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 and skylights, 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. 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 Overview
- 3.2 Fenestration
- 3.3 Opaque Envelope Insulation
- 3.4 Cool Roofs
- 3.5 Infiltration and Air Leakage
- 3.6 Relocatable Public School Buildings
- 3.7 Overall Envelope Approach
- 3.8 Performance Approach
- 3.9 Additions and Alterations
- 3.10 Compliance Documentation

3.1.1 Prescriptive Requirements

Standards Table 143-A, B and C

The prescriptive requirements consist of a specific requirement for each envelope component: roofs and ceilings, 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.

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 requirements 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.

Standards Tables 143-A and 143-B are organized in a similar manner and are grouped into five different climate regions shown as columns in the tables. One set of criteria (column) applies to climate zones 1 and 16, the colder portions of the state in the north coast and mountains. Another applies to the middle coast (climates 3 through 5). The other regions include the south coast (climate zones 6 through 9); the inland valleys (climate zones 2, and 10 through 13), and the southern desert (climate zones 14 and 15). Figure 3-1 shows these climate regions.

The top portions of the prescriptive tables have requirements for the opaque portions of the building envelope, including roofs, walls, and floors. The criteria are given in two ways, as minimum insulation R-values with some constraints on when this can be used and as maximum U-factors. 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. For floors, criteria are given for mass floors and other floors.

Under the Component Envelope Approach, each of the envelope assemblies (walls, roofs, floors, windows, 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 or the performance approach, either of which allows tradeoffs between components.

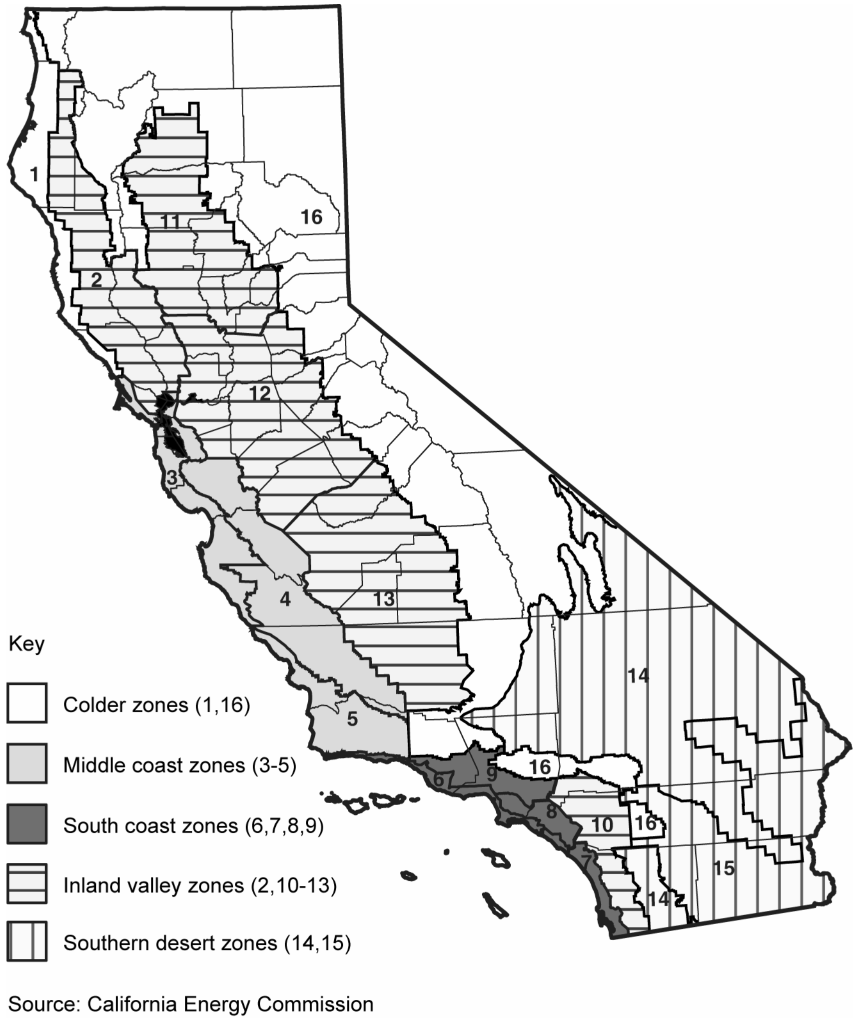

Figure 3-1 – Nonresidential Climate Regions

3.1.2 Overall Envelope Approach

§143(b)

The overall envelope approach treats envelope components as a system and offers the ability to make simple trade-offs between envelope components. §143(b) of the Standards describes the overall envelope approach. The overall envelope approach allows the performance of some building envelope components to be increased while the performance of others is reduced, as long as overall heat gain and loss are no greater than a building in minimum compliance with the prescriptive requirements.

The overall envelope approach permits tradeoffs between many building envelope components, but no tradeoffs are permitted with the indoor lighting system or mechanical systems. The performance approach is required in order to make these tradeoffs.

The overall envelope approach uses two measures of envelope performance: the overall heat loss and the overall heat gain. The overall heat loss is a measure of the insulating quality of all the envelope components together, including both opaque and glazing surfaces. The overall heat gain considers insulation, solar heat gain through windows and skylights, and the reflectance of the roof.

The code baseline for both heat gain and heat loss is determined using the insulation and solar heat gain coefficient values from the prescriptive requirements, applying them to the envelope surface areas of the proposed building (with some limits on glazing area). The proposed design's overall heat loss and heat gain are calculated based on the installed insulation, fenestration performance, and roof surface properties. If the proposed heat loss and heat gain are no higher than the standard heat loss and heat gain, then the envelope complies. See Section 3.7 for a more complete discussion of the overall envelope approach.

3.1.3 Performance Approach

(§141)

The performance approach may be used for envelope-only 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 Section 3.8 for a more complete discussion of the performance approach.

3.1.4 What's New for 2005

With the 2005 update to the Standards, there were several important changes to the building envelope requirements, as described below:

- Determining U-factors of wall, roof and floor constructions is simplified with the addition of Appendix IV in the Joint Appendices. This document, which contains pre-calculated U-factors for most construction assemblies and methods for adjusting U-factors for unusual conditions, must now be used to select each assembly used in the compliance calculations.
- The criteria for metal building roofs are clarified. Only the U-factor method (not the minimum R-value method) may be used with this construction class. Separate criteria are added to Standards Tables 143-A and 143-B to deal with metal building roofs.
- West-facing glazing area is now limited to no more than 40% of the west wall area. This change helps reduce peak loads and peak electricity demand.
- Cool roofs are now a prescriptive requirement for low-slope roof applications (and a compliance option for high-sloped roofs).

