wall window area must be decreased, even though the south window area is only 33 percent of the south exterior wall area.

The wall areas of the standard building are adjusted so that the gross exterior wall area on each façade remains at 300 ft².

Step 3 – Use Prescriptive Envelope Criteria from the Standards

For the standard design building, the U-factors are set to the prescriptive requirements in Standards Tables 143-A, 143-B and Table 143-C. The criteria for walls, roofs and floors depend upon whether or not the construction is a lightweight or mass construction.

For windows, the relative solar heat gain (RSHG), which accounts for the solar heat gain coefficient of the window as well as shading effects of overhangs, is used. The RSHG coefficient criterion depends on the window-wall ratio and window orientation. For higher WWR, the criterion is more stringent. The visible light transmittance of the standard design windows is 1.2 times the relative solar heat gain coefficient.

For skylights, the solar heat gain coefficient for the standard building depends upon the skylight type (glass with curb, glass without curb, or plastic), the ratio of the skylight area to roof area, and climate zone. There are two categories for this skylight area to roof area ratio (0-2 percent and 2.1-5 percent). This is taken from Standards Table 143-A, 143-B, or 143-C. The standard design type of skylight must match the proposed design; if the proposed design has a curb, then the standard design would as well.

Step 4 – Look Up Weighting Coefficients

Weighting coefficients are selected from Table NA5-3 of Reference Nonresidential Appendix NA5 for nonresidential buildings with normal occupancy patterns, Table NA5-4 for buildings with 24-hour occupancy (i.e., high-rise residential, hotels), or Table NA5-5 for retail buildings. The development of these tables for the various occupancies is based on the U-factor Tables in 143-A, B and C in the Standards. The coefficients were developed using the occupancy schedules for each of the occupancies included in the Nonresidential ACM Manual, which resulted in the differences in the coefficients for retail operation versus other nonresidential occupancies.

Table NA5-1 shows which coefficient categories to use with each table from Reference Joint Appendix JA4. For roofs, separate coefficients exist for light roofs, attic roofs, and mass roofs.

For walls, the heat capacity of the construction determines whether it is considered light, medium mass or heavy mass construction. The light wall coefficient is used for all framed constructions; mass wall coefficients are only used if the heat capacity is greater than 7.0 Btu/ft²-F. The construction is considered medium mass if it has a heat capacity between 7.0 and 15.0 Btu/ft²-F and heavy mass if it has a heat capacity greater than 15.0 Btu/ft²-F.

For windows, the weighting coefficients depend on orientation and climate zone. Three weighting coefficients are used for each window: the solar glazing weighting coefficient (C_{Gs}), the visible transmittance coefficient (C_{Gt}), and the U-factor coefficient (C_{Gu}).

Step 5 – Calculate the TDV Energy Use

The TDV energy use of each building envelope component is then calculated. For opaque constructions, the TDV energy use is simply the product of the weighting coefficient, area and U-factor.

$$TDV_W = A_W \times C_W \times U_W$$

For windows and skylights, the TDV energy use is given by:

$$TDV_G = A_G \times [(C_{Gu} \times U_G) + (C_{Gs} \times SHGC_G) + (C_{Gt} \times VT_G)]$$

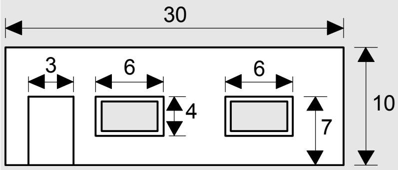
$$TDV_S = A_S \times [(C_{Su} \times U_S) + (C_{Ss} \times SHGC_S) + (C_{St} \times VT_S)]$$

The effect of the glazing visible transmittance (VT) and skylight VT on TDV energy is estimated through the use of the weighting coefficients C_{Gt} and C_{St}. Visible transmittance was introduced to account for the effects of single-pane versus multiple-pane glazing. The solar heat gain coefficient (SHGC) is measured at a normal angle of incidence. At high angles of incidence, the solar heat gain coefficient drops off more quickly for multiple-pane glazing than it does for single-pane glazing. As a result, SHGC underestimates the heat gain effects of single-pane glazing over the course of the day. Including a term for visible transmittance better models the heat gains that occur at various sun angles throughout the day. For a given SHGC, a lower visible transmittance corresponds to either multiple glazing layers or to films, both of which reduce angular SHGC more quickly as incidence angle increases.

Example 3-26

Question

A west-facing wall as shown below has 2x4 construction with R-13 insulation. Windows are double-paned with a U-factor of 0.57 and a solar heat gain coefficient of 0.48 and visible transmittance of 0.58. The door has a U-factor of 0.7. What is the standard design energy use associated with this wall if the building is in climate zone 3?



Answer

The wall has a net surface area of 231 ft², the windows a surface area of 48 ft² and the door 21 ft². The U-factor criterion from Standards Table 143-A Wood framed is 0.110 for the wall and 0.70 for the swinging door. The coefficient for the wall and door is taken from Table NA5-3 of Reference Nonresidential Appendix NA5 as C_w = 79.89. The light wall coefficient is used for all framed constructions; mass wall coefficients are only used if the heat capacity is greater than 7 Btu/ft²-˚F. The coefficients for the window U-factor, SHGC and VT from Table NA5-3 are $C_{Gu(west)}$=20.45, $C_{Gs(west)}$ =206.01, and $C_{Gt(west)}$= 8.34, respectively. For a window-wall ratio of 48/300=0.16, the window prescriptive criteria from Table 143-A of the Standards are 0.77 for U-factor, 0.55 for RSHGC Non-North. The visible transmittance of the standard design windows is 1.2 times the relative solar heat gain coefficient transmittance and is set equal to 1.2 x RSHGC, or 0.66.

The wall and door TDV is calculated by:

$TDV_W = C_W \times U_W \times A_W$ = 79.89 x 0.110 x 231 = 2030.0

$TDV_D = C_W \times U_D \times A_D$ = 79.89 x 0.70 x 21 = 1174.4

The window TDV energy is calculated by:

$TDV_G = A_G \times [(C_{Gu} \times U_G) + (C_{Gs} \times SHGC_G) + (C_{Gt} \times VT_G)$

= 48 x [(20.45 x 0.77) + (206.01 x 0.55) + (8.34 x 0.66)] = 6,458.7

3.7.3 TDV Energy of the Proposed Building – Calculation Details

The TDV energy of the proposed building is calculated by Equation NA5-2 in Reference Nonresidential Appendix NA5. There are six steps to calculating the proposed TDV energy use:

Step 1 - Calculate areas of each type of envelope assembly (walls, windows, roofs, etc.).

Step 2 - If the building includes a large enclosed space, a minimum area of skylights is required. Determine the minimum skylight area as described in Section 3.2.4.

Step 3 - Specify U-factors for all constructions, and SHGC and VT for fenestration.

Step 4 - Determine the roof aged reflectance and thermal emittance values.

Step 5 - Look up the appropriate weighting coefficient from tabulated data in Reference Nonresidential Appendix NA5. (This is done automatically by the spreadsheet tool.)

Step 6 - Multiply the U-factors, areas and weighting coefficients to calculate the TDV energy use for the building envelope component.

These steps are repeated for each building envelope component, and the TDV energy use is summed to obtain the total TDV energy use for the proposed building. Each step is described below in greater detail.

Step 1 – Calculate Areas

First, identify each type of assembly in the building envelope, where a complex building may have varied types of assemblies. Assemblies are different if they have different materials or thermal properties. For example, a steel stud framed wall with a 1 in. stucco exterior would be different from a steel stud framed wall with 4 in. brick cladding.

Next, calculate the areas of each assembly. All dimensions are taken at the exterior surface of the assembly. The sum of all the vertical surface areas is the gross exterior wall area (including windows, doors etc.). The exterior wall area is the opaque wall area (only excluding windows and doors).

In the case of windows, the area is based on the rough opening dimensions. The actual window area is always used for the proposed design window area (even if it exceeds the prescriptive limit).

Step 2 – Determine Minimum Required Skylight Area

This step applies only for large enclosed spaces in Climate zones 2 through15 with a floor area greater than 8,000 ft², and a ceiling height of at least 15 ft. Refer to Section 3.2.4, and §143(c) of the Standards for details. The required skylight area is based on daylit area or effective aperture – see Section 5.2.1 for details on calculating effective aperture.

If the building contains a large enclosed space that meets these criteria, the skylight area of the proposed building must exceed the minimum required area. The actual skylight area of the proposed building is used in the standard TDV energy budget.

Step 3 – Determine Assembly Thermal Properties

The assembly thermal properties are taken from the appropriate table of Reference Joint Appendix JA4. The selection from the JA4 table determines the U-factor for opaque constructions. For windows, the U-factor, solar heat gain coefficient (SHGC) and visible transmittance (VT) are taken from NFRC rating information. If NFRC rating information is not available, default values for U-factor and SHGC are selected from Table 116-A and Table 116-B of the Standards, and the default value for VT is equal to 1.2 times the default SHGC.

For windows, the presence of overhangs is accounted for by a projection factor (PF). This is defined as the ratio of the horizontal projection of the overhang to the vertical distance from the top of the window to the overhang.

Step 4 – Determine Roof Reflectance and Emittance

This step only applies to roof elements. A portion of the solar radiation absorbed by the roof will be conducted through the envelope to the building space. The Standards prescriptively require high solar reflectance and thermal emittance for both steep-sloped and high sloped applications. Nonresidential buildings with low-sloped or steep-sloped roofs in all climate zones except 1 (north coast) and 16 (mountains) require a cool roof. Cool roofs absorb less of the solar energy, thus reducing the heat gain to the space (see Section 3.4).

The proposed aged value of roof reflectance from CRRC Rated Product Directory should be used in the calculation. If aged value for the reflectance is not available in the CRRC Rated Product Directory, then the equation below may be used to calculate aged reflectance:

$$\rho_{aged,prop} = 0.2 + 0.7\ [\rho_{i,prop} - 0.2]$$

Where $\rho_{i,prop}$ = Initial Reflectance listed in the CRRC Rated Product Directory.

If the initial reflectance is not known, a default of 0.1 is assumed. If emittance is not known, a default of 0.75 is assumed. (The lower reflectance for non-CRRC tested roofs is penalizing, since this will result in a higher value for the radiation absorbed and conducted through the roof.)

The roof reflectance and emittance are combined into a cool roof multiplier, which is used in the TDV energy calculation:

$$M_{CR,i} = 1 + c_{Ref} \times (\rho_{aged,prop} - \rho_{aged,std}) + c_{Emit} \times (\varepsilon_{prop} - \varepsilon_{std})$$

The $\rho_{aged,std}$ and ε_{std} represent the aged solar reflectance and thermal emittance for the standard design. The standard design aged solar reflectance and thermal emittance values are taken from Table 143-A, Table 143-B or Table 143-C of the Standards. Different values are provided for low-sloped and steep-sloped roofs (with a rise to run greater than 2:12). If the proposed aged reflectance and emittance equal the standard design aged reflectance and emittance, the cool roof multiplier is 1. The coefficients c_{Ref} and c_{Emit} are taken from Table NA5-3, NA5-4 or NA5-5 of Reference Nonresidential Appendix NA5.

Step 5 – Determine weighting coefficient

Once the areas and allowed U-factors are determined for each assembly, the weighting coefficient is obtained from a set of tables in Reference Nonresidential Appendix NA5. This weighting coefficient accounts for the impacts of the envelope component on TDV energy use. Separate tables are provided for nonresidential buildings (Table NA5-3) with normal occupancy, 24-hour occupancy (Table NA5-4), and retail occupancy (Table NA5-5). The 24-hour occupancy table would apply to high-rise residential buildings and hotels and motels. For a given building component, the weighting coefficient for the proposed design matches the coefficient for the standard design. The tables also include two weighting coefficients to account for overhangs on windows (see next step).

Step 6 – Calculate Overall Envelope TDV energy

For walls and doors, the Overall Envelope TDV energy is the product of the U-factor, the area, and the weighting coefficient. The TDV term for walls from equation NA5-2 is:

$TDV_W = A_W \times U_W \times C_W$

Heat gain and heat loss through windows and skylights occurs by both conduction and radiation. Windows and skylights use three separate weighting coefficients: one for the U-factor, one for the solar heat gain coefficient and one for the visible light transmittance. The window TDV energy term from equation NA5-2 is:

$TDV_G = A_G \times [(C_{Gu} \times U_G) + (C_{Gs} \times SHGC_G \times M_{OH}) + (C_{Gt} \times VT_G)]$

For windows an overhang multiplier MOH is calculated based on two weighting coefficients and the projection factor:

$M_{OH} = 1 + a \times PF + b \times PF^2$

Coefficients “a” and “b” are taken from Table NA5-3, NA5-4 or NA5-5 as appropriate, and are dependent on orientation. If no overhang is present, the projection factor equals 0, and the overhang multiplier term equals 1.

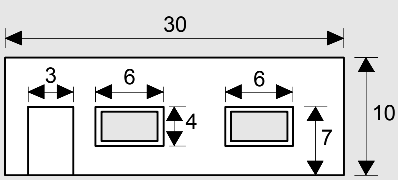
A similar term is used to calculate the effect of skylights on TDV energy:

$TDV_S = A_S \times [(C_{Su} \times U_S) + (C_{Ss} \times SHGC_S) + (C_{St} \times VT_S)]$

Example 3-27

Question

A west-facing wall for an office building (nonresidential occupancy) as shown below has 2x4 construction with studs 16 inches o.c. and with R-13 insulation. Windows are double-paned with a U-factor of 0.57 and a solar heat gain coefficient of 0.48 and visible transmittance of 0.58. The door has a U-factor of 0.70. What is the energy use associated with this wall if the building is in climate zone 3?



Answer

The wall has a net surface area of 231 ft², the windows a surface area of 48 ft² and the door 21 ft². The U-factor for the wall from Table 4.3.1 of Reference Joint Appendix JA4 is 0.102. The coefficient for the wall and door is taken from Table NA5-3 of Reference Nonresidential Appendix NA5 as 79.89. The coefficients for the window U-factor, SHGC and VT from Table NA5-3 are 20.45, 206.01, and 8.34, respectively. No overhang is present, so the overhang multiplier is 1.

The wall TDV is calculated by:

$TDV_W = C_W \times U_W \times A_W = 79.89 \times 0.102 \times 231 = 1882.4$

The door TDV is calculated by:

$TDV_D = C_W \times U_D \times A_D = 79.89 \times 0.70 \times 21 = 1174.4$

The window TDV is calculated by:

$TDV_G = A_G \times [(C_{Gu} \times U_G) + (C_{Gs} \times SHGC_G \times M_{OH}) + (C_{Gt} \times VT_G)$

$= 48 \times [(20.45 \times 0.57) + (206.01 \times 0.48 \times 1) + (8.34 \times 0.58)] = 5{,}538.2$

As seen from the calculation, the windows contribute to most of the TDV energy use. The roof TDV term is the product of the area, U-factor, weighting coefficient and cool roof multiplier:

$TDV_R = A_R \times U_R \times C_R \times M_{CR}$

Example 3-28

Question

A 1200 ft² standing seam low-sloped metal roof for a retail building in Los Angeles (climate zone 6) has R-19 insulation draped over purlins. It has an aged roof reflectance of 0.45 and an emittance of 0.75. What is the TDV energy associated with this roof?

Answer

The U-factor from Table 4.2.7 of Reference Joint Appendix JA4 is 0.065. The coefficients for the roof U-factor, reflectance and emittance are taken from Reference Nonresidential Appendix Table NA5-5 as 68.50, -4.76, and -1.59, respectively. (The "light roof" coefficient is used since the heat capacity of the roof is less than 7 Btu/ft²-˚F. In contrast, span deck and concrete roofs use the "mass roof" coefficient. The weighting coefficient is automatically selected when the spreadsheet tool is used.) The standard design aged solar reflectance and thermal emittance from Table 143-A of the Standards is 0.55 and 0.75.