- The overall envelope approach is modified to consider roof reflectance and roof emittance as continuous variables.
- A new section [§143(c)] adds a prescriptive requirement for skylights in large enclosed spaces in low-rise nonresidential buildings.
- Fenestration product U-factors were modified prior to the 2005 update, but these changes did not represent a change in stringency. The NFRC rating procedure for windows was changed, and this resulted in the same window having a slightly lower U-factor. The criteria changes bring the requirements in line with the test results; a window that complied with the 2001 standards will still comply with the 2005 standards, as both the criteria and the rated value are slightly lower.

3.2 Fenestration

Windows, glazed doors, and skylights have the largest impact on 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
ACM Manual Appendix NI

The Administrative Regulations (§10-111) and the Standards (§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 Fenestration (Factory-Assembled) Label Certificates

Each manufactured fenestration (factory-assembled) 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 has two choices 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 CEC 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 section 116(a)1,U-factor criteria of Section 116(a)2, and SHGC criteria of Section 116 (a)3, 2005 *California Energy Efficiency Standards for Residential and Nonresidential Buildings*. Product meets the air infiltration requirements of Section 116 (a) 1, U-factor criteria of Section 116 (a) 2, and SHGC criteria of Section 116 (a) 3, 2005 California Energy Efficiency Standards for Residential and Nonresidential Buildings.

Figure 3-2 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. For site-built fenestration products, the label certificate will likely be generated by the glazing contractor after the construction project is awarded. 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. For site-built fenestration that will be NFRC certified), the designer should select a U-factor and SHGC for the fenestration system that is reasonable and achievable. For U-factor, Nonresidential ACM Manual Appendix NI should be used as a guide. The SHGC equations there in combination with SHGC data for glazing materials should be used to determine a reasonable value for SHGC to use 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 building department field inspectors to easily read, 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 “CEC Default U-factor” followed by the correct value for that fenestration product from Table 116-A in the Standards and the words “CEC 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. The NFRC certified products directory indicates when a skylight 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. This can be done by placing the term “Meets Thermal-Break Default Criteria” on the temporary label. Note 2 of the Default U-factor table provides for positive or negative adjustments to the U-factors in the table for specific fenestration products. For example, products with low-e glazing or air gaps between panes greater than 7/16 in. are adjusted to lower U-factors, and products with true divided lites or metal cladding are adjusted to raise U-factors. These adjustments must be included in the U-factor shown on the temporary label. The special features that cause these adjustments should be identified on the label. The manufacturer may also include the VLT factor from glass manufacturer's data. This factor is important to determine whether daylit area credit may be taken in conjunction with daylighting controls.

CEC Default Label	**XYZ Manufacturing Co.**
Key Features:	Double-pane Operable Metal, Thermal Break Air space 7/16 in. or greater Tinted
CEC Default U-factor 0.61	CEC Default SHGC 0.53

Product meets the air infiltration requirements of Section 116 (a) 1, U-factor criteria of Section 116 (a) 2, and SHGC criteria of Section 116 (a) 3, 2005 California Energy Efficiency Standards for Residential and Nonresidential Buildings.

Figure 3-2 – 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; they must also have an NFRC label certificate for site-built fenestration. 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) 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 CEC Default U-factor and SHGC.

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 procedures, a Default Label Certificate can be provided by the person (e.g., architect, glazing contractor, extrusion manufacturer, IG fabricator or glass manufacturer) taking responsibility for fenestration compliance using a Default Label Certificate approved by the Commission.

Figure 3-3 is a sample CEC Default Label Certificate, CF-1, when using default values from Standards Table 116-A and Table 116-B, and Figure 3- 4 is a sample of the CEC Alternate Default Label Certificate, CF-2, when using default U-factors and calculated SHGC from ACM Manual Appendix NI for buildings with less than 10,000 ft^2 of site-built fenestration. A separate 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.

If the product claims the default U-factor for a thermal-break product, the Default Label Certificate should also contain the words "Meets Thermal-Break Default Criteria". The Default Label Certificate should also identify any special features that raise or lower the default U-factor as specified by the Default U-factor table. For skylights, the Default Label Certificate must indicate the same information about whether the skylight is rated with a curb as described for the Default Temporary Label above.

The Default Label Certificate may also include the visible light transmittance (VLT) 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.

Field-Fabricated Fenestration

Site-built fenestration is not the same as field-fabricated 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 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. Buildings with 10,000 or more square ft of vertical glazing must have no more than 1,000 square ft of field-fabricated fenestration.

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. The fenestration system consists of two lights of clear 1/4 in. (6mm) glass separated by a ½ in. (12 mm) airspace gap. An 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?

Answer

One of the following three methods may be used:

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

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.

There is a third option for Site-built fenestration less than 10,000 ft². Site-built fenestration less than 10,000 ft² does not have to be rated through the NFRC 100 and NFRC-200 procedures and may use the default values form Nonresidential ACM Manual as described in the following bullets:

The Alternate U-factor may be selected from Nonresidential ACM Manual Appendix NI, Table NI-1. The U-factor for the specified product is 0.73 from the Appendix, which is taken from the first column of the table for double glass with a ½ in. airspace gap (12 mm) without Thermal Break.

The SHGC is also determined from the Nonresidential ACM Manual Appendix NI. The SHGC for the center of the glass is known from manufacturer's data and is 0.70. The SHGC for the fenestration product (including the frame) is 0.68 as determined using the following equation (from ACM Manual appendix NI):

$SHGC_{FEN} = 0.08 + (0.86 \times SHGCc)$

$= 0.08 + (0.86 \times 0.70)$

$= 0.68$

An Alternative Default Label Certificate, 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 1/4" [6 mm] to 3/4" [18 mm]) filled with air or other gas. Two panes of glazing laminated together do not constitute double-pane glazing.

CEC DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE FORM					FC-1
PROJECT INFORMATION					
PROJECT NAME:				DATE:	
PROJECT ADDRESS:					
CEC DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE (Use only for Site-Built Fenestration Product Lines) Method 1- CEC Default Certificate may be used for site-built glazing installed in all non-residential buildings. Site-built fenestration in large projects (more than or equal to 10,000 ft² of site-built fenestration area.			U-factors and SHGC are derived from the California Energy Commission Fenestration Default U-factors and SHGC Default Table based on data reported below. U-factor = ___ SHGC = ___ This Fenestration Product Line meets the air infiltration requirements of Section 116(a) 1, 2005 California Energy Efficiency Standards for Residential and Nonresidential Buildings.		
PRODUCT LINE INFORMATION (Complete a separate Default Label Certificate for each fenestration product line in the project)					
Total Number of units for this product line:			Total square footage of this product line:		
Elevation drawing page:			Fenestration (window & door) schedule page:		
Location(s) on building: S, N, E, W (Enter appropriate orientation(s))			Total Fenestration Area (ft^2) on project:		
❑ Method 1 - DEFAULT FENESTRATION U-FACTOR AND SHGC FROM STANDARD TABLES 116-A AND 116-B OF THE 2005 *California Energy Efficiency Standards for Residential and Nonresidential Buildings.*					
Frame Type	❑ Metal	❑ Metal Thermal Break (or Structural Glazing)		❑ Nonmetal	
U-factor Table 116-A Product Type	❑ Operable	❑ Fixed	❑ Greenhouse, Garden Window	❑ Door	❑ Skylight
Glazing Type	❑ Single Pane	❑ Double-pane	Default U-factor =		(If no U-factor adjustment, insert value in above gray box next to U-factor)
SHGC Table 116-B Product Type	❑ Operable	❑ Fixed			
SHGC Table 116-B Glazing Tint	❑ Clear	❑ Tint	Default SHGC =		(Insert default value in above gray box next to SHGC)
U-Factor Adjustment (See Table 116-A, Footnote 1 and 2)					
❑ Nonmetal-framed manufactured fenestration products with metal cladding must add 0.04 to the listed U-factor ❑ Subtract 0.05 for spacers of 7/16 inch or wider ❑ Subtract 0.05 for products certified by the manufacturer as low-E glazing. ❑ Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide. ❑ Add 0.05 for products with true divided lite (dividers through the panes).					
U-Factor Adjustment = ____________________		(If applicable insert adjustment result in above gray box next to U-factor)			
PERSON TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE CONTACT PERSON:					
Contact Person:					
Company name and address:					
Phone:	Fax:		Signature:		