The cool roof multiplier and roof TDV is calculated by:

$M_{CR} = 1 + c_{Ref} \times (\rho_{aged,prop} - \rho_{aged,std}) + c_{Emit} \times (\varepsilon_{prop} - \varepsilon_{std})$

$= 1 - 4.76 \times (0.45 - 0.55) - 1.59\ (0.75 - 0.75) = 1.476$

$TDV_R = C_R \times U_R \times A_R \times M_{CR} = 68.50 \times 0.065 \times 1200 \times 1.476 = 7886.3$

For a complete example of how the standard building TDV energy and proposed building TDV energy are calculated and compared using the overall tradeoff approach, see Example 3-29.

Example 3-29

Question

A proposed nonresidential building in San Diego (Climate Zone 7) is designed with metal frame, fixed, single clear glass, which does not meet the prescriptive criteria for fenestration U-factor or SHGC. Moreover, the building does not have a certified cool roof. The building owner would prefer to upgrade insulation levels in the roofs and walls, rather than install double-paned glass. Is it possible to comply with the Standards using this overall envelope method?

The building is two stories with 50,000 ft² of roof area and 180,000 ft² of gross wall area. The building has slab-on-grade floor construction. Exterior walls are constructed of 2x6 metal studs spaced at 16 in. on center. The building has 4 exterior doors, each with a surface area of 25 ft² and a U-factor of 0.70. R-19 batt insulation is installed in the cavities and R-7 continuous insulation is installed on the exterior of the wall. The roof construction consists of a low-sloped roof of 2x12 wood joists on 16-inch centers with R-38 insulation in the cavities.

Fenestration area totals 18,000 ft² with 5,000 ft² on the north and south respectively and 4,000 ft² each on the east and west. The SHGC of the fenestration assembly is 0.78, the U-factor is 1.19 and the visible light transmittance is 0.88. All of the 5 ft high windows are shaded by overhangs with a 3 ft projection, located 2 ft above the top of the window.

Answer

The overall envelope approach can be used to demonstrate compliance. It is necessary to show that the proposed building has a lower Overall Envelope TDV energy than a standard building that meets the minimum requirements of the prescriptive standards. Overall Envelope TDV energy for the proposed and standard buildings is calculated from the equations in Reference Nonresidential Appendix NA5.

The window wall ratio is 18,000 / 180,000 = 0.10, so no window area adjustment is required. The projection factor (PF) is 1, since the horizontal projection (H) is greater than the vertical distance above the window (V). The wall U-factor from Table 4.3.3 of Reference Joint Appendix JA4 is 0.080.

For the proposed design:

$TDV_W = A_W \times U_W \times C_W = 161{,}900 \times 0.080 \times 75.52 = 978{,}135.0$

$TDV_D = A_D \times U_D \times C_W = 100 \times 0.70 \times 75.52 = 5{,}286.4$

The overhang multiplier is given by:

$M_{OH,north} = 1 + a_{north} \times PF + b_{north} \times PF^2 = 1 – 0.43 \times 1 + 0.21 \times 12 = 0.78$

$M_{OH,south} = 1 + a_{south} \times PF + b_{south} \times PF^2 = 1 – 0.98 \times 1 – 0.04 \times 12 = - 0.02$

$M_{OH,east} = 1 + a_{east} \times PF + b_{east} \times PF^2 = 1 – 0.78 \times 1 + 0.32 \times 12 = 0.54$

$M_{OH,west} = 1 + a_{west} \times PF + b_{west} \times PF^2 = 1 – 0.78 \times 1 + 0.32 \times 12 = 0.54$

The TDV energy for each window orientation can now be calculated:

$TDV_{G,north} = A_G \times [(C_{G,U} \times U_G) + (C_{G,S} \times SHGC_G \times M_{OH}) + (C_{G,T} \times VT_G)$

$= 5{,}000 \times [(4.97 \times 1.19) + (151.32 \times 0.78 \times 0.78) + (0.67 \times 0.88)] = 492{,}834.9$

$TDV_{G,south} = 5{,}000 \times [(60.43 \times 1.19) + (127.19 \times 0.78 \times -0.02) + (-20.69 \times 0.88)] = 258{,}601.68$

$TDV_{G,east} = 4{,}000 \times [(1.81 \times 1.19) + (279.82 \times 0.78 \times 0.54) + (5.40 \times 0.88)] = 499{,}064.3$

$TDV_{G,west} = 4{,}000 \times [(2.92 \times 1.19) + (348.89 \times 0.78 \times 0.54) + (1.89 \times 0.88)] = 608{,}361.9$

The total TDV energy for the windows is the sum of the totals above, or 1,858,862.8.

The roofs solar reflectance and thermal emittance defaults to 0.1 and 0.75, respectively. The roofing product (cool roof) multiplier is:

$M_{CR} = 1 + c_{Ref} \times (\rho_{aged,prop} - \rho_{aged,std}) + c_{Emit} \times (\varepsilon_{prop} - \varepsilon_{std})$

$= 1 – 3.27 \times (0.1 – 0.55) – 0.93 \times (0.75 – 0.75) = 2.4715$

The U-factor from Table 4.2.2 of Reference Joint Appendix JA4 is 0.029. The roof TDV energy is calculated by:

$TDV_R = A_R \times U_R \times C_R \times M_{CR} = 50{,}000 \times 0.029 \times 94.40 \times 2.4715 = 338{,}298.9$

Since the weighting coefficient for a mass floor is 0, the TDV term for the floor drops out of the equation.

The total TDV energy of the proposed building is:

$TDV_{prop} = TDV_W + TDV_D + TDV_G + TDV_R$ = 978,135.0 + 5,286.4+ 1,858,862.8 + 338,298.9 = **3,180,583.1**

Now the TDV energy of the standard design building can be calculated. Wall and door U-factors are taken from Table 143-A of the Standards.

For the proposed design:

$TDV_W = A_W \times U_W \times C_W$ = 161,900 x 0.098 x 75.52 = 1,198,215.4

$TDV_D = A_D \times U_D \times C_W$ = 100 x 0.70 x 75.52 = 5,286.4

For windows the U-factor criteria from Table 143-A is 0.77, and the SHGC is 0.61. VT is 1.2 x SHGC = 0.732

The same weighting coefficients are used.

$TDV_{G,north} = A_G \times [(C_{G,U} \times U_G) + (C_{G,S} \times SHGC_G) + (C_{G,T} \times VT_G)$

= 5,000 x [(4.97 x 0.77) + (151.32 x 0.61) + (0.67 x 0.732)] = 483112.7

$TDV_{G,south}$ = 5,000 x [(60.43 x 0.77) + (127.19 x 0.61) + (-20.69 x 0.732)] = 544859.6

$TDV_{G,east}$ = 4,000 x [(1.81 x 0.77) + (279.82 x 0.61) + (5.40 x 0.732)] = 704146.8

$TDV_{G,west}$ = 4,000 x [(2.92 x 0.77) + (348.89 x 0.61) + (1.89 x 0.732)] = 865819.12

The total window TDV energy is the sum of the TDV energy from each orientation, or 2,597,938.22.

The standard design roof TDV is calculated by:

$TDV_R = A_R \times U_R \times C_R$ = 50,000 x 0.067 x 94.40 = 316,240

The total TDV energy of the standard building is:

$TDV_{std} = TDV_W + TDV_D + TDV_G + TDV_R$ = 1,198,215.4 + 5,286.4 + 2,597,938.22+ 316,240 = **4,117,680**

The proposed building has a lower TDV energy than the standard building, so the building meets the overall envelope requirements of the Standards.

3.7.4 Roof Alterations

The overall envelope approach may be used for roof alterations, to trade-off roof insulation with roofing products (cool roof) thermal performance. The installer may wish to add additional insulation in place of a cool roof. In this case, the standard design depends upon the existing level of roof insulation.

For low-sloped roofs, Table 149-A in the Standards shows the minimum level of insulation required for alterations. For nonresidential buildings this is R-8 continuous insulation (U-factor of 0.081) in climate zones 1 and 3 through 9 and R-14 continuous insulation (U-factor of 0.055) in climate zones 2 and 10 through 16. However, the insulation level of the standard design is the greater of the existing insulation or the minimum required in Table 149-A unless the roof qualifies for one of the 4 *Exceptions* to §149(b)1Biv:

1. If the existing roof is insulated with at least R-7 insulation or has a U-factor lower than 0.089, no additional roof insulation is required. In this

case, if the designer wishes to tradeoff increased insulation in lieu of installing a cool roof, the standard design used for comparison is the existing insulation level.

2. If mechanical equipment is located on the roof and it will not be disconnected and lifted as part of roof replacement (*Exception* 2 to 149(b)1Biv), 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. In this case, since additional insulation would reduce the height from the roof membrane to the top of the base flashing, no tradeoff is allowed with roof reflectance. A cool roof is required when the designer claims this exception.
3. If adding the required insulation will reduce the base flashing height to less than 8 inches at penthouse or parapet walls (*Exception* 3 to 149(b)1Biv), the insulation added might be limited to the maximum insulation thickness that will allow a height of 8 inches from the roof surface to the top of the base flashing. In this case, since additional insulation would reduce the base flashing height, no tradeoff is allowed with roof reflectance. A cool roof is required when the designer claims this exception.

For steep-sloped roofs, the U-factor criteria of Tables 143-A and 143-B of the Standards apply to the standard design building.

TDV energy of the roof is calculated much in the same way as it is with the whole building overall envelope tradeoff method. The TDV energy of the standard design building is calculated by:

$TDV_R = A_R \times U_R \text{ X } C_R$

The TDV energy of the proposed building includes the cool roof multiplier term (MCR) that was described in a previous section:

$TDV_R = A_R \times U_R \times C_R \times M_{CR}$

Where $MCR = 1 + c_{Ref} \times (\rho_{aged,prop} - \rho_{aged,std}) + c_{Emit} \times (\varepsilon_{prop} - \varepsilon_{std})$

Weighting coefficients are taken from Table NA5-3, NA5-4 or NA5-5 from Reference Nonresidential Appendix NA5.

Example 3-30

Question

A designer wishes to add additional insulation to a 5,000 ft² wood-framed rafter roof in a nonresidential building in climate zone 6 to avoid having to install a cool roof upon reroofing. The rafters are spaced at 24 inches on centerc. What level of insulation is required if the existing roof has R-11 insulation installed below the roof deck? The new roofing product has an aged reflectance of 0.1 and emittance of 0.75.

Answer

The existing roof has a U-factor of 0.081, which is equal to the minimum insulation requirement of Table 149-A of 0.081. Thus, the standard design roof has a U-factor of 0.081. Since a cool roof is required, the standard design aged roof reflectance is 0.55 and thermal emittance is 0.75.

The coefficients CR, c_{Ref} and c_{Emit} are taken from Reference Nonresidential Appendix NA5, Table NA5-3.

The TDV energy of the Standard design is:

$TDV_R = A_R \times U_R \times C_R = 5000 \times 0.081 \times 83.90 = 33{,}979.5$

The TDV energy of the proposed design is:

$M_{CR,i} = 1 + c_{Ref} \times (\rho_{aged,prop} - \rho_{aged,std}) + c_{Emit} \times (\varepsilon_{prop} - \varepsilon_{std})$

$M_{CR} = 1 - 2.16 \times (0.1-0.55) + 0.19 \times (0.75-0.75) = 1.972$

The TDV energy of the proposed roof cannot exceed that of the standard design.

$TDV_R = A_R \times U_R \times C_R \times M_{CR} = 33{,}979.5$

$5000 \times UR \times 83.90 \times 1.972 = 33{,}979.5$

Solving for U_R yields $U_R = 0.041$. The U-factor of the proposed roof must be 0.041 or lower. The designer could add the equivalent of R-14 insulation above the deck as part of the reroof project to achieve a total equivalent of R-25 insulation to obtain a U-factor of 0.039.

3.8 Performance Approach

Under the performance approach, the energy use of the building is modeled by compliance software approved by the Energy Commission. The compliance software does an hourly simulation of the proposed building, including a detailed accounting of envelope heat transfers using the assemblies and fenestration input, and including the precise geometry of exterior overhangs or side fins. The most accurate tradeoffs between different envelope components – and between the envelope, the mechanical system and the installed lighting design – are therefore accounted for and compared with the standard design version of the building. The proposed design has to have TDV energy less than or equal to the standard design. This section presents some basic details on the modeling of building envelope components. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program. All compliance software, however, are required to have the same basic modeling capabilities. A discussion on the performance approach, and fixed and restricted inputs, is included in Chapter 9.

The following modeling capabilities are required by all approved nonresidential compliance software. These modeling features affect the thermal loads seen by the HVAC system model.

3.8.1 Opaque Surface Mass Characteristics

Heat absorption, retention and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled. Typical inputs are spacing, thickness, Standard U-factor, JA4 Table references, Framed Cavity R-value and 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 Joint Appendix JA4. Effective R-values for interior and exterior insulation are provided in Table 4.3.13 of Reference Joint Appendix JA4.

3.8.2 Opaque Surface

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

1. Surface areas by opaque surface type.
2. Surface orientation and slope.
3. Thermal conductance of the surface. The construction assembly U-factor is chosen from tabulated values in Reference Joint Appendix JA4.
4. Surface absorptance. Surface absorptance is a restricted input (except for roofs).

Surface absorptance and emittance are variable inputs in the proposed design for roofs to provide a 'cool roof credit' in climate zones where a cool roof is not required. The roof reference design is set with a cool roof surface absorptance for nonresidential buildings in climate zones 2 through 15. The difference in surface absorptance creates a credit that can be used with both the building envelope trade-off option and the whole building performance method. Cool roofs have both a high reflectance and a high emittance. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance ensures that when the roof does warm up, its heat can escape through radiation to the sky. To model the proposed design as a cool roof, the roofing product must be listed in the Rated Product Directory of the Cool Roof Rating Council. 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 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.

3.8.3 Fenestration Heat Transfer

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

1. Fenestration areas. The glazing width and height dimensions are those of the rough-out opening for the window or fenestration product. Window area of the standard design is limited to the prescriptive limit of 40 percent of the gross wall area or 6 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 energy penalty from fenestration.
2. Fenestration orientation and slope.
3. Fenestration thermal conductance. The overall U-factor shall be taken from NFRC rating information, default values in Table 116-A of the

Standards or from the Alternative Default Fenestration, Reference Nonresidential Appendix NA6, if less than 10,000 ft².

4. Fenestration solar heat gain coefficient. The SHGC shall be taken from NFRC rating information default values in Table 116-B of the Standards or from the Alternative Default Fenestration, Reference Nonresidential Appendix NA6 if less than 10,000 ft².

5. If the compliance software requires input of the shading coefficient (SC) instead of the SHGC, the shading coefficient shall be calculated by the following formula:
SC = SHGC / 0.87

3.8.4 Overhangs and Vertical Shading Fins

Approved compliance software programs are able to model overhangs and vertical fins. Typical inputs are overhang projection, height above window, window height and the 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 must assume that the extension is zero (i.e., overhang width is equal to window width) which results in less 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).

3.8.5 Interzone Surfaces

Heat transfer modeled through all surfaces separating different space conditioning zones may be modeled with inputs such as surface area, surface tilt and thermal conductance. Thermal mass characteristics may be modeled using the thickness, specific heat, density and types of layers that comprise the construction assembly. Demising partitions separating a conditioned space from an unconditioned space that are insulated with R-13 cavity insulation or with a U-factor less than 0.218 are modeled as adiabatic partitions (no heat transfer). Walls that separate directly conditioned zones from other conditioned zones are modeled as “air walls” with no heat capacity and an overall U-factor of 1.0 Btu/h-ft²-˚F.

3.8.6 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 perimeter slab area is defined by 2 ft times the perimeter length in feet. The interior slab area is the total slab area minus the perimeter slab area. The surface condition (whether or not the slab is carpeted or exposed), the insulation depth and insulation R-value affect the heat loss through the slab. The insulation depth and insulation R-value affect heat loss through basement floors.

3.8.7 Historic Buildings

Exception 1 to §100(a) states that qualified historic buildings, as defined in the California Historical Building Code (Title 24, Part 8 or California Building Code, Title 24, Part 2, Volume I, Chapter 34, Division II) are not covered by the Standards. However, non-historical components of the buildings, such as new or replacement mechanical, plumbing, and electrical (including lighting) equipment, additions and alterations to historic buildings, and new appliances in historic buildings may need to comply with Building Energy Efficiency Standards and Appliance Efficiency Regulations, as well as other codes. For more information about energy compliance requirements for Historic Buildings, see Section 1.7.1, Building Types Covered, in Chapter 1, the Overview of this manual.