Figure 3-3 – CEC Default U-Factor and SHGC Label Certificate

ALTERNATIVE DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE	**FC-2**
PROJECT INFORMATION	
PROJECT NAME:	DATE:
PROJECT ADDRESS:	
CEC ALTERNATIVE U-FACTOR AND SHGC LABEL CERTIFICATE (Use only for Site-Built Fenestration Product Lines) Method 2 - Alternative Default Certificate shall be used for site-built fenestration in buildings with less than 10,000ft^2 of site-built fenestration area.	U-factors and SHGC are derived from the California Energy Commission Fenestration Default U-factors and SHGC Default Table based on data reported below. U-factor = ___ SHGC = ___ This Fenestration Product Line meets the air infiltration requirements of Section 116(a) 1, 2005 *California Energy Efficiency Standards for Residential and Nonresidential Buildings.*

PRODUCT LINE INFORMATION (Complete a separate Default Label Certificate for each fenestration product line in the project)

Total Number of units for this product line:		Total square footage of this product line:	
Elevation drawing page:		Fenestration (window & door) schedule page:	
Location(s) on building: S, N, E, W (Enter appropriate orientation(s))		Total Fenestration Area (ft^2) on project:	

❑ Method 2 DEFAULT FENESTRATION U-FACTOR FROM ACM MANUAL APPENDIX NI Table NI-1 and MANUFACTURER'S DOCUMENTATION FOR SHGCc.

Product Type	❑ Glazed Wall Systems	❑ Skylight with Curb	❑ Skylight without Curb			
Frame Type	❑ Aluminum	❑ Aluminum Metal Thermal Break	❑ Wood/Vinyl	❑ Reinforced Vinyl/ Aluminum Clad Wood	❑ Structural Glazing	
Glazing Type and thickness	❑ Single ⅛" Glass	❑ Single ⅛" Acrylic/polycarb	❑ Single ¼ " Acrylic/polycarb	❑ Double-Glazing	❑ Triple-Glazing	❑ Quadruple-Glazing
Coating Emissivity	❑ 0.05	❑ 0.10	❑ 0.20	❑ 0.40	❑ 0.60	
Coated Surfaces	❑ 2 or 3	❑ 2, 3, 4, or 5	❑ 2 or 3 and 4 or 5			
Glazing Spacing	❑ 1/4" Airspace	❑ 1/2" Airspace				
Gas Fill Between Panes		❑ Air	❑ Argon	❑ Krypton		

CEC ALTERNATIVE DEFAULT FENESTRATION U-FACTOR =		From Assembly U-Factors – ACM Manual Appendix NI Table NI-1 (Insert value in above gray box next to U-factor)

DEFAULT SOLAR HEAT GAIN COEFFICIENT

SHGC for Center of Glass **SHGCc** =		From Manufacturer's Documentation (Insert value "**SHGCc** " in equation below)
Calculate SHGC Fenestration Equation from 2005 Appendix NI-2005 (NI.1 Solar Heat Gain Coefficient)	$SHGC_{fen}$ = 0.08 + (0.86 x SHGCc) _________	(Insert calculated result value in above gray box next to SHGC)

ATTACHED MANUFACTURED DOCUMENTATION

Manufacturer's documentation must be attached showing the Product Type, Frame Type, Glazing Type, and SHGCc information needed to determine the Default U-factor and SHGC from the Applicable Table or equation.

PERSON TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE CONTACT PERSON:		
Contact Person:		
Company name and address:		
Phone:	Fax:	Signature:

Figure 3-4 – CEC Alternate Default U-Factor and SHGC Label Certificate

§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% of the gross wall area (encompassing conditioned space) for the building. Likewise, the west facing window area may not exceed 40% 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% 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% 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 3-5 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.

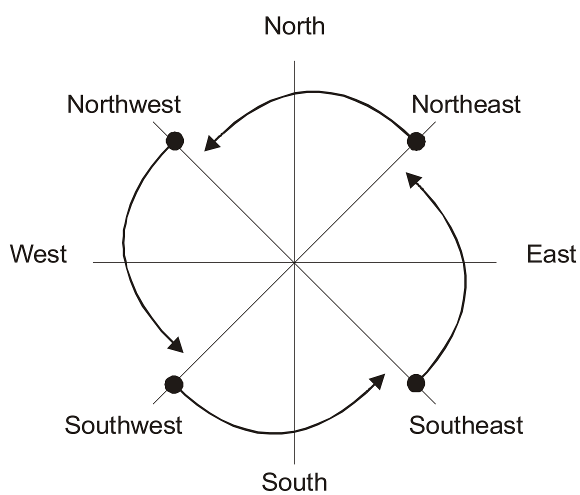

Figure 3-5 – Four Surface Orientations

Window U-factor

§143(a)5.B.

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-ºF-ft² for the valley, desert and cold climates. The criterion is 0.77 Btu/h-ºF-ft² for the middle coast and south coast climates. For residential buildings, the criterion is 0.47 for all 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 NFRC data and ACM Manual Appendix NI.

Table 3-2 – Window Requirements

Space Type	Criterion	Climate Zones 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)5.C.

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 also 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)5.C). 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)5.C.ii). 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 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	1.18	1.42	1.42	1.18	1.18
		Glass wo/Curb	0.68	0.82	0.82	0.68	0.68
		Plastic w/Curb	1.04	1.56	1.56	1.32	1.32
	SHGC Glass	0-2% SRR	0.68	0.79	0.79	0.46	0.46
		2.1-5% SRR	0.46	0.40	0.40	0.36	0.36
	SHGC Plastic	0-2% SRR	0.77	0.79	0.77	0.77	0.71
		2.1-5% SRR	0.58	0.65	0.62	0.62	0.58
Residential High-rise	U-factor	Glass w/Curb	1.18	1.42	1.42	1.18	1.18
		Glass wo/Curb	0.68	0.82	0.82	0.68	0.68
		Plastic w/Curb	1.04	1.56	1.56	1.32	1.04
	SHGC Glass	0-2% SRR	0.46	0.58	0.61	0.46	0.46
		2.1-5% SRR	0.36	0.32	0.40	0.32	0.31
	SHGC Plastic	0-2% SRR	0.71	0.65	0.65	0.65	0.65
		2.1-5% SRR	0.55	0.39	0.65	0.34	0.27

Summary from Standards Tables 143-A and 143-B

Skylight Area

§143(a)6.A.