3.9 Additions and Alterations

The Standards offer prescriptive approaches and a performance approach to additions and alterations (but they do not apply to repairs). The prescriptive approaches are discussed in this section, and the performance method is discussed in Chapter 9 of this manual.

Here are some relevant definitions from §101(b):

An **addition** is a change to an existing building that increases conditioned floor area and volume. See §149(a)1 and §101(b) for detailed definition.

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

An **alteration** is a change to an existing building that is not an addition. An alteration could include a new HVAC system, lighting system, or change to the building envelope, such as a new window. See §149(b)1 and §101(b). Roof replacements (reroofing) and reconstructions and renewal of the roof are considered alterations and are subject to all applicable Standards requirements.

A **repair** is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. For example, a repair could include the replacement of a pane of glass in an existing multi-lite window without replacing the entire window. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration. See §149(c) and §101(b).

The Standards provide both prescriptive and performance compliance for additions and alterations. For additions, the compliance options include:

1. The prescriptive envelope component approach;
2. The prescriptive overall envelope TDV energy approach;
3. The addition alone performance approach.

For existing-plus-addition-plus alteration, use the performance approach. For more information on the performance approach with additions and alterations, refer to Chapter 9, Section 9.3 of this Manual.

1. For alterations, the compliance options include:
2. The prescriptive envelope component approach;

3. The prescriptive overall envelope TDV energy approach;
4. The existing-plus-alteration performance approach.

3.9.1 Mandatory Measures for Additions and Alterations

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

§116 - Mandatory Requirements for Fenestration Products and Exterior Doors;

§117 - Mandatory Requirements for Joints and Other Openings; and

§118 - Mandatory Requirements for Insulation and Roofing Products (Cool Roofs).

For more details on these requirements, see Sections 3.2.1, Mandatory Measures (Fenestration); 3.3.1 Mandatory Measures (Opaque Envelope Insulation); and 3.4.1 Mandatory Labeling Requirements (Cool Roofs).

3.9.2 Additions – Prescriptive Requirements

Prescriptive compliance for the building envelopes of additions is addressed in §143, Prescriptive Requirements for Building Envelopes. §143 provides two prescriptive compliance options for building envelopes:

§143(a) - Envelope Component Approach, or

§143(b) - Overall Envelope TDV Energy Approach.

All additions must also comply with §143(c), Minimum Skylight Area for large enclosed spaces in buildings with three or fewer stories.

For more details on the prescriptive requirements for additions, see Sections 3.1, Overview (Building Envelope); 3.1.1, Prescriptive Requirements (Building Envelope); 3.2.2, Window Prescriptive Requirements; 3.2.3, Skylight Prescriptive Requirements; 3.3.2, Prescriptive Requirements (Opaque Envelope Insulation); 3.4.2, Prescriptive Requirements (Cool Roofs); and 3.7, Overall Envelope TDV Energy Approach.

Alternatively, the addition may meet compliance by using the performance compliance approach of §141, 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.

3.9.3 Alterations – Prescriptive Requirements

In general, any alteration to an existing building that involves changes to a portion of the building envelope triggers the Standards. The prescriptive requirements for alterations to building envelopes are in §149(b)1A and B.

Opaque Envelope

§149(b)1A

All nonresidential building alterations involving exterior walls, demising walls, external floors, or soffits must either comply as a component with the requirements in Tables 143-A, B or C in the Standards, or calculations must be provided which demonstrate that the overall TDV energy use of the overall building or component is equal to or less than the unaltered configuration.

Fenestrations

§143(a)5, §149(b)1A

Alterations to fenestration must comply with §143(a); which means that the new fenestration must meet the U-factor and SHGC requirements listed in Standards Tables143-A, B or C. In cases where the fenestration is temporarily removed and then reinstalled compliance with §143(a) is not required.

In cases where small amounts of fenestration area are changed, a number of options exist. If less than 150 ft² of fenestration area is replaced throughout the entire building, then the Standards require that only the U-factor requirements in Tables 143-A, B or C are met. The SHGC or relative Solar Heat Gain Coefficients requirements need not be met. The same requirements and exceptions apply if 50 ft² or less of fenestration area is added. A typical example of this may be changing a door from a solid door to a glass door.

For hotels/ motels or high rise residential buildings. Up to 150 ft² of added fenestration area is exempt from the 40 percent limitation on west-facing orientation, U-factor, and the total area no greater than 40 percent of the gross wall area limitation in §143(a)5. This additional window must meet the RSHG requirement for the 30-40 percent of the WWR of Standards Table 143-B.

In addition, up to 50 ft² of skylight area is exempt from having no greater than 5 percent of the gross exterior roof area limitation in §143(a)6A in the Standards. In addition the added skylights shall meet the SHGC requirements in Table 143-B for the 2.1 to 5 percent area.

Roofing Products

§149(b)1B

When more than 2,000 ft² or more than 50 percent of a roof (whichever is less) is being replaced on a conditioned building, energy code requirements for roof surface radiative (cool roofs) properties and roof insulation levels are triggered. Thus when a small repair is made, these requirements don't apply. The Standards requirement regarding roof insulation would not be "triggered" if the existing roof surface were overlaid instead of replaced.

It should be noted that these envelope requirements only apply to conditioned spaces and do not apply to unconditioned and process spaces. However, these requirements do apply to roofs over office spaces in buildings that also have process spaces. These roof areas can be delineated by the fire separation walls between process areas and large scale office areas.

Replacement Roof Solar Reflectance and Thermal Emittance (Cool Roofs)

Roofing products with high solar reflectance and high thermal emittance are referred to as “cool roofs” because they absorb less solar heat and give off more heat to their surroundings. These roofs are cooler and thus reduce air conditioning loads in the space below. Roof radiative properties are rated and listed by the Cool Roofs Rating Council (http://www.coolroofs.org/).

Solar Reflectance Index (SRI) is a new concept in the Standards. The temperature of a surface depends on the incident solar radiation, surface’s reflectance, and emittance. The SRI measures the relative steady-state surface temperature of a surface with respect to standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient condition. A calculator has been produced by the staff at Lawrence Berkeley National Laboratory that calculates the SRI by designating the Solar Reflectance and Thermal emittance of the desired roofing material. To use the calculator contact the Energy Hotline at 1-800-772-3300. SRI calculations must be based on moderate wind velocity of 2-6 meters per second. To calculate the SRI the 3-year aged value of the roofing product must be used. By using the SRI calculator a cool roof may comply with an emittance lower than 0.85 as long as the aged reflectance is higher and visa versa.

As described in §149(b)1B, roof radiative property requirements are different for steep-sloped and low-sloped roofs. Low-sloped roofs are defined as having a rise of 2 ft or less for every 12 ft of run (horizontally); they have a slope of 9.5 degrees or less from the horizontal. Steep-sloped roofs are defined as having a rise of more than 2 ft for every 12 ft of run (horizontally); they have a slope greater than 9.5 degrees from the horizontal. Low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is high in the sky. Also the color aesthetic considerations are less for low-sloped products because it is harder to see low-sloped roofs from street level.

Cool roofs with a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75 are required on low-sloped nonresidential roofs in climate zones 2 through 15 when roofing is replaced or recovered when using the prescriptive method. Alternatively one can specify a roof with a minimum solar reflectance index[5] (SRI) of 64. The Standards have dropped the requirements for cool roofs on low-sloped nonresidential buildings in climate zone 1 (North Coast) and climate zone 16 (Mountains) as these climates do not have enough cooling loads to warrant cool roofs. New for the Standards is that the cool roof requirements are defined in terms of their aged reflectance and emittance. These aged values are measured after 3 years of outdoor exposure. The Cool Roof Rating Council (CRRC) rating and labeling program reports both initial and aged solar reflectance and thermal emittance values.

For new products that do not yet have aged ratings, the following calculation can be used to calculate an aged reflectance, R_{aged}, from the CRRC initial solar reflectance rating, $\rho_{initial}$.[6] $R_{aged} = [0.2+0.7[\rho_{initial} -0.2]$,

[5] Calculated according to ASTM E1980 - 01 Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces American Society for Testing and Materials. West Conshohocken, Pennsylvania. The Solar Reflectance Index provides a trade-off between aged reflectivity and thermal emittance.

[6] Section 118(i)2.

There is no similar derating of the aged thermal emittance when using the initial thermal emittance rating.

The Standards expanded the cool roof requirements to cover low-sloped roof replacements on high-rise residential buildings, hotels and motels in the hottest climate zones in the Central Valley and desert (climate zones 10, 11, 13, 14 and 15). Low-sloped cool roofs are required to have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75. As described above, a roof having a solar reflectance index (SRI) of 64 would also comply.

New to the Standards are steep-sloped cool roof requirements. The radiative property requirements are more stringent for lightweight roofing materials (like asphalt shingles, metal roofing products, and composite roofing) than for roofs that weigh 5 lbs/ft^2 or more (such as concrete and clay tile).

Lightweight steep-sloped roofing materials, weighing less than 5 lbs/ft^2, installed in climate zones 2 through 16 must have a minimum aged solar reflectance of 0.20, and a minimum thermal emittance of 0.75 or a solar reflectance index (SRI) of 16. Note that there are no cool roof requirements for climate zone 1 (North Coast).

Heavyweight steep-sloped roofing materials, weighing 5 lbs/ft^2 or more, installed in any climate, must have a minimum aged solar reflectance of 0.15, and a minimum thermal emittance of 0.75 or a solar reflectance index (SRI) of 10.

Roof areas covered by building integrated photovoltaic panels and building integrated solar thermal panels and existing roof areas that have thermal mass over the roof membrane with a weight of at least 25 lb/ft^2 are exempted for this requirement as per *Exceptions* 3 and 4 to §143(a)1Ai.

Adding Insulation When Roofing Removed to Roof Deck

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

When re-roofing more than 2,000 ft^2 or re-roofing more than 50 percent of the roof area (whichever is less) on a conditioned building with a low-sloped (2:12 or less rise to run ratio) roof, and the roof deck or recover boards are exposed, adding insulation to roofs with no or little insulation may be required before re-installing the roof membrane. If the roof has at least R-7 insulation or has an overall U-factor of 0.089 Btu/hr• ft^2•°F, no additional insulation is required. This overall U-factor is the thermal transmittance of the entire roofing assembly and can include insulation under the roof deck as well as insulation on top of the roof deck. Pre-calculated U-factors must be used from the Reference Joint Appendix JA4. Steep-sloped (greater than a 2:12 rise to run ratio) roofs are not required to add insulation.

The amount of insulation required varies by climate zone and building type and is given in Table 149-A of the Standards. 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, or insulation can be added below the roof deck between roof joists or a combination of insulation above and below the roof deck.

For nonresidential roofs in climate zones 2, 10-16 the minimum required amount of insulation is R-14 (or an overall roof U-factor of 0.055 Btu/hr• ft²•°F).

For nonresidential roofs, in the milder climate zones 1, 3-9 the minimum required insulation is R-8 (or an overall roof U-factor of 0.081 Btu/hr• ft²•°F).

For high-rise residential and hotel/motel roofs, the minimum required amount of insulation is R-14 (or an overall roof U-factor of 0.055 Btu/hr• ft²•°F) in all climate zones.

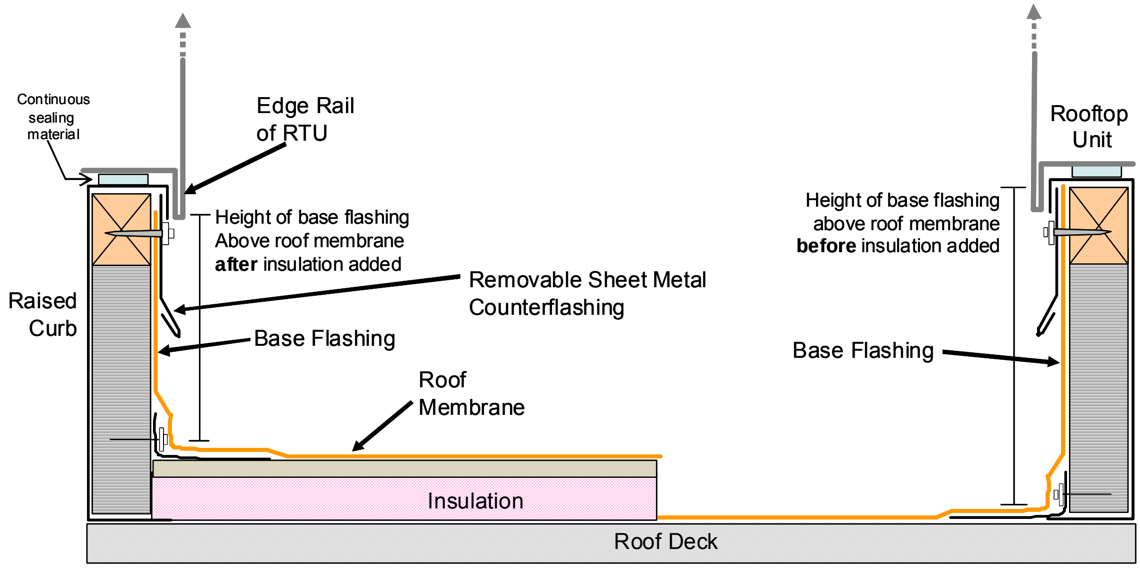


Figure 3-19 - Base flashing on roof top unit curb detail

When insulation is added on top of a roof, the elevation of the roof membrane is increased. As shown in Figure 3-19, when insulation is added to a roof and the curb height (or reglet or counterflashing for walls) is unchanged, the height of the base flashing above the roof membrane will be reduced. In some cases when the overhanging edge of the mechanical equipment is very close to the side of the curb, this may also limit how far up the curb the base flashing may be inserted. Many manufacturers and the National Roofing Contractors Association (NRCA) recommend maintaining a minimum base flashing height of 8 inches above the roofing membrane.

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

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

1. If there is any mechanical equipment on the roof that is not disconnected and lifted during reroofing the condition of this "undisturbed" equipment will determine how much, if any, insulation must be added to the entire roof. That is, if the equipment that is not disconnected and lifted is situated on a curb that is 9 inches above the roof membrane, only 1 inch of insulation must be added to the roof. If the undisturbed equipment is situated on a curb that is 8 inches (20 cm) or less above the roof membrane, no additional insulation is required.
2. Roofs having a "significant length" of penthouse walls or parapet walls with a cladding other than the roofing material and this cladding material must be removed to increase the base flashing height. The criteria for "significant length" varies by building type and climate zone and is based upon the ratio of replaced roof area to length of wall requiring cladding material removal as follows[7]:
   - Nonresidential buildings in climate zones 2 and 10 -16 with less than **25** ft² of roof per linear foot of affected wall length.
   - Nonresidential buildings in climate zones 1 and 3 -9 with less than **100** ft² of roof per linear foot of affected wall length.
   - High rise residential buildings and hotel/motels in all climate zones with less than **25** ft² of roof per linear foot of affected wall length.

Increasing the elevation of the roof membrane by adding insulation may also affect roof drainage. The Standards allow tapered insulation to be used to maintain slope-to drain, provided that the average R-value of the insulation equals or exceeds the required minimum.

Roof areas covered by building integrated photovoltaic panels and building integrated solar thermal panels and existing roof areas that have thermal mass over the roof membrane with a weight of at least 25 lb/ft² are exempted for this requirement as per *Exceptions* 3 and 4 to §143(a)1Ai.

Example 3-31

Question

A building is being re-roofed and the roofing is torn off down to the roof deck. The roof has no insulation but it does have a single layer radiant barrier that is stapled to the underside of the roof joists. This forms an air cavity between the underside of the roof deck and the radiant barrier. The radiant barrier has a low emissivity (around 5 percent). Does this create enough of an insulating value that the roof does not need to be insulated?

[7] Exception 2 to Section 149(b)1Biv

Answer

Added insulation is not required when the existing roof insulation exceeds R-7 or the roof has an overall U-factor less than 0.089 Btu/h•ft²•°F. [*Exception* 1 to §149(b)1Biv] However the effective R-value of a sealed air cavity formed by a single layer radiant barrier on the bottom, roof joists on the side and the roof deck on top is around R-2, much less than the needed R-7 insulation. Thus, upon re-roofing where the roof deck is exposed, added insulation would be required.