The area limit for skylights is 5% of the gross exterior roof area. This effectively prevents large skylights under the envelope component approach. The limit increases to 10% for buildings with an atrium over 55 ft high (see Joint Appendix I definition). The 55-ft height is also the height limitation at which the Uniform Building Code requires a mechanical smoke-control system for such atriums (CBC Sec. 1715). This means that the 10% 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 ACM Manual Appendix NI. 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 -mounts the skylight above the level of the roof (see Figure 3-6) 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) t. For special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5 Section 5.2.1.4, Daylighting Controls.

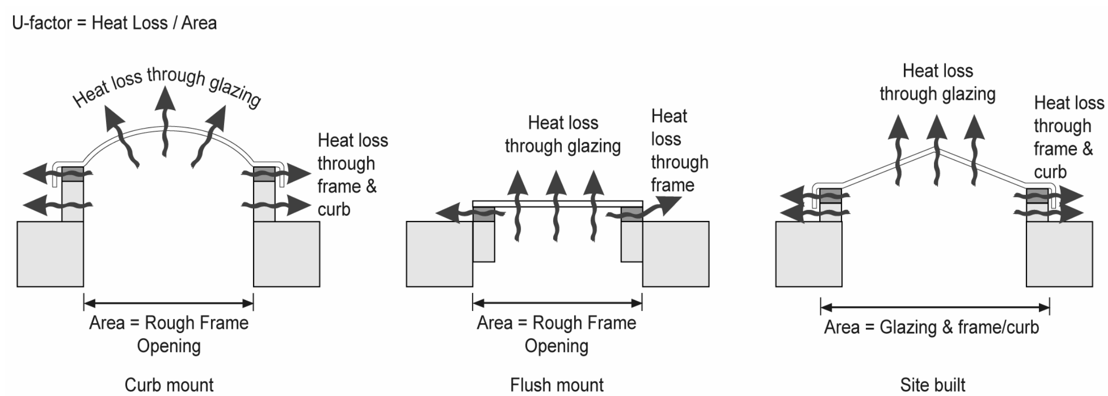

Figure 3-6 – Skylight Area

Skylight U-factor

§143(a)6.B.

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 without a curb. All plastic skylights must meet the requirements for plastic skylights with a curb.

Skylight SHGC

§143(a)6.C.

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% of the exterior roof, and greater than 2% but less than or equal to 5%. 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.

3.2.4 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, Indoor lighting, 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.

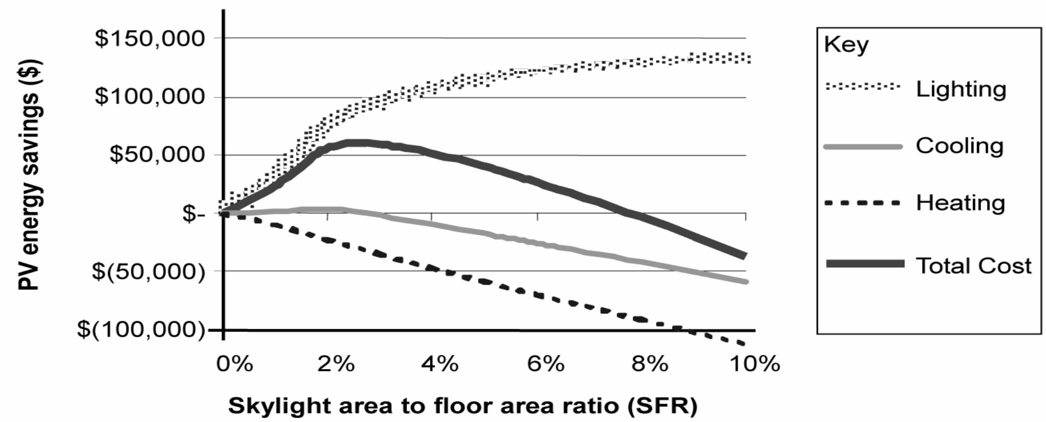

Figure 3-7 – Present Value Savings of Skylight
50,000 ft² Warehouse in Sacramento

Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required only in enclosed spaces (rooms) that are larger than 25,000 ft^2, occur directly under a roof and are greater than 25,000 ft², 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 (including 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.*

Climate zone 1 (North Coast) and climate zone 16 (Mountains) have less sunlight available and colder weather than the rest of California. These climate zones are exempt from the minimum skylight requirements of §143(c).

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; however, skylights over conditioned spaces must meet the U-factor and SHGC requirements in §143(a).

When skylights are prescriptively required by §143(c), half of the floor area in the enclosed space must be in the "daylit area under skylights," 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%).

Such spaces also require automatic lighting controls as specified in §131(c)2. See Section 5.2.1.4.

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. Please also refer to Section 5.2.1.4 as it describes the daylit area and the mandatory electric lighting controls for the daylit area. The daylit area is the "footprint" of the skylight opening with the edge of the daylit area expanding by adding 70% of the floor-to-ceiling height to each side of the skylight footprint, the distance to the nearest 60-inch or higher permanent partition, or one half the horizontal distance to the edge of the closest skylight or vertical glazing. The daylit area illuminated by vertical glazing shall be the daylit depth multiplied by the daylit width, where the daylit depth is 15 ft or the distance on the floor perpendicular to the glazing, to the nearest 60-inch or higher permanent partition, whichever is less; and the daylit width is the width of the window plus, on each side, either 2 ft, the distance to a permanent partition, or one half the distance to the closest skylight or vertical glazing, whichever is least. In Figure 3-8, the 8 ft x 4 ft skylight over a 20 ft ceiling will have a 36 ft x 32 ft daylit area (Figure 1-8).

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).

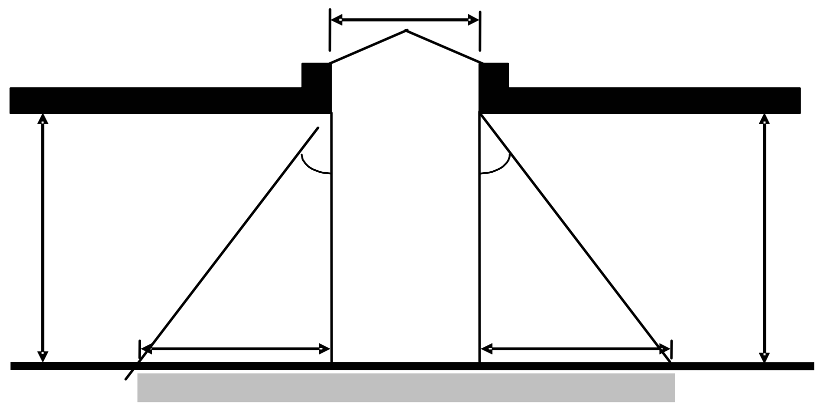

Figure 3-8 – Daylit Area under Skylights

For good uniformity the daylit areas under skylights should overlap. In this case 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).

The purpose of the skylight requirement is to reduce electric lighting with sunlight transmitted by skylights. Spaces with greater lighting need (and therefore afforded a greater electric lighting power allowance) also require more daylight to meet the needs of the space. Thus, as shown in Standards Table 143-F (Table 3-4 below), the minimum skylight area to daylit area ratio increases as the prescriptive lighting power density increases.

Table 3-4 – Standards Table 143-F Minimum Skylight Area to Daylit Floor Area or Minimum Skylight Effective Aperture in Low-Rise Enclosed Spaces >25,000 ft^2 directly Under a Roof

General Lighting Power Density in Daylit Areas (W/ft^2)	Minimum Skylight Area to Daylit Area Ratio	Minimum Skylight Effective Aperture
1.4 W/ft^2 ≤ LPD	3.6%	1.2%
1.0 W/ft2 ≤ LPD < 1.4	3.3%	1.1%
0.5 W/ft^2 ≤ LPD < 1.0 W/ft^2	3.0%	1.0%

If skylight transmittance is increased, less skylight area is needed to provide the same amount of daylight. For highly transmitting skylight systems, an alternative to skylight area / daylit area ratio, is the skylight effective aperture. The skylight effective aperture (as defined in Standards Equation 146 A in §146(a)4F) is a measure of the skylight system's transmittance including light loss due to dirt, glazing transmittance, transmittance of louvers, diffuser or other light controlling elements, and transmittance of the light well (well efficiency). As shown in Standards Table 143-F, the skylight effective aperture requirements are 1/3 that of the skylight area to daylit area ratios. See Chapter 5 of this manual for more information on how to calculate effective aperture.

Refer to Standards Table 143-F for minimum skylight area to daylit floor area or minimum skylight effective aperture in low-rise enclosed spaces greater than 25,000 ft^2 directly under a roof.

It should be noted that the minimum skylight areas are minimums; 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 outweigh the electric light savings (see Figure 3-7). 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[3] and has a haze rating greater than 90%, the skylight system is deemed to be "diffusing" and complies with the haze requirement of §143(c). 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 at least 90% to make the skylight system comply.

Any skylight system that is used to comply with §143(c) invokes the mandatory 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 ft^2 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 big box 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. If the building shell is expected to have a low lighting power density, for example, a warehouse with 0.3 W/ft^2, but there is also a good possibility that some portion or all of the building may be converted into office, retail, or other function areas with higher lighting power densities than the warehouse, it is advisable to use the largest skylight areas required in Standards Table 143-F.

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

Example 3-3

Question

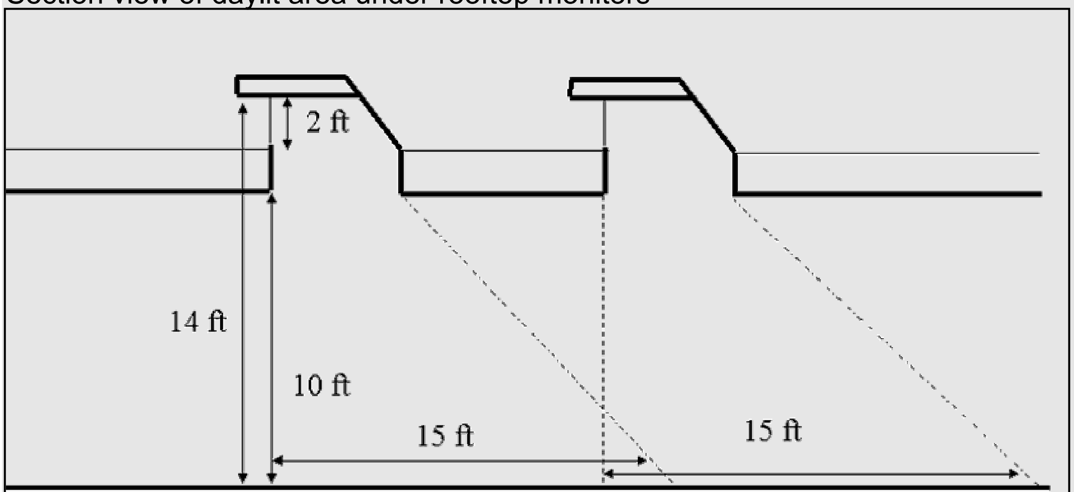
Are rooftop monitors considered to be windows or skylights?

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 15 ft 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



Daylit area under rooftop monitors

The power adjustment factors for electric lighting in the daylit area controlled by photocontrols is a function of the transmittance of the glazing in the monitor as well as the window to wall ratio of the "virtual wall" created by the monitor. As is shown in the figure, the glazing height is 2 ft whereas the virtual wall height is 14 ft. Thus the window to wall ratio is the ratio of these heights 2/14 = 14%. From Table 146 A in the Standards, electric lighting controlled by a dimming photocontrol is eligible for a Power Adjustment Factor of 30% in daylit areas having glazing with greater than 60% visible light transmittance and a window to wall ratio less than 20%. This power adjustment factor would adjust the installed lighting power in the daylit area by subtracting 30% of the controlled lighting watts.

3.2.5 Determining Fenestration U-factors

§116 and §141(c)4.D

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.

For skylights rated with curb as described in Tables 143-A, 143-B, and 143-C, there is a portion of the 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.

Joint Appendix I 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 3-5 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 3-5 – 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	✓	✓	✓	✓
Default U-factors from ACM Manual Appendix NI		✓	✓	

Note 1: The default U-factors from Nonresidential ACM Manual Appendix NI may also be used for site-built horizontal glazing. Site-built horizontal glazing is considered to be a skylight.

Note 2: The default U-factors from ACM Manual Appendix NI 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 3-6 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 less likely to be available for skylights than they are for windows, there are limited test data can be extended through calculations for skylights. Typically, acrylic skylights must be individually tested for NFRC rating purposes. Since NFRC data might not be available, the default U-factors from ACM Manual Appendix NI may be used for skylights. These values are taken from the ASHRAE Fundamentals (2001) 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 alternate default U-factors for site-built fenestration in buildings with less than 10,000 ft^2 of site-built glazing are also listed in Appendix NI.

The recommended method for determining the U-factor of site-built fenestration systems (curtain walls and storefront systems) is the NFRC 100 (2002) procedure. This requires that a sample of the curtain wall assembly be assembled and tested in an NFRC-approved laboratory. If the building has less than 10,000 ft^2 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 selected from ACM Manual Appendix NI, NFRC 100, or Title 24 default values.