In Section 4.1.4 of the Reference Joint Appendix JA4, “Accounting for Unusual Construction Layers,” the calculation of the effective thermal resistance of an air cavity is described as follows:

“The thermal resistance of air layers shall be taken from the 2005 ASHRAE Handbook of Fundamentals, for a mean temperature of 50°F, a temperature difference of 20 °F and an effective emittance of 0.82. R-values for air layers for roof and ceiling assemblies shall be based on heat flow up.” Applying these conditions but using an effective emittance of 0.05 the thermal resistance values for a cavity depth of 3.5 inches in the appropriate table in the ASHRAE Handbook of Fundamentals[8] yields an effective R-value of 2.33 ft²•°F•h/Btu. If one assumes surface degradation (or slight condensation) of the radiant barrier to an emittance of 0.2, the effective R-value is 1.77 ft²•°F•h/Btu.

Example 3-32

Question

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

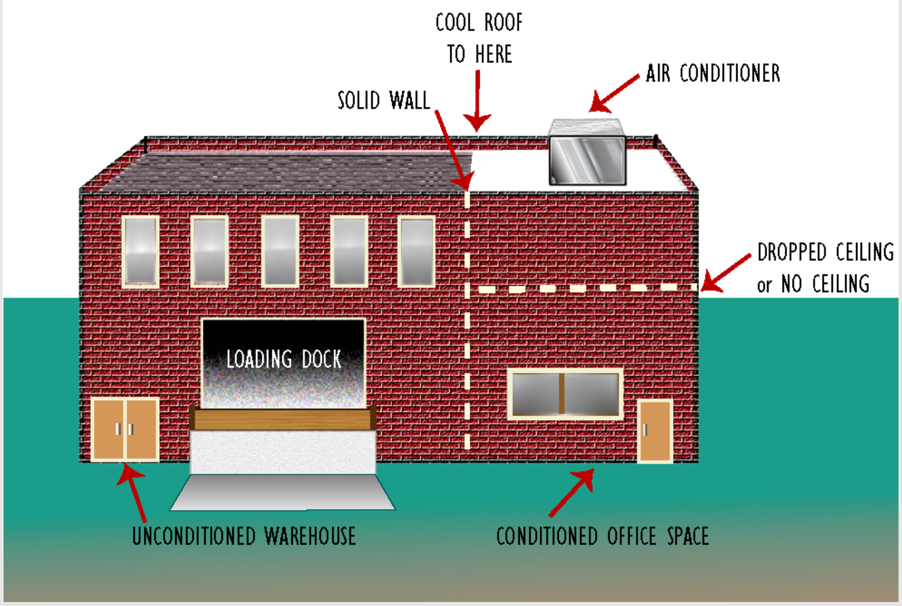
Answer

Scenario 1.

In this situation (see picture below), we now have 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.

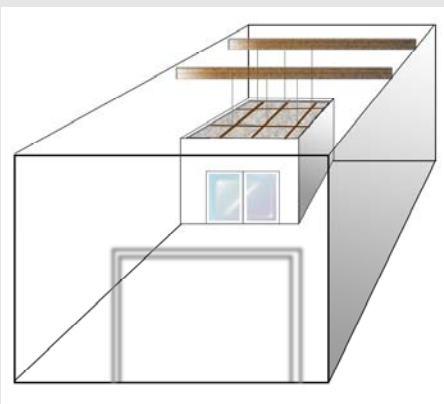
The walls of the conditioned space go all the way up to the underside of the warehouse.

[8] p. 25.4, 2005 ASHRAE Fundamentals Handbook Table 3: “The Thermal Resistances of Plane Air Spaces, ft²•°F•h/Btu



Scenario 2.

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



Example 3-33

Question

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

Answer

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

Example 3-34

Question

As shown in Figure 3-20, 40 percent of the low-sloped roof on a 500 ft by 100 ft retail building in Concord, California (CZ12) is being re-roofed. 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 re-roofing?

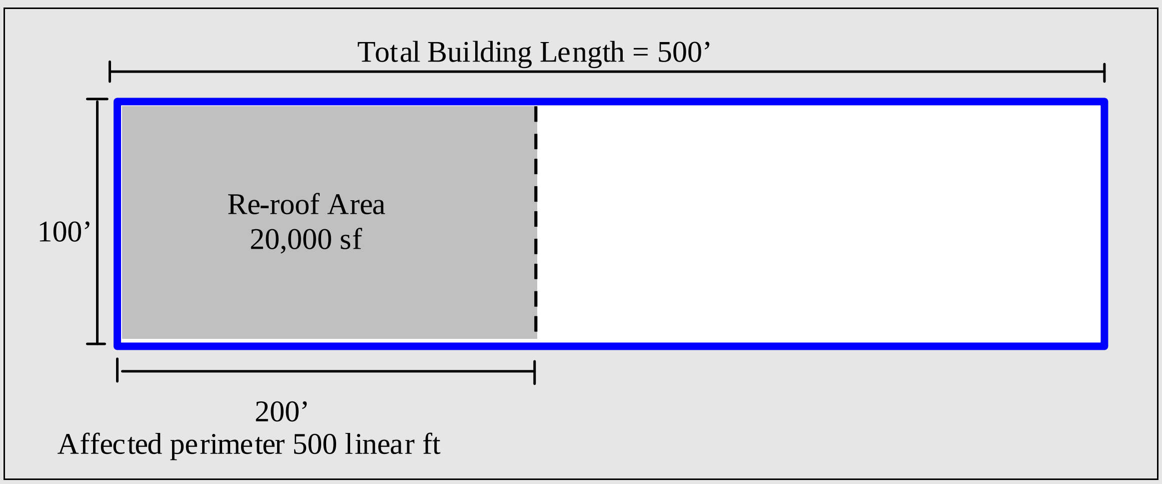


Figure 3-20 - Plan View of Partial Building Re-roofing Project

Answer

Yes, §149(b)1B requires when either 50 percent (or more) of the roof area or 2,000 ft² (whichever is less) is re-roofed down to the roof deck or recover boards, that insulation be installed if the roof has less than R-7 insulation. Though the re-roofing covers only 40 percent of the roof area, the requirements still apply because the 20,000 ft² of replacement roof area is greater than the threshold area of 2,000 ft². As stated in the question, the roof does not have any insulation and therefore it is required to add insulation.

Concord, California is in climate zone 12[9]. As per Standards Table 149-A "Insulation Requirements for Roof Alterations," for nonresidential buildings in climate zone 12, the requirement for insulation is either R-14 continuous insulation or an effective roof U-factor of 0.055 Btu/h•ft²•°F. If the ratio of replaced roof area to affected clad wall length is less than 25 ft² of roof per linear ft of wall, then the insulation thickness is allowed to be limited to the maximum thickness that will maintain a base flashing height of no less than 8 inches above the roof membrane.

The ratio of the replaced roof to the affected wall area is 20,000 ft² / 500 linear ft = 40:1. Since this ratio is greater than 25:1, the full required insulation must be installed regardless of the existing base flashing height. This may require changing the height of the base flashing, removing some of the parapet wall cladding and moving the counterflashing (or reglet) higher up on the wall. Alternatively, the installer may ask for the roofing manufacturer to provide a variance in the warrantee to accept a slightly lower base flashing height above the roof surface. The specific risk of roof leakage at a given site has to be considered carefully before reducing the base flashing height. When access to the underside of the roof deck is available, an alternative method of compliance that does not affect base flashing heights is to add insulation below the roof deck to the overall U-factor levels given in Standards Table 149-A.

Example 3-35

Question

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

Answer

Yes. San Francisco (as shown in Reference Joint Appendix JA2) is in Climate Zone 3. In Standards Table 149-A from §149(b)1Biv "Insulation Requirements for Roof Alterations," for nonresidential buildings in climate zone 3 is R-8 or a U-factor of 0.081.

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

Example 3-36

Question

A nonresidential building is having 5,000 ft² of roofing replaced. During roofing replacement the roof deck will be exposed. This building has a rooftop air conditioner that is sitting on an 8 inches (20 cm) high curb above the roof membrane level. The roof is currently uninsulated. If the rooftop air conditioner unit is not disconnected and not lifted off of the curb during re-roofing, is adding insulation required?

[9] A listing of climate zones by city is found in Reference Joint Appendix JA2.

Answer

No, *Exception* 2 to §149(b)1Biv, specifically exempts re-roofing projects when mechanical 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 (20 cm) 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 (20 cm) above the roof membrane, no added insulation is required.

Example 3-37

Question

What if the rooftop air conditioner from Example 3-36 is lifted temporarily during re-roofing to remove and replace the roofing membrane? Is added insulation required?

Answer

Yes, insulation is required. *Exception* 2 to §149(b)1Biv specifically applies when the mechanical 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 (20 cm) above the roof membrane. When the rooftop unit is lifted as part of the re-roofing project, the incremental cost of replacing the curb or adding a curb extension is reduced. Thus to maintain the 8 inch (20 cm) base flashing height, one can replace the curb or add a curb extension before re-installing the roof top unit. Alternatively one can ask for a roofing manufacture's variance to their warrantee from the typical minimum required 8 Inches (20 cm) 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 149-A of §149(b)1Biv.

Example 3-38

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 inches (20 cm) high curb above the roof membrane level. The roof is currently uninsulated. Is added insulation required?

Answer

Yes, insulation is required. *Exception* 2 to §149(b)1Biv specifically applies when mechanical equipment is not lifted. Unit skylights are not mechanical equipment and thus the exception does not apply. Removing a unit skylight and increasing its curb height is substantially less effort than that for mechanical equipment.

Example 3-39

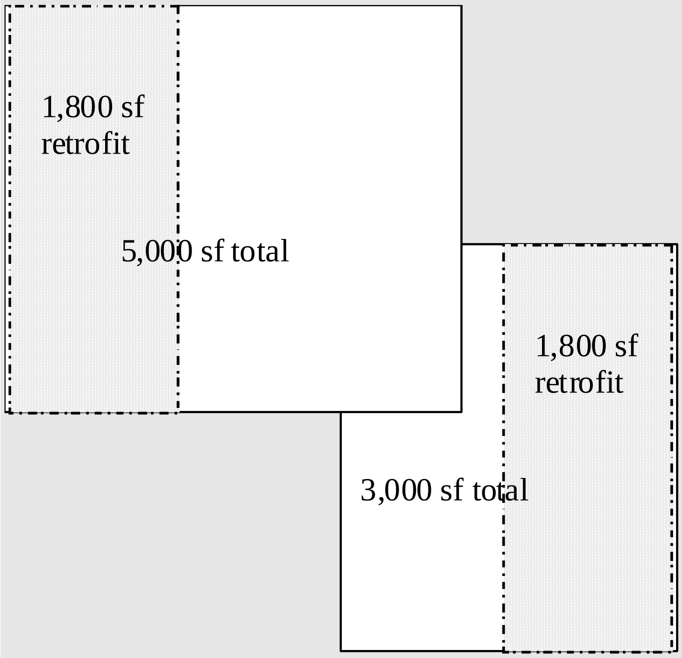


Figure 3-21 – Building with two roofs configurations.

Scenario 1

A building has low-sloped roofs at two different elevations.(Figure 3-21) 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 re-roofed and the roof deck is exposed, is that portion of the roof required to be insulated and be a “cool roof” (high reflectance and emittance)?

Answer

Yes, the re-roofed section of the roof is required to be insulated and have a “cool roof”. §149(b)1B requires insulation and cool roofs for low-sloped roof alterations if the alteration is greater than 2,000 ft² or greater than 50 percent of the roof area. Since 1,800 ft² is 60 percent of 3,000 ft², the cool roof and insulation requirements apply.

Scenario 2

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

Answer

No. The 1,800 ft² retrofit is 36 percent of the 5,000 ft² roof. Thus the 1,800 ft² retrofit is less than 50 percent of the roof area and it is also less than 2,000 ft², thus it is not required to comply with the insulation and cool roof requirements in §149(b)1B.

Example 3-40

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 roof top units on this section of the roof that is being altered. One roof top unit has a curb with a 9 inches (23 cm) base flashing and the other has a modern curb with a 14 inches (36 cm) base flashing. Consider the following three scenarios:

Scenario 1

The roof top unit with the 9 inches (23 cm) base flashing is disconnected and lifted during re-roofing. However, the rooftop unit on the curb with the 14 inches (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 inches (20 cm) base flashing on the unit with the lower curb?

Answer

No. The unit with the 9 inches (23 cm) base flashing was disconnected and lifted and thus it does not qualify for *Exception* 2 to §149(b)1Biv: "not be disconnected and lifted as part of the roof replacement." One could add as much as 6 inches (15 cm) or more of insulation before the base flashing height would be reduced below 8 inches (20 cm) on the un-lifted rooftop unit with a 14 inches (36 cm) 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 (15 cm). Thus the full R-14 insulation would be required.

Scenario 2

The roof top unit with the 9 inches (23 cm) base flashing is **not** disconnected and lifted during re-roofing. In this situation, is the insulation that must be added limited to the amount of insulation that will result in an 8 inches (20 cm) base flashing on the unit with the lower curb?

Answer

Yes. The unit with the 9 inches (23 cm) base flashing was not disconnected and lifted and thus it qualifies for *Exception* 2 to §149(b)1Biv. One could add only 1 inch (2.5 cm) of insulation before the base flashing height would be reduced below 8 inches (20 cm) on the un-lifted 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). Therefore, only 1 inch (2.5cm) of additional insulation is required because adding any more insulation would reduce the base flashing height below 8 inches (20 cm) on the unlifted rooftop unit with a 9 inches (23 cm) base flashing.

Scenario 3

In scenario 2 above, does this reduced amount of required insulation apply only to the area immediately surrounding the un-lifted unit or to the entire roof?

Answer

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

Example 3-41

Question

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

Answer

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

Example 3-42

Question

If I am doing a reroof, would Exceptions 1 through 4 to §143(a)1Ai apply to reroofing and roof alterations?

Answer

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

Example 3-43

Question

Why does §149(b)1Bii have different climate zone and different solar reflectance and SRI requirements?

Answer

§149(b)1Bii refers to materials with less density, and others with greater density so the material with less density performs differently compared to the greater density materials that have a tendency to retain some gained heat. As a result of the performance characteristic and difference in the analysis, each of the two types of density materials was separately evaluated for each climate zone.

Example 3-44

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 different sets of rules in §149 (b)1Bi 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. Note that these requirements are climate zone-based and vary based on the density of the outer roofing layer.

For more details on the prescriptive requirements for alterations, see Sections 3.1, Overview (Building Envelope); 3.1.1, Prescriptive Requirements (Building Envelope); 3.2.2, Window Prescriptive Requirements; 3.2.3, Skylight Prescriptive Requirements; 3.3.2, Prescriptive Requirements (Opaque Envelope Insulation).

3.10 Compliance Documentation

Field Inspection Energy Checklist

New for the compliance forms is the Field Inspection Energy Checklist now combined with ENV-1C, LTG-1C, MECH-1C and RWH-1C. The Checklist is designed to help Field Inspectors look at specific features that are critical to envelope compliance and is submitted as part of the Energy Documentation that accompanies the plans. Field inspector checkboxes are incorporated directly into the ENV-1C as part of the Opaque Surfaces, Fenestration Surface Details and Roofing Product sections of the form.

Under the Prescriptive Approach, the Documentation Author is responsible for completing the Field Inspection Energy Checklist. For the Performance Approach this Checklist will automatically be completed by the approved computer program.

A copy shall be made available to the Field Inspector so that during different stage inspection. This is where the Field Inspector will verify whether or not the energy features installed in the field match the values listed in the ENV-1C, LTG-1C, MECH-1C and RWH-1C.

As an example, the Field Inspection Energy Checklist portion is designed to help Field Inspectors look at specifics features that are critical to envelope compliance. These features should match the building plans as indicated on the ENV-1C. If they do, then feature “Passes” – if they don’t, then it “Fails.”

The Field Inspector must verify after the installation of each measure (e.g. Opaque Surface, Fenestration Surface Details and Roofing Products). The Field Inspector in addition must collect a signed ENV-INST (Installation Certificate) from the installer.