For buildings with more than 10,000 ft^2 of site-built fenestration area, there are two compliance choices with regard to U-factor and labeling of site-built fenestration:

- Go through the NFRC process and obtain a label certificate. This is the option described in §10-111(a)1A.
- 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 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 this class of fenestration, U-factors must be taken from Standards Table 116-A.

Field-Fabricated Fenestration Product or Exterior Door

Field-fabricated fenestration does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits, or curtain walls). 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 Joint Appendix IV, Table IV.28. 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 3-6 – Standards Table 116-A Default Fenestration Product U-Factors

FRAME TYPE[1]	PRODUCT TYPE	SINGLE PANE U-FACTOR	DOUBLE-PANE U-FACTOR[2]
Metal	Operable	1.28	0.79
Metal	Fixed	1.19	0.71
Metal	Greenhouse/garden window	2.26	1.40
Metal	Doors	1.25	0.77
Metal	Skylight	1.98	1.3
Metal, Thermal Break	Operable	N/A	0.66
Metal, Thermal Break	Fixed	N/A	0.55
Metal, Thermal Break	Greenhouse/garden window	N/A	1.12
Metal, Thermal Break	Doors	N/A	0.59
Metal, Thermal Break	Skylight	N/A	1.11
Nonmetal	Operable	0.99	0.58
Nonmetal	Fixed	1.04	0.55
Nonmetal	Doors	0.99	0.53
Nonmetal	Greenhouse/garden windows	1.94	1.06
Nonmetal	Skylight	1.47	0.84

[1] Metal includes any field-fabricated product with metal cladding. Nonmetal-framed manufactured fenestration products with metal cladding must add 0.04 to the listed U-factor. Nonmetal frame types can include metal fasteners, hardware, and door thresholds. Thermal break product design characteristics are as follows:

a. The material used as the thermal break must have a thermal conductivity of not more than 3.6 Btu-inch/hr/ft^2/°F,

b. The thermal break must produce a gap of not less than 0.210 inch, and

c. All metal members of the fenestration product exposed to interior and exterior air must incorporate a thermal break meeting the criteria in Items a. and b. above.

In addition, the fenestration product must be clearly labeled by the manufacturer that it qualifies as a thermally broken product in accordance with this standard. Thermal break values shall not apply to field-fabricated fenestration products.

[2]For all double-glazed fenestration products, adjust the listed U-factors as follows:

a. Subtract 0.05 for spacers of 7/16 inch or wider.

b. Subtract 0.05 for products certified by the manufacturer as low-E glazing.

c. Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide.

d. Add 0.05 to any product with true divided lite (dividers through the panes).

3.2.6 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 3-9) or taken from Table 3-7 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 3-9. 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 3-9. 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.

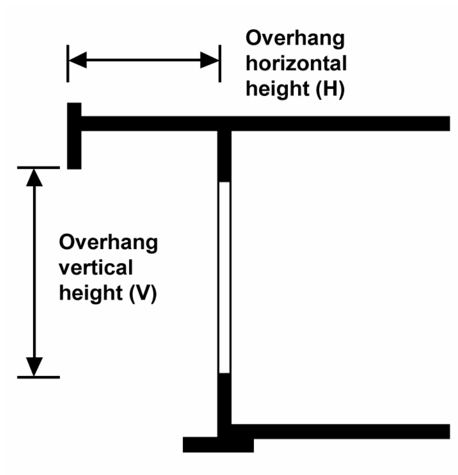


Figure 3-9 – Overhang Dimensions

Equation 3-1– Relative Solar Heat Gain

RSHG = SHGCwin x OHF

Where

RSHG = Relative solar heat gain.

SHGCwin = 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 3-7 – 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 3-7, 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 3-7, 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 3-10 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%). East, west and south overhangs can achieve reductions of 55%–60%. The benefits of the overhang level off as the overhang becomes large. (Note: this graph is presented only to illustrate the benefits of overhangs.)

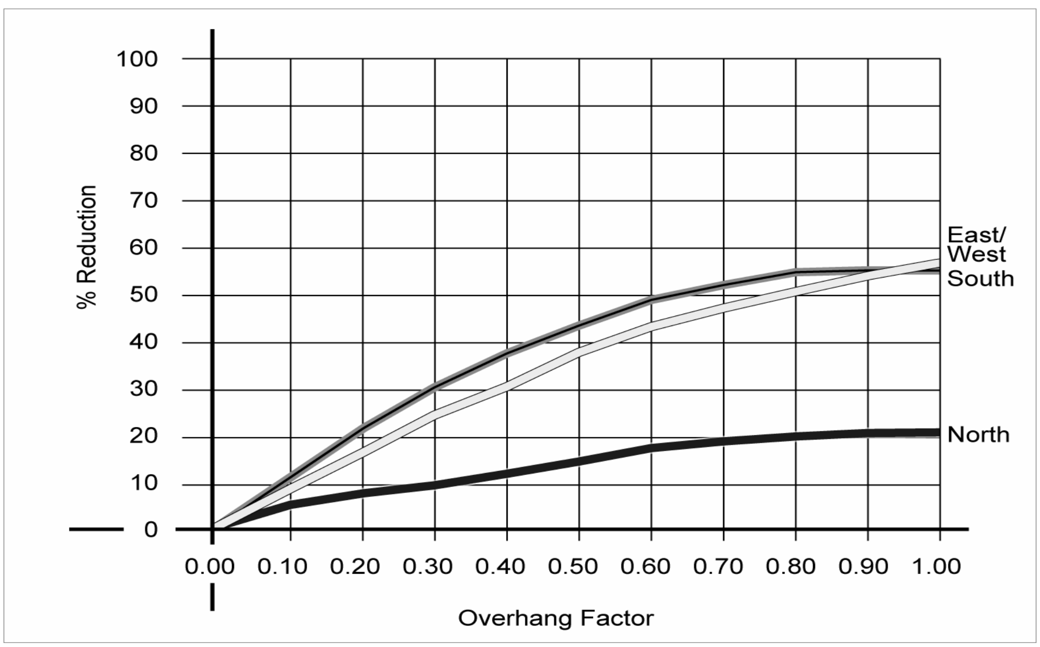


Figure 3-10 – Graph of Overhang Factors

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 three ft out from the plane of the glass (H = 3), and is six ft above the bottom of the glass (V = 6). The overhang extends more than three ft beyond each side of the glass and the top of the window is less than two 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 3-7. 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.

3.2.7 Determining Solar Heat Gain Coefficients

§141(c)5

The solar heat gain coefficient (SHGC) is a measure of the quantity of solar heat entering a window or skylight; the lower the SHGC, the less solar heat gain. 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: 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 (TDD's or tubular skylights) is appropriate only for attic configurations where the insulation layer is directly on top of the ceiling. For spaces with insulated roofs, use the NFRC or default rating of the top dome only.