In the case if the Field Inspection Energy Checklist does not match exactly the building plans or the ENV-INST form, the field inspector must verify the features are meeting the minimum efficiency or better and if so no further compliance is required from the Architect or responsible party. In the case the features fails to meet the efficiencies (worse), the enforcement agency shall require resubmittal of the actual energy compliance documentation to reflect the actual installed features.

Opaque Surface Details

The Field Inspector need only check the Pass or Fail check boxes only after the measures have been verified. If the Special Feature is check, the plan examiner should pay special attention to the items specified in the checklist. The local enforcement agency determines the adequacy of the justification, and may reject a building or design that otherwise complies based on the adequacy of the special justification and documentation. See ENV-1C Page1 of 4.

Fenestration Surface Details

The Field Inspector need only check the Pass or Fail check boxes only after the measures have been verified. If the Special Feature is check, the enforcement agency should pay special attention to the items specified in the checklist. The local enforcement agency determines the adequacy of the justification, and may reject a building or design that otherwise complies based on the adequacy of the special justification and documentation. See ENV-1C Page 1 of 4.

Roofing Product (Cool Roofs)

The Field Inspector need only check the Pass, Fail or Not Applicable (N/A) check boxes only after the measures have been verified. If the Special Feature is check, the enforcement agency should pay special attention to the items specified in the checklist. The local enforcement agency determines the adequacy of the justification, and may reject a building or design that otherwise complies based on the adequacy of the special justification and documentation. See ENV-1C Page 2 of 4.

Discrepancies

If any of the Fail boxes are checked off, the field inspector shall indicate appropriate action of correction(s). See ENV-1C Page 2 of 4.

3.10.1 ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist

ENV-1C Page 1 of 4

The ENV-1C Certificate of Compliance and Field Inspection Energy Checklist has four pages. All pages must appear on the plans (usually near the front of the architectural drawings). A copy of these forms should also be submitted to the enforcement agency along with the rest of the compliance submittal at the time of building permit application. With enforcement agency approval, the applicant may use alternative formats of these forms (rather than the Energy Commission's forms), provided the information is the same and in similar format.

Project Description

PROJECT NAME and ADDRESS is the title of the Project and Address, as shown on the plans and known to the enforcement agency.

DATE is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

CLIMATE ZONE is the official California climate zone number where the building is located. Refer to California Climate Zone Description, Reference Joint Appendix JA2 or at http://www.energy.ca.gov/maps/building_climate_zones.html for a listing of cities and their climate zones.

CONDITIONED FLOOR AREA (CFA) has specific meaning under the Standards. Refer to §101 for a discussion of this definition. Typically CFA is defined as conditioned space, which includes floor and volume.

General Information

BUILDING TYPE is specified because there are special requirements for Nonresidential, High-Rise Residential and Hotel/Motel Guest room occupancies. All other occupancies that fall under the Nonresidential Standards are designated "Nonresidential" including Schools. Check either the Conditioned Space or Unconditioned or if the building contains both the marked both. It is possible for a building to include more than one building type, in which case check all applicable types here. See §101(b) for the formal definitions of these occupancies.

Skylight Area for Large Enclosed Spaces - This requirement applies only if the proposed building contains an enclosed space with floor area greater than or equal to 8,000 ft², a ceiling height greater than 15 ft and an LPD for general lighting of at least 0.5 W/ft². If Skylight area is checked then also include the ENV-4C, Minimum Skylight Area Worksheet.

Relocatables Structures

Note: Relocatable Public School buildings, special conditions apply. The relocatable structure can comply with either a specific climate zone or all climate zones.

In the case of relocatables structures, there are two choices of prescriptive criteria:

5. Table 143-C in the Standards may be used for relocatable school buildings that can be installed in any climate zone in the state. In this case, the compliance is demonstrated in climates 14, 15, and 16 and this is accepted as evidence that the classroom will comply in all climate zones. These relocatables will have a permanent label that allows it to be used anywhere in the state.
6. Table 143-A in the Standards may be used for relocatable school buildings that are to be installed in only specific climate zones. In this case, compliance is demonstrated in each climate zone for which the relocatable has been designed to comply. These relocatables will have a permanent label that identifies in which climate zones it may be installed. It is not lawful to install the relocatable in other climate zones. See Reference Nonresidential Appendix NA4 for further details.

PHASE OF CONSTRUCTION indicates the status of the building project described in the documents:

A. NEW CONSTRUCTION should be checked for all new buildings, newly conditioned space or a stand-alone addition submitted for envelope compliance.

B. ADDITION should be checked for an addition which is not treated as a stand-alone building, but which uses existing plus addition performance compliance, as described in See §149(a).

C. ALTERATION should be checked for alterations to existing building envelopes. See §149(b)

APPROACH OF COMPLIANCE indicates which method is being used and documented with this submittal:

1. COMPONENT for the envelope component method. Form ENV-2C must be included in the compliance documentation as well as the ENV-1C.
2. OVERALL ENVELOPE TDV Energy Approach for the overall envelope method. Form ENV-3C must be included in the compliance documentation.
3. UNCONDITIONED should be checked when the building is not intended as conditioned space, or when the owner chooses to defer demonstrating envelope compliance, see Section 1.7.3 Speculative Buildings for a full discussion. The enforcement agency may require the owner to file an affidavit declaring the building to be unconditioned and acknowledging that all the Standards requirements must be met when the building is conditioned. See §100(e), Sections Applicable to Particular Buildings.
4. Select the buildings Front Orientation: N, E, S, W or indicate in Degrees: _______**.** This information may be found on building plans.

ENV-1C Page 1 of 4

Field Inspection Energy Checklist

The information on Page 1 summarizes the information about the building envelope that can be readily verified by the plans examiner and the field inspector. This form should be included on the plans. Alternatively, the information may be incorporated into construction wall and roof assembly and glazing schedules on the plans, provided it is complete and in substantially the same format as this form.

Opaque Surfaces Details

1. TAG/ID – Provide a name or designator for each unique type of opaque surface such as Wall-1, Ceiling-1, Roof-1 and Floor-1. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.
2. ASSEMBLY NAME – Indicate the identifying name of the assembly such as, Wall-1, Ceiling-1, Roof-1 and Floor-1.
3. FRAME TYPE – Indicate the type of assembly to include; Wood or metal 2x4 frame, LW CMU 8" Mass, Furred Wall, etc. Additional assemblies can be found in the Reference Joint Appendix JA4.
4. FURRING FRAMMING MATERIAL - Enter the framing material type (wood or metal)and refer to ENV-2C Furring Strips Construction worksheet for additional information.
5. SURFACE AREA – Indicate the total gross surface area of the surface of each different assembly type.
6. SURFACE ORIENTATION – Indicate the actual orientation of the assembly type. If multiple different walls exist in the same orientation indicate on a

separate line or an additional page. Typically the front entrance is the front door or entrance to the building.

7. CAVITY R-VALUE – Entered the proposed R-Value in the cavity for framed walls
8. CONTINUOUS R-VALUE – If proposed continuous insulation R-value is being used then enter the R-value of the insulation.
9. FURRING – If a furring wall is plan to be used on the proposed assembly then check off the box. This alerts the Plan Examiner and Field Inspector that such wall will be installed.
10. EXTERIOR FURRING FRAMMING R-VALUE – Enter the proposed R-value of the cavity when a furred wall is being installed; otherwise enter N/A (not applicable)
11. INTERIOR FURRING FRAMMING R-VALUE – Enter the proposed R-value of the cavity when a furred wall is being installed; otherwise enter N/A (not applicable)
12. CONDITION STATUS – Indicate the status of the opaque surface by choosing either N for New, E for Existing, or A for Alteration. This alerts the Plan Examiner and Field Inspector the type of wall being installed as new, existing or altered.
13. PASS/FAIL - Looking at the Opaque Surfaces table on the ENV-1C, the last two columns on the right-hand side of table contain Pass/Fail check boxes. This is where the Field Inspector will verify whether or not the energy features of an assembly installed in the field match the values listed in the table. If they do, the assembly “PASSES” if they don’t the assembly “FAILS.”

Fenestration Surface Details

Note: If applicable at the time of submittal provide either an NFRC label certificate or the Energy Commission Default U-factor and SHGC Label Certificate Form, FC-1/FC-2. The label shall be made available no later and before installation phase. The ENV-2A Acceptance form must be filled out by the responsible party or the installer; see Section 3.2.1. Also see Nonresidential Appendix NA7.4 for Acceptance testing.

A. TAG/ID – Provide a name or designator for each unique type of fenestration surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) such as, Window-1, Skylight-1 and etc…to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. FENESTRATION TYPE – Provide a designator for each unique type of window (i.e., Metal, Vinyl, Thermal Block Window, Curtain Wall, Skylight, Clear, Tinted, Reflective, low-e, etc.) in the Column.

C. SURFACE AREA – Indicate the total ft² of all of the fenestration with the same like characteristics.

D. SURFACE ORIENTATION – Indicate the actual orientation of the fenestration type. If multiple different fenestrations exist in the same orientation indicate on a separate line or an additional page.

E. NUMBER OF PANES – Indicate whether it's a single or double pane.

Maximum U-factor

F. U-FACTOR VALUE – Indicate the proposed Maximum U-factor for windows from Table 143-A, B or C, NFRC Label Certificate or the Energy Commission's Default Table U-factors Table 116-A, See Section 3.2.1 or Reference Nonresidential Appendix NA6 Alternative Calculation.

G. (R)SHGC - Enter the proposed Maximum SHGC value for windows using NFRC Label Certificate or the Energy Commission's Default Table U-factors Table 116-B, See Section 3.2.1 or Reference Nonresidential Appendix NA6 Alternative Calculation.

H. SOURCE – Enter the source of the U-factor and SHGC, either from NFRC, or from the Energy Commission's Fenestration Certificate FC-1/ FC-2.

I. OVERHANG – Check box if overhangs are going to be used in the project. Overhangs dimensions and location should be indicated on the building plans for verification by the enforcement agency.

J. CONDITION STATUS – Indicate the status of the fenestration surface by choosing either N for New, E for Existing, or A for Alteration. This alerts the Plan Examiner and Field Inspector the type of wall being installed as new, existing or altered.

K. PASS/FAIL - Looking at the Opaque Surfaces table on the ENV-1C, the last two columns on the right-hand side of table contain Pass/Fail check boxes. This is where the Field Inspector will verify whether or not the energy features of an assembly installed in the field match the values listed in the table. If they do, the assembly "PASSES" if they don't the assembly "FAILS."

Roofing Products (Cool Roofs)

The mandatory measures require that roofing products be tested and labeled through the Cool Roof Rating Council. Liquid applied products also must meet minimum standards for performance and durability per §118(i)4. Note that installing cool roofs is *not* a mandatory measure.

If the roofing product in not listed with the Cool Roof Rating Council (CRRC) then the Prescriptive Envelope Component Approach may not be used, go to the Prescriptive Overall Envelope TDV Energy approach or the Performance approach.

ALTERNATIVES/EXEMPTION TO THE ROOFING PRODUCTS “COOL ROOF” REQUIRMENT – There are seven alternatives/exceptions to the minimum prescriptive requirements for solar reflectance and thermal emittance or the SRI. By checking the box for any of the exception will exempt the cool roof criteria.

1. CRRC PRODUCT ID NUMBER – The Product ID Number can be obtained from the Cool Roof Rating Council’s Rated Product Directory at www.coolroofs.org/products/search.php.
2. ROOF SLOPE – Check the appropriate box for the slope ratio for roofs less than or equal to 2:12 or if the ratio is greater than 2:12 of the roof which the cool roof is being applied on.
3. PRODUCT WEIGHT – Indicate the unit weight of the product which is being considered to be installed, less then 5lb/ft² roofing materials (like asphalt shingles, metal roofing products, and composite roofing) than for roofs that weigh 5lb/ft² or more (such as concrete and clay tile). This information may be obtained from the manufactures data sheet.
4. PRODUCT TYPE- Indicate the type of product is being used for the roof top. For example, is the roof top an asphalt roof, metal roof, single-ply roof, etc...
5. AGED SOLAR REFLECTANCE – The aged solar reflectance can be obtained from the Cool Roof Rating Council’s Rated Product Directory at www.coolroofs.org/products/search.php or from the CRRC label on the product packaging. If the aged reflectance is not available in the Cool Roof Rating Council’s Rated Product Directory then use the initial reflectance value from the directory and use the equation (0.2+0.7($\rho_{initial}$ – 0.2) to obtain a calculated aged value. Also, check the box if the aged reflectance is a calculated value using the equation.
6. THERMAL EMITTANCE – The thermal emittance can be obtained from the Cool Roof Rating Council’s Rated Product Directory at www.coolroofs.org/products/search.php or from the CRRC label on the product packaging.
7. SRI – To calculate the SRI the 3-year aged value of the roofing product must be used. The calculator can be found at http://www.archenergy.com/library/cectools.
8. PASS/FAIL - Looking at the Opaque Surfaces table on the ENV-1C, the last two columns on the right-hand side of table contain Pass/Fail check boxes. This is where the Field Inspector will verify whether or not the energy features of an assembly installed in the field match the values listed in the table. If they do, the assembly “PASSES” if they don’t the assembly “FAILS.”

LIQUID FIELD APPLIED COATINGS – There are a number of qualifying liquid products, including elastomeric coatings and white acrylic coatings. The Standards specify minimum performance and durability requirements for liquid field applied coatings. Please note that these requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail in Section 3.4.

The coating must be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the coating manufacture, taking in consideration the substrate on which the coating is applied. Also, the liquid coatings must meet the requirements listed in §118(i)4 and Table 118-B.

Check the Aluminum –Pigmented Asphalt roof Coating or Cement-Based Roof Coating or chose other and identify coating.

DISCREPANCIES – If there is a discrepancy then the field inspector shall list and describe the discrepancy. The plan examiner should be made aware of the discrepancy so that corrective action can be taken.

ENV-1C (Page 3 of 4)

Required Acceptance Test

DESIGNER- The designer is required to check the acceptance tests and list all the fenestration products that require an acceptance test. If all the site-built fenestration of a certain type requires a test, list the different fenestration products and the number. Section NA7, in the Appendix of the Nonresidential Reference Appendices Manual, describes the test. Since this form will be part of the plans, completion of this section will allow the responsible party to budget for the scope of work appropriately.

BUILDING DEPARTMENTS - Before Occupancy Permit is granted for a newly constructed building or space or when ever new fenestration is installed in the building or space shall be certified as meeting the Acceptance Requirements.

The ENV-2A form is not considered a complete form and is not to be accepted by the enforcement agency unless the boxes are checked and/or filled and signed. In addition, a Certificate of Acceptance forms shall be submitted to the enforcement agency that certifies plans, specifications, installation certificates, and operating and maintenance information meet the requirements of §10-103(b) of Title 24 Part 6. The field inspector must receive the properly filled out and signed forms before the building can receive final occupancy. A copy of the ENV-2A for each different fenestration product line must be provided to the owner of the building for their records.

ENV-1C (Page 4 of 4)

Documentation Author's Declaration Statement

DOCUMENTATION AUTHOR is the person who prepared the energy compliance documentation and who signs the Declaration Statement. The person's telephone number is given to facilitate response to any questions that arise. A Documentation Author may have additional certifications such as an Energy Analyst or a Certified Energy Plans Examiner certification number. Enter number in the EA# or CEPE# box if applicable.

Principle Designer's Declaration Statement

The Declaration Statement is signed by the person responsible for preparation of the plans for the building and the documentation author. This principal designer is also responsible for the energy compliance documentation, even if the actual work is delegated to someone else (the Documentation Author as described above). It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans and therefore to sign this statement. See Section 2.2.2 Permit Application for applicable text from the Business and Professions Code.

The person's telephone number is given to facilitate response to any questions that arise.

Envelope Mandatory Measures Note Block

The Documentation Author will indicate the location of the Mandatory Measures on the building plans.

The mandatory measures should be incorporated into the construction documents. The designer may use whatever format is most appropriate for specifying the mandatory measures in the plan set. In general, this will take the form of a note block near the front of the set, possibly with cross-references to other locations in the plans where measures are specified. This is offered as a starting point for designers; it should be incorporated into the organization of the plan set and modified to be specific to the building design. When complying with the mandatory measures, the following must be considered if they apply:

Sample Note Block - Envelope Mandatory Measures

- ☐ **Manufactured fenestration products and exterior doors** shall have air infiltration rates not exceeding 0.3 cfm/ft² of window area, 0.3 cfm/ft² of door area for residential doors, 0.3 cfm/ft² of door area for nonresidential single doors (swinging and sliding), and 1.0 cfm/ft² for nonresidential double doors (swinging), when tested according to NFRC-400 or ASTM E 283 at a pressure differential of 75 Pascals (or 1.57 pounds/ft²), incorporated herein by reference. Air infiltration rates are certified by the manufacturer per §116(a)1.
- ☐ **U-factor.** A fenestration product's U-factor shall be rated in accordance with NFRC 100, or the applicable default U-factor set forth in Table 116-A and
- ☐ **SHGC.** A fenestration product's SHGC shall be rated in accordance with NFRC 200 for site-built fenestration, or use the applicable default SHGC set forth in Table 116-B.
- ☐ **Labeling.** Fenestration products shall:
  - A. Have a temporary label (or label certificate for site-built fenestration) meeting the requirements of Section 10-111(a)1, not to be removed before inspection by the enforcement agency, listing the certified U-factor and SHGC, and certifying that the air leakage requirements of Section 116(a)1 are met for each product line; and
  - B. Have a permanent label (or label certificate for site-built fenestration) meeting the requirements of Section 10-111(a)2 if the product is rated using NFRC procedures.
- ☐ **Fenestration Acceptance Requirements**. Before an occupancy permit is granted site-built fenestration products in other then low-rise residential buildings shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7 to ensure that site-built fenestration meet Standards requirements, including a matching label certificate for each product installed and be readily accessible at the project location. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the fenestration product meets the acceptance requirements.

  Fenestration products removed and reinstalled as part of a building alteration or addition need not comply with acceptance requirement. As specified in Section 116(a)5
- ☐ **Field-fabricated fenestration and field-fabricated exterior doors** shall be caulked between the fenestration products or exterior door and the building, and shall be weatherstripped. As specified in section 116(b) of the Energy Standards.
- ☐ ***All Exterior Joints and openings*** in the building envelope that are observable sources of air leakage shall be caulked, gasketed, weather-stripped or otherwise sealed. As specified in Section 117 of the Energy standards.
- ☐ ***Installed Insulating Material*** shall have been certified by the manufacturer to comply with the California Quality Standards for Insulating Material and with the flame spread rating and smoke density requirements of California Building Code. As specified in section 118(a) of the Energy Standards.

- ☐ **Placement of roof/ceiling insulation.** Insulation installed to limit heat loss and gain through the top of conditioned spaces shall comply with Section 117.
- ☐ **Demising Walls in Nonresidential Buildings**. The opaque portions of framed demising walls in nonresidential buildings shall be insulated with an installed R-value of no less than R-13 between framing members. As specified in Section 118(f) of the Energy standards.
- ☐ **Insulation Requirements for Heated Slab Floors**. Heated slab-on-grade floors shall be insulated according to the requirements in TABLE 118-A. As specified in Section 118(g) of the Energy standards.
- ☐ **Wet Insulation Systems.** When insulation is installed on roofs above the roofing membrane or layer used to seal the roof from water penetration, the effective R-value of the insulation shall be as specified in Reference Joint Appendix JA4. As specified in Section 118(h) of the Energy standards.
- ☐ **Roofing Products Solar Reflectance and Thermal Emittance.** 1. In order to meet the requirements of Sections 141, 142, 143(a)1, 149(b)1B, 151(f)12, 152(b)1H or 152(b)2, a roofing product's thermal emittance and 3-year aged solar reflectance shall be certified and labeled according to the requirements of Section 10-113. As specified in Section 118(i) of the Energy standards.

Instructions to Applicant

Check the appropriate box of forms to be included with the submittals. The ENV-1C form needs to be incorporated into the building plan set by copying the form unto an informational sheet or near the front of the building plans. All other forms are optional to be incorporated into the building plan set. All checked forms need to be submitted before enforcement agency approval.

3.10.2 ENV-2C: Envelope Component Approach

ENV-2C Page 1 of 4

Exterior Roofing Products (Cool Roofs)

The mandatory measures require that roofing products be tested and labeled through the Cool Roof Rating Council. Liquid applied products also must meet minimum standards for performance and durability per §118(i)4 and §143(a)1A . Note that installing cool roofs is *not* a mandatory measure.

If the roofing product in not listed with the Cool Roof Rating Council (CRRC) then the Prescriptive Envelope Component Approach may not be used, go to the Prescriptive Overall Envelope TDV Energy approach or the Performance approach.

ALTERNATIVES/EXEMPTION TO THE ROOFING PRODUCTS "COOL ROOF" REQUIRMENT – There are seven alternatives/exceptions to the minimum prescriptive requirements for solar reflectance and thermal emittance or the SRI. By checking the box for any of the exception will exempt the cool roof criteria.

1. CRRC PRODUCT ID NUMBER – The Product ID Number can be obtained from the Cool Roof Rating Council's Rated Product Directory at www.coolroofs.org/products/search.php.
2. ROOF SLOPE – Check the appropriate box for the slope ratio for roofs less than or equal to 2:12 or if the ratio is greater than 2:12 of the roof which the cool roof is being applied on.
3. PRODUCT WEIGHT – Indicate the unit weight of the product which is being considered to be installed, less then 5lb/ft² roofing materials (like asphalt shingles, metal roofing products, and composite roofing) than for roofs that weigh 5lb/ft² or more (such as concrete and clay tile). This information may be obtained from the manufactures data sheet.
4. PRODUCT TYPE- Indicate the type of product is being used for the roof top. For example, is the roof top an asphalt roof, metal roof, single-ply roof, etc...
5. SOLAR REFLECTANCE – The aged solar reflectance can be obtained from the Cool Roof Rating Council's Rated Product Directory at www.coolroofs.org/products/search.php or from the CRRC label on the product packaging. If the aged reflectance is not available in the Cool Roof Rating Council's Rated Product Directory then use the initial reflectance value from the directory and use the equation (0.2+0.7($_{\rho initial}$ – 0.2) to obtain a calculated aged value. Also, check the box if the aged reflectance is a calculated value using the equation.
6. THERMAL EMITTANCE – The thermal emittance can be obtained from the Cool Roof Rating Council's Rated Product Directory at www.coolroofs.org/products/search.php or from the CRRC label on the product packaging.
7. SRI – To calculate the SRI the 3-year aged value of the roofing product must be used. The calculator can be found at http://www.archenergy.com/library/cectools.

LIQUID FIELD APPLIED COATINGS – There are a number of qualifying liquid products, including elastomeric coatings and white acrylic coatings. The Standards specify minimum performance and durability requirements for liquid field applied coatings. Please note that these requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail in Section 3.4.

The coating must be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the coating manufacture, taking in consideration the substrate on which the coating is applied. Also, the liquid coatings must meet the requirements listed in §118(i)4 and Table 118-B.

Check the Aluminum –Pigmented Asphalt roof Coating or Cement-Based Roof Coating or chose other and identify coating.

ENV-2C Page 2of 4

Opaque Surface Details

Opaque surfaces details are now broken in two separate sections to include the Mass and Furring Strips Construction Table. The Opaque Surface Details focuses on all assembly types found in Reference Joint Appendix JA4 accept for furred mass wall surface assembly. When furred mass walls assembly's are to be used then the Mass and Furring Strips Construction section or table need to be filled first before the Opaque Surfaces Details is filled. The final Assembly U-factor value on the Mass and Furring Strips Construction will be inserted into the Opaque Surface Details in Column J, Proposed Assembly U-factor.

Proposed Assembly

A. TAG/ID – Provide a name or designator for each unique type of fenestration surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) such as, Window-1, Skylight-1 and etc…to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. ASSEMBLY NAME OR TYPE - Provide a name or designator for each unique type of Assembly: Indicate Roof/Ceiling, Walls, Floors, Slabs, Crawl Space, Doors and etc.…

C. FRAMING MATERIAL AND SIZE - Indicate the Frame type and Size: For Wood, Metal, Metal Buildings, and Mass, enter 2x4, 2x6, or etc… see JA4 for other possible frame type assemblies. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

D. THICKNESS, SPACING, OR OTHER - For framed spacing enter; 16"or 24"OC; For thickness, enter thickness in inches, for other enter Heat Capacity (HC) or possibly other descriptive term found in Table-4.3.5 through 4.3.7.

   For light-weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies, but if it is blank, the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

   Standard

E. STANDARD U-FACTOR - Based on the Climate Zone; enter the Standard U-factor from Table 143-A, B or C for each different Assembly NAME or Type.

   Proposed Values

F. JA4 TABLE REFERENCE/NUMBER - List the appropriate JA4 table number to match the new Proposed Assembly U-factor, Column J. (i.e. Table 4.3.5)

G. FRAMED CAVITY R-VALUE - List the Cavity R-value if a frame walled type is used; Otherwise, enter "0". The PROPOSED value is the R-value for the insulation product alone, not the total R-value for the assembly

This section is used for assemblies that are shown to comply by this option under the envelope component method. If the assembly U-factor option is used, this space may be left blank.

H. CONTINUOUS INSULATION R-VALUE - Enter the Continuous Insulation R-value for the proposed assembly; otherwise, enter “0”. This section is used for assemblies that are shown to comply by this option under the envelope component method. If the assembly U-factor option is used, this space may be left blank.

I. JA4 ASSEMBLY CELL VALUE – USE COLUMN B AND D TO determine the row and column number of the cell value. (i.e. row 10 and column B or 10B)

J. PROPOSED ASSEMBLY U-FACTOR - Enter the **Proposed** Assembly U-factor, Column J. Must be equal to or less than the **Standard** U-factor in Column E to comply.

This section is used for assemblies that are shown to comply by this option under the envelope component method. If the insulation R-value option is used, this space may be left blank. It must be consistent with the U-factor listed on the ENV-1C, Page 1 of 4, Opaque Surfaces.

Furring Strips Construction Table for Mass Walls Only

A. MASS THICKNESS - Indicate the thickness of assembly to include; Hollow Unit Masonry Walls, Solid Unit Masonry, Solid Concrete Walls, Etc. Additional assemblies can be found in the Reference Joint Appendix JA4

B. ASSEMBLY NAME OR TYPE – Provide a name or designator for each unique type of Assembly: Indicate mass wall type, Indicate the Frame type and Size: For Wood, Metal, enter 2x4, 2x6, or etc… see JA4 for other possible frame type assemblies. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

C. JA4 TABLE REFERENCE/NUMBER - List the appropriate JA4 table number to match the new Proposed Assembly U-factor, Column J. (i.e. Table 4.3.5)

D. JA4 – MASS CELL VALUE – Enter the row and column number of the cell value. (i.e. row 10 and column B or 10B)

E. MASS U-FACTOR - This is the U-Factor based on the thickness of the assembly in inches from Column A.

Added Interior or Exterior Insulation in Furring Space FROM REFERENCE Joint Appendix Table 4.3.13

F. INTERIOR OR EXTERIOR OF INSULATION LAYER – Enter the thickness of the insulation of the interior or exterior layer.

G. FRAME THICKNESS - From Table 4.3.13 left column.

H. FRAME TYPE WOOD/METAL – Enter the frame type either wood or metal. If both frame types are used in the same building then enter a separate entry for each in the Mass and Furring Strips Construction table.

I. FURRING CAVITY R-VALUE - From Table 4.3.13 top row. Enter R-values from R-0 through R-21.

J. JA4 – MASS CELL VALUE – Enter the row and column number of the cell value. (i.e. row 10 and column B or 10B)

K. EFFECTIVE R-VALUE – IS the cell value found from the row and column in Column J.

L. FINAL ASSEMBLY R-VALUE – Is the calculated U-factor value from Equation 4-2 or Equation 4-4 found in Page JA4-4 or JA4-5. The U-factor in entered in Column K and the inverse (1/U), R-value, is entered in Column J.

M. COMMENT – Enter comment to explain any special requirements or uniqueness about this type of assembly.

ENV-2C Page 3 of 4

West Window Area Calculation

This calculation determines whether the window area for the building exceeds the allowable maximum for the Envelope Component Approach.

A. GROSS WEST EXTERIOR WALL AREA – It's the Gross Exterior Wall Area multiplied by 0.40 to determine the maximum allowed 40 percent of fenestration in the West Exterior Wall Area.

B. WEST DISPLAY PERIMETER – It's the West linear perimeter multiplied by 6 ft to determine the maximum DISPLAY AREA for glazing limits.

C. Enter the Larger of A or B for the MAXIMUM STANDARD AREA.

D. PROPOSED WEST WINDOW AREA – Enter the proposed total area of windows as indicated on the building plans.

Note: If the Proposed West Window area is greater than the Maximum Standard West Area of 40% then the Envelope Component Approach may not be used.

Window Area Calculation (for all other than the West orientation)

E. GROSS EXTERIOR WALL AREA – It's the Gross Exterior Wall Area multiplied by 0.40 to determine the maximum allowed 40 percent of fenestration in the Exterior Wall Area.

F. DISPLAY PERIMETER – It's the linear perimeter multiplied by 6 ft to determine the maximum DISPLAY AREA for glazing limits.

G. Enter the Larger of E or F for the MAXIMUM STANDARD AREA.

H. PROPOSED WINDOW AREA – Enter the proposed total area of windows as indicated on the building plans.

Note: If the Proposed Window area is greater than the Maximum Standard Area of 40% then the Envelope Component Approach may not be used.

Window Details

A. WINDOW NAME – Provide a name or designator for each unique type of window. This designator should be used consistently throughout the plan set (elevations, window schedules, etc.) to identify each window. It should also be consistently used on the other forms in the compliance documentation.

B. AREA – Enter the area of each different fenestration product.

C. TYPE - Enter the type of fenestration; **M**=Manufactured, **SB**=Site-built, and **F**=Field Fabricated.

D. ORIENTATION – Indicate orientation of each unique type of window. Should match ENV-1C Page 1 of 4 orientations.

E. NO. OF PANES – Indicate “2” for double glazed, “1” for single glazed windows.

U-Factor

F. PROPOSED glazing U-factor should match ENV-1C Page 1 of 4 Surfaces Area.

G. ALLOWED U-factor is taken from Standards Tables 143-A, 143-B, or 143-C.

H. PROPOSED glazing (R)SHGC should match ENV-1C Page 1 of 4 Surfaces Area.

I. ALLOWED (R)SHGC is taken from Standards Tables 143-A, 143-B, or 143-C.

Overhang

Overhang Dimensions

J. H = horizontal distance from window out to the bottom of overhang. If an overhang does not exist, then the H is 1.0.

K. V = vertical distance from bottom of window to a plane at the same height as the bottom of lower edge of overhang. If an overhang does not exist, then the V is 1.0.

L. OVERHANG FACTOR - H/V - Use Table 3-6 to determine the factor for each orientation. Measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cut-off point of the overhang (V). If an overhang does not exist, then the overhang factor is 1.0.

M. PROPOSED (R)SHGC is calculated by multiplying the Overhang Factor by the proposed SHGC of the window.

N. ALLOWED (R)SHGC – The maximum relative solar heat gain allowed, taken from Standards Tables 143-A, 143-B, or 143-C for the appropriate window orientation (north or non-north).

Note: Add all the Total Site-Built fenestration in Column B to include site-built skylight area. This information helps provide the plan checker/reviewer verify the amount of site-built fenestration against the building plans.

ENV-2C Page 4of 4

Skylight Area Calculation

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the standard envelope.

A. If the height distance from the floor to the above is less than or equal to 55 ft then multiply the Actual Gross Roof Area by 5 percent (0.05) for the STANDARD ALLOWED SKYLIGHT AREA.

B. If the height distance is greater than 55 ft then multiply Actual Gross Roof Area by 10 percent (0.10) for the STANDARD ALLOWED SKYLIGHT AREA.

C. PROPOSED SKYLIGHT AREA – The total area of proposed skylights shown on the plans is entered here.

D. SKYLIGHT % - If the Proposed Skylight Area is greater than the Standard Allowed Skylight Area then the Envelope Component approach may not be used.