A third method is to use the SHGC Defaults from Standards Table 116-B. 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.

The fourth method, applicable only to skylights and site-built fenestration in buildings with less than 10,000 ft^2 of site-built fenestration, is to use the procedure defined in ACM Manual Appendix NI. This method allows, under limited conditions, the use of Standards Equation 116-A for determining SHGC. This equation calculates an overall SHGC for the fenestration ($SHGC_{fen}$) assuming a default framing factor and using the center-of-glass SHGC value ($SHGC_c$) for the glazing from the manufacturer's literature.

Buildings that have 10,000 ft^2 or more of site-built fenestration cannot use the site-built Standards Equation 116-A.

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 for 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 (2002)			✓	
Default SHGC values from Standards Table 116-B)	✓	✓	✓	✓
SHGC alternative procedure from ACM Manual Appendix NI. $SHGC_{fen} = 0.08 + 0.86 \times SHGC_c$		✓	✓(Note 1)	

Note 1: The SHGC procedure defined in Nonresidential ACM Manual Appendix NI 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.

3.2.8 Determining Visible Light Transmittance (VLT)

Visible light Transmittance (VLT) is a property of glazing materials that has a varying relationship to SHGC. VLT 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. VLT 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 VLT 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 VLT 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 VLT that is 20% or so higher than the SHGC. Higher VLT can result in energy savings in lighting systems.

The value of VLT for a given material is found in the manufacturer's literature. VT from NFRC cannot be used in lieu of VLT. For more information on how to determine VLT, refer to Section 5.2.1.4, Daylighting Controls, of this manual.

3.2.9 Determining Site-Built Fenestration Performance

(§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.

NFRC 100 addresses the special needs of site-built fenestration products. The NFRC procedures are recommended for all site-built fenestration systems or use Table 116-A for large construction projects. Large construction projects are those that have 10,000 ft^2 or more of site-built fenestration, which includes windows, non-opaque doors, and skylights. The requirement is intended to apply to large office buildings and other nonresidential buildings with large curtain wall systems. Many of the costs for testing and labeling site-built glazing systems are fixed, so the cost per ft^2 is lower in larger projects. This is the primary rationale for NFRC testing and labeling.

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 an NFRC license and establish a relationship with an NFRC certified simulation laboratory, an NFRC certified testing laboratory, and an NFRC certified independent agent (IA). For more information on the licensing process, refer to the NFRC web site at http://www.nfrc.org/.

The responsible party must work with the glazing or curtain wall supplier(s) to carry out the following steps:

- Arrange for an NFRC accredited simulation laboratory to evaluate and determine the thermal performance of each product line.
- Make an arrangement with an NFRC accredited testing laboratory to conduct a validation test on each product line.
- Forward copies of the simulation and test reports to an NFRC-accredited IA for review.

The IA then issues an NFRC Label Certificate that is kept on file in the general contractor's construction office and posted on-site for review by the building inspector. The NFRC Label Certificate serves the same function as the temporary label that is required for manufactured fenestration products.

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 IA, a simulation laboratory and a testing laboratory, the process works smoothly and should not delay either the design or construction process.

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 ACM Manual Appendix NI. If the values used for compliance are within 5% of the Appendix NI values, then the values may be considered reasonable for plan check. If the compliance values are outside the 5% range, the plans examiner should request information from the designers to justify the proposed values. It may be necessary for the design team to consult with NFRC simulation laboratories to determine what technologies might be required to achieve the specified level of performance.

After the construction contract is awarded, the glazing contractor or other appropriate party assumes responsibility for getting the simulations and tests made and for obtaining the NFRC Label Certificate. The IA issues a separate label certificate for each "product line." 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 ACM Manual Appendix NI is 0.59. The proposed factor of 0.57 is within 5% and should be considered reasonable.

Example 3-6

Question

The envelope and space conditioning system of an office building with 120,000 ft^2 of conditioned floor area is being altered. The building has 24,000 ft^2 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 ft^2) is removed and replaced with site-built fenestration.

Answer

NFRC label certificate requirement does not apply to scenarios 1, and 2 but does apply to scenario 3.

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

2. Exception to §116(a) 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 ft^2 (more than the threshold value of 10,000 ft^2) of new fenestration is being installed.

4. Use either NFRC 100 or the applicable default U-factor set forth in Nonresidential ACM Manual Appendix NI with less than 10,000 ft^2 of site-built fenestration.

Defining Product Lines for Site-Built Fenestration

Please see NFRC Certified Products Directory and NFRC 100 Combined: Procedures for Determining Fenestration U-factors – http://www.nfrc.org.

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 3-11). 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.

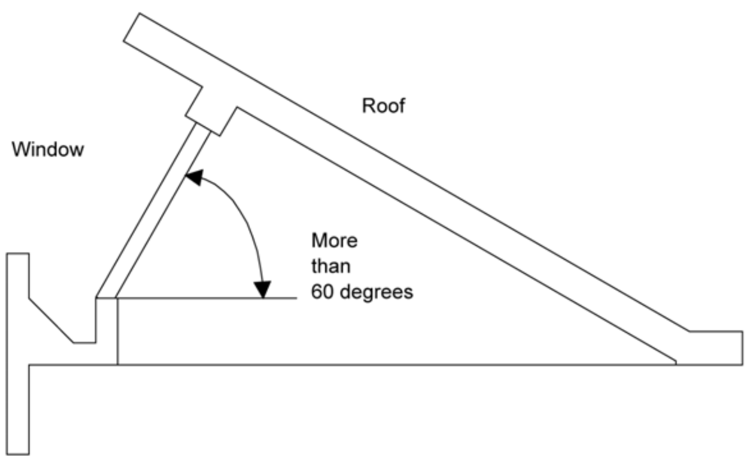


Figure 3-11 – Slope of a Wall or Window (Roof or Skylight slope is less than 60°)

The window is considered part of the wall because the slope is over 60º. Where the slope less than 60º, 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 the types of insulating materials listed in Table 3-9 unless the product has been thus certified. Builders and enforcement agencies should use the Department of Consumer Affairs *Consumer Guide and Directory of Certified Insulation Material* to check compliance. (Note: this is not an Energy Commission publication.) If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Thermal Insulation Program, at (916) 574-2041.

Table 3-9 – Insulation Materials Requiring Certification

Type	Form
Aluminum foil	Reflective foil
Cellular glass	Board form
Cellulose fiber	Loose fill and spray applied
Mineral aggregate	Board form
Mineral fiber	Blankets, board form, loose fill
Perlite	Loose fill
Phenolic	Board form
Polystyrene	Board form, molded extruded
Polyurethane	Board form and field applied
Polyisocyanurate	Board form and field applied
Urea formaldehyde	Foam field applied
Vermiculite	Loose fill

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 four mil 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 efficiency 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 ft^2 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 Joint Appendix IV, Table IV.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.