If the PROPOSD SKYLIGHT AREA is greater than the STANDARD ALLOWED SKYLIGHT AREA then the Envelope Component Approach may not be used. The skylight percentage determines the appropriate row for the maximum U-factor allowed TO BE USED IN THE Skylight Details. See Table 143-A, B or C.

Skylight Details

A. SKILIGHT NAME - Provide a name or designator for each unique type of skylight. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each skylight. It should also be consistently used on the other forms in the compliance documentation.

Skylight Glazing

Note: Only one box can be checked off for each Skylight row.

B. GLASS WITH CURB – Indicate by checking off the box if the glazing includes a curb. This affects the allowed U-factor and solar heat gain coefficient.

C. GLASS WITH OUT CURB – Indicate by checking off the box if the glazing has no curb. This affects the allowed U-factor and solar heat gain coefficient.

D. PLASTIC - check off the box if the skylight is made out of plastic.

E. AREA – Enter the area of each different skylight product.

F. TYPE - Enter the type of skylight; M=Manufactured, SB=Site-built, and F=Fabricated.

G. # of PANES – Indicate “2” for double glazed, “1” for single glazed skylights.

U-Factor

H. PROPOSED - Skylight glazing U-factor is determined as discussed in Section 3.2.

I. ALLOWED - U-factor value is the maximum solar heat gain coefficient taken from the prescriptive envelope criteria in the Standards for the appropriate glazing. The value is taken from Standards Tables 143-A, 143-B, or 143-C, depending on the building occupancy type

SHGC

J. PROPOSED– Skylight glazing solar heat gain coefficient is determined as discussed in Section 3.2

K. ALLOWED value is the maximum solar heat gain coefficient taken from the prescriptive envelope criteria in the Standards for the appropriate glazing. The value is taken from Standards Tables 143-A, B or C, depending on the climate zone.

Relocatable Public Schools Buildings

Note: Check the applicable box for either Specific Climate Zone(s) or Any (All) Climate Zone:

Option 1 - Specific Climate Zone

When the manufacturer/builder certifies that the relocatable building is manufactured for use in specific climate zones and that the relocatable building cannot be lawfully used in other climate zones, the energy budget must be met for each climate zone that the manufacturer/building certifies, assuming the prescriptive envelope criteria in Standards Table 143-A, including the non-north window RSHG and skylight SHGC requirements for each climate zone.

The manufacturer/builder shall meet the requirements for identification labels specified in §143(a)8. Indicate location on the building plans.

Option 2 - Any (All) Climate Zone

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 NA5, assuming the prescriptive envelope criteria in Standards Table 143-C.

The manufacturer/builder shall meet the requirements for identification labels specified in §143(a)8. Indicate location on the building plans.

3.10.3 ENV-3C: Overall Envelope TDV Energy Approach

This compliance worksheet should be used only when the envelope is shown to comply using the Overall Envelope Energy approach.

1. PROJECT NAME is the title of the project, as shown on the plans, on the ENV-1C, and known to the building department.
2. DATE is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.
3. CLIMATE ZONE - is the official California climate zone number where the building is located. Refer to California Climate Zone Description, Reference Joint Appendix JA2 or at http://www.energy.ca.gov/maps/building_climate_zones.html for a listing of cities and their climate zones.

ENV-3C Page 1 of 6

The first page of this form involves tests of glazing area for windows and skylights. If either of these tests does not pass, then the glazing area and associated wall area must be adjusted to meet the standard envelope requirements.

Window RATIO Calculation for ALL WALLS

A. TOTAL LINEAR DISPLAY PERIMETER – This is multiplied by 6 ft to determine the DISPLAY AREA for glazing limits.

B. TOTAL GROSS EXTERIOR WALL AREA – This is multiplied by 0.40 to determine the 40 percent of the Gross Exterior Wall Area for glazing limits.

C. Enter the Larger of A or B for the MAXIMUM STANDARD AREA.

D. PROPOSED WINDOW AREA – The total area of proposed windows shown on the plans is entered here.

Note: If the PROPOSED WINDOW AREA is greater than the MAXIMUM STANDARD AREA, then the envelope component method may not be used.

E. WINDOW WALL RATIO – (Row D) Divided by (Row B).

WEST WINDOW RATIO Calculation

F. WEST LINEAR DISPLAY PERIMETER – This is multiplied by 6 ft to determine the west display area for glazing limits.

G. WEST EXTERIOR WALL AREA – This is multiplied by 0.40 to determine the 40 percent west wall window limit for the standard design.

H. ENTER THE LARGER OF F AND G – For the Maximum Standard West Area.

I. ENTER PROPOSED WEST WINDOW AREA – The total area of windows on the west wall of the proposed building is entered here.

If the PROPOSED WEST WINDOW AREA is greater than the MAXIMUM STANDARD WEST AREA then the envelope component method may not be used.

J. WEST WINDOW WALL RATIO – (Row I) Divided by (Row G).

Combined Area for North, East and South Walls

K. N/E/S DISPLAY PERIMETER – This is the DISPLAY PERIMETER (Box A) minus the WEST PERIMETER (Box F). The result is multiplied by 6 ft.

L. N/E/S EXTERIOR WALL AREA – This is the GROSS EXTERIOR WALL AREA (Box B) minus the WEST EXTERIOR WALL AREA (Box G). The result is multiplied by 0.40.

M. Enter the larger of K or L – For the Maximum Standard N/E/S/Area.

N. PROPOSED N/E/S WINDOW AREA – This is the PROPOSED WINDOW AREA (Box D) minus the PROPOSED WEST WINDOW AREA (Box I).

Window adjustment

O. If D is greater than C, calculate 1 for all walls or 2 for west wall below, otherwise, go to the skylight area test on the Window area adjustment calculations portion of Page 6.

1. If D is greater than C:

Divide the MAXIMUM STANDARDS AREA (Box C) by the PROPOSED WINDOW AREA (Box D) and enter the result into the WINDOW ADJUSTMENT FACTOR box; otherwise enter a 1.0 in this box.

2. If I is less than H:

Divide MAXIMUM STANDARD WEST AREA (Box H) by the PROPOSED WEST AREA (Box I) and enter into the box for WEST WINDOW ADJUSTMENT FACTOR (WAF_w), and

Divide the MAXIMUM STANDARD AREA (Box C) by the PROPOSED WINDOW AREA (Box D) and enter the result into the WEST WINDOW ADJUSTMENT FACTOR box; otherwise enter a 1.0 in this box.

The WINDOW ADJUSTMENT FACTOR numbers are carried to Page 6 of 6, Window and Skylight Area Adjustment, of the form to calculate the adjusted window and wall areas. Upon completion of those calculations, Page 3, and Page 4 Page may be completed.

ENV-3C Page 2 of 6 Skylight Area Calculation

Enter the ATRIUM or SKYLIGHT HEIGHT – distance from the floor to the ceiling in FT.

A. If the height distance from the floor to the ceiling is less than or equal to 55 ft then multiply the GROSS ROOF AREA by 5 percent (0.05) for the STANDARD ALLOWED SKYLIGHT AREA.

B. If the height distance is greater than 55 ft then multiply GROSS ROOF AREA by 10 percent (0.10) for the STANDARD ALLOWED SKYLIGHT AREA.

STANDARD ALLOWED SKYLIGHT AREA – The maximum allowed standard skylight area is the product of the previous two numbers.

C. PROPOSED SKYLIGHT AREA – The total area of proposed skylights shown on the plans is entered here.

D. SKYLIGHT RATIO PROPOSED –Calculate the ration by dividing Row c by Row the Actual Gross Roof Area.

E. MAXIMUM ALLOWED SKYLIGHT ROOF RATIO = Maximum Allowed Standard Skylight Area (Row A or B) Divided by Total Gross Exterior Roof Area.

IF THE PROPOSED SKYLIGHT AREA IS GREATER THAN THE STANDARD SKYLIGHT AREA PROCEED TO THE NEXT CALCULATION FOR THE SKYLIGHT AREA ADJUSTMENT. IF NOT GO TO PAGE 3 OF 6.

SKYLIGHT ADJUSTMENT FACTOR

IF F>D, Proceed To Calculation Step 1

Step 1. Calculated the Skylight Adjustment Factor (SAF).

The SKYLIGHT ADJUSTMENT FACTOR is carried to Page 6 OF 6, Window and Skylight Area Adjustment, to calculate the adjusted skylight and roof areas. Upon completion of those calculations, Parts 3 through 5 may be completed.

ENV-3C Page 3 of 6 OVERALL ENVELOPE TDV ENERGY APPROACH

TDV for the Standard Design Building

Check the applicable Occupancy Type and use the Reference Nonresidential Joint Appendix tables accordingly. See Section 3.7, Overall Envelope TDV Energy Approach for further information.

- Nonresidential, See, Table NA5-3
- 24-Hour Use, See, Table NA5-4
- Retail, See, Table NA5-5

A. ASSEMBLY TYPE – Indicate type of assembly for the Envelope (e.g. Wall, Floor, Roof, Window, and Skylight & Door). One assembly type for each row. Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. Grouping of like assemblies and in the same orientation is allowed; indicate the number of same in column C.

B. ORIENTATION – Orientation (applicable only for walls, doors and windows); for each different coefficient category in Column J, K, and L.

C. NUMBER OF LIKE ASSEMBLY/COMPONENT TYPE – Number of components of the applicable envelope feature of the standard design (wall, floor, roof, glazing/window, skylight, and door). Grouping of like assemblies in the same orientation is allowed; indicate the number of like in Column C.

D. ROOFS OR FLOOR MASS TYPE – For roofs, the categories are attic, light (HC<7) and mass (HC>7). For floors the categories are light and mass. For walls, the categories are light (HC<7), medium mass (7≤HC<15) and heavy mass (HC≥15).

E. EXTERIOR SURFACE AREA – Indicate the exterior surface area of the mass of the assembly type as indicated in Column A.

F. FENESTRATION TYPE – Indicate the type of fenestration type (single, double, low E, and etc…)

Criteria

G. U-factor – From the Standards Table 143-A, Table 143-B or Table 143-C indicate the standard design U-factor in Btu/hr-ft²-°F for the wall, floor, roof, window, skylight and door as appropriate.

H. RSHGC – The relative solar heat gain coefficient for windows and skylights from the Standards Table 143-A, Table 143-B or Table 143-C, as applicable.

I. VT – The visible transmittance, VT, for the standard design shall be calculated as 1.2 times the standard design SHGC, From Column H.

Coefficients For

Note: Descriptions of Coefficients for the TDV Energy of the Standard Design are found in Reference Nonresidential Appendix in Section NA5.2.

J. U-factor $Cs_{u,i}$ – Dependent on the Climate Zone and Occupancy Type the U-factor coefficient's for the wall, floor, roof, windows, skylights and doors respectively are found in Table NA5-3, Table NA5.4, or Table NA5-5 of Section NA5.4.

Note: The index "i" represents a unique combination of occupancy, orientation, and coefficient designator. The coefficient type is determined based on Table NA5-1.

K. SHGC $Cs_{s,i}$ – Dependent on the Climate Zone and Occupancy Type the SHGC coefficient's for the windows, skylights and doors respectively are found in Table NA5-3, Table NA5.4, or Table NA5-5 of Section NA5.4.

Note: The index "i" represents a unique combination of occupancy, orientation, and coefficient designator. The coefficient type is determined based on Table NA5-1.

L. VT $Cs_{t,i}$ – Dependent on the Climate Zone and Occupancy Type the Visible Transmission coefficient's for the windows, skylights and doors respectively are found in Table NA5-3, Table NA5.4, or Table NA5-5 of Section NA5.4.

Note: The index "i" represents a unique combination of occupancy, orientation, and coefficient designator. The coefficient type is determined based on Table NA5-1.

M. TDV Energy – TDV energy of the standard design, for space cooling and heating only. Calculate the TDV Standard Design for each assembly type: TDVStd = Column C x [Column E x ((U-factor$_{Si}$ x C_{Sui}) + (SHGC$_{Si}$ x C_{Ssi}) + (VT$_{Si}$ x C_{Sti}))] for each Envelope Component Type. See Nonresidential Manual Examples in Section 3.7, Overall Envelope TDV Energy Approach.

ENV-3C Page 4 of 6 TDV for the Proposed Design Building

A. ASSEMBLY TYPE – Indicate type of assembly for the Envelope (e.g. Wall, Floor, Roof, Window, and Skylight & Door). One assembly type for each row. Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. Grouping of like assemblies and in the same orientation is allowed; indicate the number of same in column C.

B. ORIENTATION – Orientation (applicable only for walls, doors and windows); for each different coefficient category in Column J, K, and L.

C. NUMBER OF LIKE ASSEMBLY/COMPONENT TYPE – Number of components of the applicable envelope feature of the standard design (wall, floor, roof, glazing/window, skylight, and door). Grouping of like assemblies and in the same orientation is allowed; indicate the number of like in Column C.

D. EXTERIOR SURFACE AREA – Indicate the exterior surface area of the mass of the assembly type as indicated in Column A.

E. FENESTRATION TYPE – Indicate the type of fenestration type (single, double, low E, and etc…)

Criteria

F. U-FACTOR – The proposed design U-factor in Btu/(hr x ft²x°F) for the wall, floor, roof, window, skylight and door component indicated by index i.

G. SHGC – The proposed solar heat gain coefficient for the window of the proposed building corresponding to Index i. Windows and skylights values are either from NFRC Certified products or from the California Energy Commission defaults Tables Table 116-B. Note that the overhangs are treated by the overhang multiplier, $M_{OH,I}$

H. VT – The proposed visible transmittance design of windows and skylights is based on NFRC optic data or certified rating or shall be calculated as 1.2 times the California Energy Commission defaults Tables Table 116-B.

Coefficients for

Proposed Coefficients are found in Reference Nonresidential Appendix Table NA5-3, Table NA5-4, or Table NA5-5.

I. U-FACTOR $C_{Su,i}$ – U-factor coefficients for the wall, floor, roof, windows, skylights and doors respectively. The index “i” represents a unique combination of occupancy, orientation, and coefficient type. The coefficient type is determined based on Reference Nonresidential Appendix Table NA5-1.

J. SHGC $C_{Ss,i}$ – Solar heat gain coefficients for the windows and skylights, respectively. The coefficient “i” is a unique combination of occupancy type and orientation.

K. VT $C_{St,i}$ – Visible transmission coefficients for the windows and skylights, respectively. The coefficient "i" is a unique combination of occupancy type and orientation.

L. COOL ROOF M_{cr} – A multiplier that accounts for differences between the prescriptive cool roof requirement and the reflectance and emittance of the proposed design. Use Page 5 of 6 to calculate the cool roof multiplier. Enter the resultant back in Column L, page 4 of 6.

M. OVERHANG M_{OH} – Use Page 5 of 6 to calculate the overhang multiplier and enter the resultant back in Column M, page 4 of 6.

N. TDV Energy – TDV energy of the proposed design, for space cooling and heating only. Cool Roof is the product of the area, U-factor, weighting coefficient and cool roof multiplier:
TDV_P = Column D x $[(U\ factor \times C_{Su}) + (C_{Rui} \times U_{Ri} \times M_{CRi}) + (SHGC_P \times C_{Ssi} \times M_{OH}) + (VT_P \times C_{St})]$.

Note: *Sum up all the Proposed TDV Energy in Column N and enter value in the cell. Similarly enter the sum of all Standard TDV Energy and compare. Proposed must be ≤ to the Standard in order to comply.*

ENV-3C Page 5 of 6 Multipliers

Check the applicable Occupancy Type and use the Reference Nonresidential Joint Appendix tables accordingly. See Section 3.7, Overall Envelope TDV Energy Approach for further information.

- Nonresidential, See, Table NA5-3
- 24-Hour Use, See, Table NA5-4
- Retail, See, Table NA5-5

Cool Roof Multiplier (M_{CR})

Coefficients of

A. REFLECTANCE C_{Ref} – Coefficient for the reflectance of the roof. This depends on occupancy type and climate zone as in the occupancy type. The coefficients are listed in Tables NA5-3, NA5-4, NA5-5.

B. EMITTANCE C_{Emit} – Coefficient for the emittance of the roof. This depends on occupancy type and climate zone as in the occupancy type. The coefficients are listed in Tables NA5-3, NA5-4, NA5-5.

C. PROPOSED AGED SOLAR REFLECTANCE $\rho_{aged\ prop}$ – Proposed aged design reflectance of the roof outside surface. This data is from the three-year aged reflectance from CRRC. If aged reflectance is not available from CRRC, then an estimate of the aged reflectance shall be used based on the CRRC initial reflectance. Use the following equation to estimate the aged reflectance: $\rho_{aged,prop} = 0.2 + 0.7 \times (\rho_{init,prop} - 0.2)$.

If neither initial nor aged reflectance data is available from CRRC for the proposed roof, then a default aged reflectance of 0.1 shall be used.

D. STANDARD AGED SOLAR REFLECTANCE $\rho_{aged\ std}$ – Standard design aged solar reflectance, as required by the prescriptive requirements of §143(a) and summarized in Reference Nonresidential Appendix Table NA8-2. Proposed

Aged Design Solar Reflectance; $\rho_{aged\ prop} = 0.7 \times (\rho_{init\ prop} + 0.06)$. Where ($\rho_{init\ prop}$) reflectance value is found in the CRRC Directory. Enter results of the Cool Roof Multiplier equation in footnote 2.

E. PROPOSED THERMAL EMITTANCE ε_{prop} – Proposed design thermal emittance of the roof outside surface from CRRC data. If CRRC data is not available, then a default value of 0.75 shall be used.

F. STANDARD THERMAL EMITTANCE ε_{std} – Thermal emittance of the roof outside surface of the standard design, as defined in Reference Nonresidential Appendix Table NA5-2.

Calculation

G. COOL ROOF MULTIPLIER $M_{CR,i}$ – A multiplier that accounts for differences between the prescriptive cool roof requirement and the reflectance and emittance of the proposed design. Enter results back on Column L on page 4 of 6 of ENV-3C.
Cool Roof Multiplier :$M_{cR,I} = 1 + C_{Ref}\ x\ (\rho_{aged\ prop} - \rho_{aged\ std}) + C_{Emit}\ x\ (\varepsilon_{prop} - \varepsilon_{std})$ **or** 1+ Col A *x* (Col C - Col D) + Col B *x* (Col E – Col F).

The following Table values are used as default values are climate zone dependent based on the pitch of the roof. Enter values appropriately in Column C and F on Page 5 of 6 of the ENV-3C.

Where: Standard design values for Solar Reflectance and Thermal Emittance. Excerpt from Table NA5-2.	Standard Aged Solar Reflectance (Column D)	Standard Thermal Emittance (Column F)
Low-Rise, Low-Sloped, CZ2 through CZ15	0.55	0.75
Low-Rise, Low-Sloped, CZ1 and CZ16	0.10	0.75
High-Rise, Low-Sloped, CZ10 through CZ15	0.55	0.75
High-Rise, Low-Sloped, CZ1-9 and CZ16	0.10	0.75
Steep-Sloped, CZ2 through CZ15	0.25	0.75
Steep-Sloped, all other	0.10	0.75

Overhang Multiplier (M_{OH})

Coefficients of

A. OVERHANG ORIENTATION – Enter the orientation.

B. 1ST PROJECTION FACTOR a_i– Enter the first coefficient. The coefficient will be based on orientation, occupancy type and climate zone. See Table NA5-3, NA5-4, NA5-5.

C. 2ND PROJECTION FACTOR b_i – Enter the second coefficient. The coefficient will be based on orientation, occupancy type and climate zone. See Table NA5-3, NA5-4, NA5-5.

Fenestration Overhang

D. HORIZONTAL PROJECTION, H,(ft²) – Horizontal projection of the overhang from the surface of the window in feet, but no greater than V.

E. VERTICAL DISTANCE, V, (ft²) – Vertical distance from the window sill to the bottom of the overhang, in feet.

F. PROJECTION FACTOR – PF = H/V (Horizontal (H) projection of the overhang from the surface of the window in feet, but no greater than V and the Vertical (V) distance from the window sill to the bottom of the overhang, in ft.) PF should be capped at 1.

Calculation

G. OVERHANG MULTIPLIER – $M_{OH,I} = 1 + a_i \times PF_i + b_i \times PF_i^2$. Enter results in Column G. Enter results back on Column L on page 4 of 6 of ENV-3C. Enter results in Column M.

ENV-3C Page 6 of 6 Window Area Adjustment Calculations

If the WINDOW AJUSTMENT from page 1 of 6 of the ENV-3C is required then proceed to the Window Area Adjustment Calculation on page 6 of 6 of the ENV-3C or if the SKYLIGHT ADJUSMENT from page 2 of 6 of the ENV-3C is required then proceed to the Skylight Area Adjustment Calculation on page 6 of 6 of the ENV-3C to determines the necessary area adjustments.

A. WINDOW OR WALL NAME - Provide a name or designator for each unique type and orientation of wall that contains windows (walls without windows will have no adjustment). If an orientation has two different wall types, list each separately. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. Check the appropriate Orientation box respectively.

B-D**:** AREAS - List the areas (in ft²). The GROSS AREA is the Gross Exterior Wall Area for the particular wall type and orientation under consideration. The DOOR AREA and WINDOW AREA are for doors and windows included in each wall.

E. WINDOW ADJUSTMENT FACTOR, WAF, is calculated on the bottom half of Page 1of 6 the ENV-3C form, and may vary by orientation.

F. ADJUSTED WINDOW AREA is calculated by multiplying the values in COLUMNS D and E.

G. ADJUSTED WALL AREA is calculated by subtracting B from the sum of C and F. If this produces a negative value enter zero.

Add Columns B, C, D, F, and G. As a check, the total of Column B should equal the sum of the totals of Columns F & G.

The total in Adjusted Column F and G are carried over Column E of the ENV-3C page 3 of 6 and Column D of the ENV-3C page 4 of 5.

Note: The carried over adjusted areas are only for those windows that require area adjustments. If more than one adjustment then use a separate row for each adjustment.

Skylight Area Adjustment Calculations

A. ROOF NAME – Provide a name or designator for each unique type of roof that contains skylights (roofs without skylights will have no adjustment). If an orientation has two different roof types, list each separately. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B-C. AREAS – List the areas (in ft²). The GROSS AREA is the gross exterior roof area for the particular roof type and orientation under consideration; note that it does not include doors, such as roof hatches. The SKYLIGHT AREA is for skylights included in each roof.

D. SKYLIGHT ADJUSTMENT FACTOR, SAF, is the skylight adjustment factor calculated on Page 2 of 6. It is the same for all skylights in the building.

E. ADJUSTED SKYLIGHT AREA is calculated by multiplying the values in COLUMNS C and D.

F. ADJUSTED ROOF AREA is calculated by subtracting E from B. If this results in a negative value enter zero.

COLUMNS B, C, E and F are added. As a check, the total of COLUMN B should equal the sum of the totals of COLUMNS E and F.

The total in Adjusted Column E and F are carried over Column E of the ENV-3C page 3 of 6 and Column D of the ENV-3C page 4 of 5.

Note: The carried over adjusted areas are only for those windows that require area adjustments. If more than one adjustment then use a separate row for each adjustment.

3.10.4 ENV-4C Minimum Skylight Area for Large Enclosed Spaces Worksheets

This form must be filled out if the building contains an enclosed space with a floor area greater than 8,000 ft², a ceiling height of greater than 15 ft and an LPD of equal or greater to 0.5 W/ft².

If this section applies, the minimum skylight area is determined either as a fraction of the daylit area or from the minimum effective aperture area. To determine the minimum area as a fraction of daylit area, fill in steps A-O of these worksheets. To determine the minimum area based on minimum effective aperture area, fill in steps E-O of this worksheet.

This is the prescriptive minimum skylight area. If skylights are not desired, an alternative building can be built as long as the proposed building is shown to consume less energy than a building with the prescriptive number of skylights.

ENV-4C Minimum Skylight Area Worksheet (Page 1 of 3)

Check the appropriate boxes that apply. Check box if the building is three or fewer stories and the floor area is greater than 8,000 ft², a ceiling height of greater than 15 ft and an LPD of equal or greater to 0.5 W/ft². Otherwise skip the next check off box and go to Step 1. **Space is exempt from minimum skylight area requirement** if less than 0.5 W/ft².

Check the box if skylights do not meet the criterion above. Stop here; this space is exempt from the minimum skylight area requirement.

Enter the proposed daylit area as indicated on the plans schedule and enter the relevant page number of the plans.

Step 1 – If using skylit daylight areas to comply with the mandatory minimum skylight area requirements, calculate if Proposed Skylit Daylight Area is greater than or equal to Minimum Daylight Area. Enter the result of the enclosed floor area and multiply by 0.50. Skylit daylight area determined in accordance with §131(c)1D.

Checks the box if Criteria 1, “Proposed Daylit Area is equal to or greater than Minimum Daylit Area,”

Step 2 – If using sidelit daylight areas to comply with the mandatory minimum skylight area requirements, calculate if Proposed Primary Sidelit Daylight Area is greater than or equal to Minimum Daylight Area. Primary sidelit daylit area determined in accordance with §131(c)1B.

Check the box if Criteria 2, “Proposed Sidelit Daylight Area is equal to or greater than Minimum Daylit Area,”

Step 3 – Calculate the combined skylit area + primary sidelit areas which are used to comply with the minimum skylight area requirements.

Check the box if Criteria 3 confirms that the total proposed daylight area is greater than or equal to the minimum daylight areas.

If Criterion 3 is checked, steps 4 and 5, on ENV-4C (Page 2 of 3) must also be filled out.

Note: Space FAILS, not enough daylight area; if Criterion 3 is unchecked.

ENV-4C Page 2 of 3

Minimum Skylight Area or Effective Aperture Worksheet

Step 4 – Calculate SKYLIGHT criteria using either Step 4a (minimum skylight area) or Step 4b (minimum effective aperture) and verify that skylight haze criteria is met Step 4c.

Step 4a – Compare Total Proposed Skylight Area to Minimum Skylight Area; Minimum Skylight Area = Skylit Daylight Area x 0.033. Enter in box E. Total Proposed Skylight Area = Sum of the areas (rough opening) of each individual skylight Enter in box F

Criterion 4a: Check if Proposed Skylight Area is equal to or greater than Minimum Skylight Area ($F \geq E$).

Step 4b – Compare Total Proposed Skylight Effective Aperture to Minimum Effective Aperture (alternative method).

Enter Minimum Skylight Effective Aperture in box G.

Enter the Proposed Skylight Effective Aperture from ENV-4C (Page 3 of 3) Cell (W) and enter in box H.

Criterion 4b: Check if Proposed Skylight Effective Aperture is equal to or greater than Minimum Skylight Effective Aperture ($H \geq G$).

Check the box if Criteria 4C, Check box if proposed Skylight glazing or diffuser haze rating is ≥ 90 percent. Haze rating is indicated on page ___ of building plans. Criterion 4C: Check if either Criterion 4a or Criterion 4b is checked and Criterion 4c is checked.

Step 5 – Enter the Minimum Skylight Effective Aperture in row I and enter the proposed Primary Sidelit Effective Aperture by determining the Effective Aperture of the Primary Sidelit Area by filing out K through O. Enter the result in Cell J in Step 5. Check box if J is greater or equal to I. Then go to Step 6.

Step 6 – Check space passes box for each criterion is met.

ENV-4C Page 3 of 3

Use Standards Equation 146-C to calculate Skylight Effective Aperture by first determining the Well Cavity Ratio either by using the rectangular or the non-rectangular equations.

P-Q: CALCULATE THE WELL CAVITY RATIO (WCR) – Determine if the well is rectangular or non-rectangular, select one of the well types, fill in columns A, B, C and calculate the WCR with the appropriate equation. See §146 for additional details.

R-T: TUBULAR SPECULAR LIGHT WELL – Enter the Tube Height, Tube Diameter and Divide cells R/S to get the L/D ratio.

R-S: WELL EFFICIENCY – calculate the average well wall reflectance – This is used with the WCR to determine the well efficiency. This reflectance is determined as shown in the Illumination Engineering Society of North America, IESNA Lighting Handbook, Ninth Edition (2000).

FC-1/FC-2 – California Energy Commission Default U-Factor and SHGC Label Certificate

This form is used when no NFRC Label Certificate is available for the specified fenestration product. Two options are allowed when no NFRC certificate is available. Method 1: For sit-built fenestration of 10,000 square feet and greater use the Energy Commission’s Default Table 116-A and Table 116-B in §116 of the Standards or Method 2: Use the Alternative Calculation found in the Reference Nonresidential Appendix NA6 for buildings with less than 10,000 ft² of glass, this includes skylights. Check off the appropriate Method box.

Note: FC-1/FC-2 is now simplified and combined together as one form.

U-FACTOR AND SHGC FENESTRATION CERTIFICATE LABEL				FC-1/FC-2
PROJECT INFORMATION				Form 1 of
PROJECT NAME:	Joe Energy			DATE: January 4, 2010
PROJECT ADDRESS:	123 Main St			CLIMATE ZONE: 12
Option 1: For buildings with less than 10,000 ft² of site-built fenestration may optionally use either CEC Default Tables 116-A and 116-B, Method 1, or the Alternative Calculation Nonresidential Reference Appendix NA6, Method 2.				
Option 2: For buildings with greater 10,000 ft² of site-built fenestration only one option is available; use CEC Default Tables 116-A and 116-B. Use Method 1 only.				
A separate (FC-1/FC-2) Label Certificate Form is required for each different fenestration product line. Unlabeled manufactured fenestration products including skylights and exterior doors shall meet the air infiltration requirements of § 116(a)1 of the 2008 California Energy Efficiency Standards applicable to Residential and Nonresidential Buildings.				
Enter the U-factor$_t$ and SHGC$_t$ in the following boxes after completing Method 1 or 2 below.				
U-factor$_t$ = 0.55		**SHGC$_t$ = 0.55**		
PRODUCT LINE INFORMATION (Complete a separate Label Certificate for each fenestration product line is required)				
Total Number of units for the same product line:		Total square footage of this product line:		
Schedule location on the building plans – Reference page:		Total Fenestration Area (ft²) on project:		
Location(s) on building: S, N, E, W				

☑ **Method 1** (For fenestration either less than or greater than or equal to 10,000 ft²)

U-FACTOR INFORMATION FROM DEFAULT See TABLE 116-A:						
Frame Type	☐ Metal	☐ Metal With Thermal Break		☑ Nonmetal		
Product Type	☐ Operable	☑ Fixed	☐ Greenhouse/ Garden Window	☐ Doors	☐ Skylights	
Glazing Type	☐ Single Pane	☑ Double Pane	☐ Glass Block	0.55	Insert value in the default U-factor gray box above	
SOLAR HEAT GAIN INFORMATION FROM DEFAULT See TABLE 116-B:						
Product Type	☐ Operable	☑ Fixed				
Glazing:	☐ Clear	☑ Tinted		0.55	Insert value in the default SHGC$_t$ gray box above	

☐ **Method 2** (For fenestration less than 10,000 ft²) **Reference Nonresidential Appendix NA6**

GLAZING INFORMATION: Alternative Calculation < less than 10,000 ft²			
STEP 1: *Determine U-Factor:*	Enter U-factor from Equation NA6-1 above in the gray box next to U-factor		
STEP 2: *Determine SHGC:*	Use Center of Glass, SHGCc, in the equation below to determine the solar heat gain coefficient with frame		
Enter Center of Glass, COG, from Manufacturer's Documentation, SHGCc			Insert Center of Glass value here
Calculate the new SHGC$_t$ of the frame.	SHGC$_t$ = 0.08 + (0.86 x SHGCc) =		Insert calculated result value here and in above gray box next to SHGC$_t$
STEP 3: ATTACHED MANUFACTURER'S LITERATURE:			
Manufacturer's literature must be attached showing the Product Type, Frame Type, Glazing, Center Of Glass(COG) U-factor, and SHGC$_c$ information needed to determine the Default U-factor$_t$ and SHGC$_t$			
PARTY TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE:			
CONTACT PERSON:			
COMPANY NAME and ADDRESS:			
PHONE:	FAX:		
SIGNATURE:	LICENSE # (if Applicable)		

FC-1/ FC-2 – SAMPLE - California Energy Commission Default U-Factor and SHGC Label Certificate SHGC Label Certificate