3.3.2 Prescriptive Requirements

The prescriptive requirements include minimum insulation levels for roofs/ceilings, walls, and floors. The requirements are expressed in two ways: a maximum U-factor and a minimum R-value. The U-factor criteria are also given for different classes of construction such as wood- framed, metal-framed, metal building, and mass walls. A roof with metal framing members or a metal deck may comply using the minimum R-value from Standards Tables 143-A, 143-B, and 143-C if a continuous insulation layer with at least that minimum R-value is installed either above the roof deck or between the roof deck and the structural members supporting the roof deck. Alternatively, a roof with metal framing members or a metal deck may comply if 1) a continuous layer of rigid insulation with a minimum R-value of R-10 is installed either above the roof deck or between the roof deck and its structural members, and 2) insulation with a minimum R-value equal to or greater than the applicable value in Standards Table 143-A, Table 143-B, or Table 143-C is installed between the structural members.

The criteria also vary by climate zone and occupancy. Standards Table 143-A has the criteria for nonresidential buildings. 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. These criteria are climate independent, since manufacturers often do not know who will buy their product and which climate zone it will be installed in. The nonresidential and residential criteria are expressed for the five climate regions described in the overview section of this chapter.

Exterior Roofs and Ceilings

§143(a)1.

Exterior roofs or ceilings can meet the prescriptive requirements in one of two ways: have the required R-value of insulation (applicable only if the roof does not have metal framing or a metal deck) or have an assembly U-factor that meets the maximum U-factor criterion (see Table 3-10). For most nonresidential buildings, a U-factor of 0.076 or R-value of R-11 is required in the south coast climates (zones 6-9) and U-factor of 0.051 or non-metal R-19 is required in other locations. For high-rise residential buildings and hotel/motel guest rooms, a U-factor of 0.051 or R-value of R-19 (for non-metal framing or deck) is required in the middle coast and south coast climates (zones 3 through 9) and U-factor of 0.036 or R-30 for non-metal is required in other California locations. For relocatable public school buildings, U-factor of 0.051 or R-19 for non-metal is required in all climate zones.

Wet Insulation Systems

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 times 0.8 before choosing the table column in Joint Appendix IV for determining assembly U-factor. See the footnotes for Tables IV.1 through IV.7 in the Joint Appendices.

Table 3-10 – Roof/Ceiling Requirements

Summary from Standards Tables 143-A and 143-B

Roof/Ceiling Space Type	**Criterion***	**Climate Zones** 1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	U-factor	0.051	0.051	0.076	0.051	0.051
	R-value	19	19	11	19	19
Residential High-rise	U-factor	0.036	0.051	0.051	0.036	0.036
	R-value	30	19	19	30	30
Relocatable Public School Buildings	U-factor	0.051	0.051	0.051	0.051	0.051
	R-value	19	19	19	19	19

**U-factors are the actual conductance of the entire assembly. R-values refer to the nominal R-value of the insulation within the framing.*

NOTE: R-value cannot be used for compliance when the roof has metal framing members or a metal deck unless additional rigid insulation is installed. See §143 (a) 1 C.

For roof structures where a metal deck is in direct contact with metal supporting members, the R-value method of compliance may be used only if the required insulation R-value is continuous over the top of the metal deck or continuous and installed between the metal supports and the metal deck. For metal building roofs, R-10 continuous (rigid) insulation may be used across the supports with insulation of the designated R-value used between the framing.

Figure 3-12 shows acceptable means of meeting the R-value criteria for metal roofs.

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

When the U-factor compliance method is used, U-factors must be selected from Joint Appendix IV.

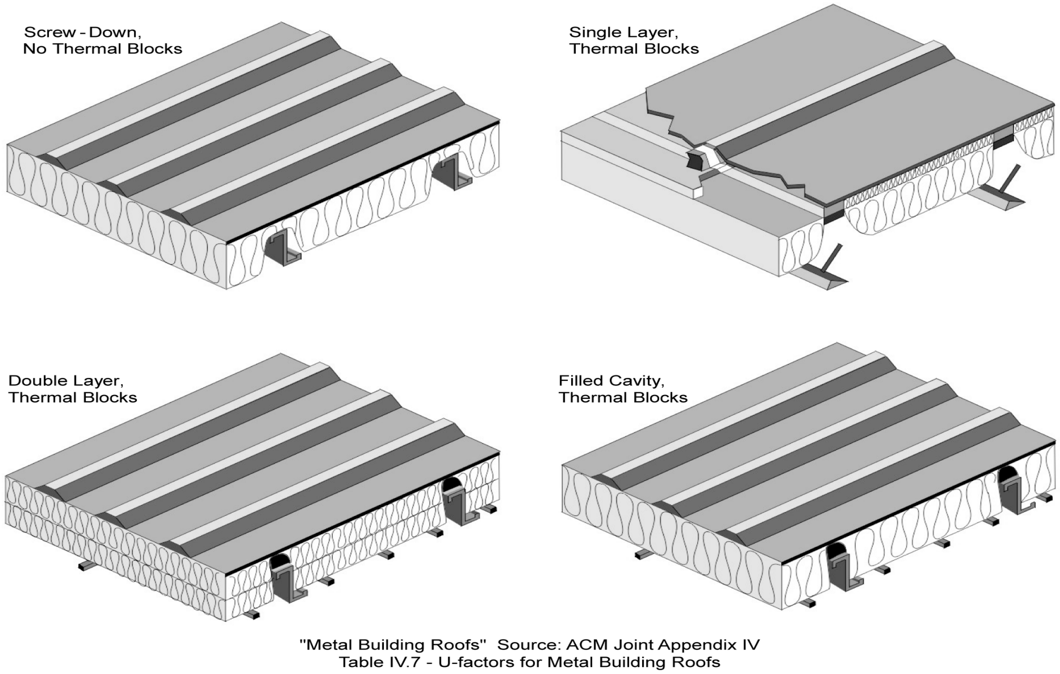


Figure 3-12 – Acceptable Metal to Metal Roof Constructions

Exterior Walls

§143(a)2

Exterior walls can meet the component requirements by either using a construction that has an assembly U-factor lower than the specified criteria as shown in Table 3-9, or installing the required R-value of insulation (Table 3-11).

For nonresidential buildings, R-11 insulation is required for the middle and south coasts (zones 3 through 9) and R-13 is required in other climate zones. For residential buildings and hotel/motel guest rooms, R-11 is required for the middle and south coast areas (zones 3 through 9); R-13 is required for the valley and desert climates (zones 2 and 10 through 15); and R-19 is required for the cold climates (zones 1 and 16). For public school buildings, R-13 is required in all climate zones.

Table 3-11 – Wall Requirements

Summary from Standards Tables 143-A and 143-B

Wall Requirements **Space Type**	**Criterion**	**Climate Zones** 1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value or	13	11	11	13	13
	U-factor					
	Wood frame	0.102	0.110	0.110	0.102	0.102
	Metal frame	0.217	0.224	0.224	0.217	0.217
	Metal building	0.113	0.123	0.123	0.113	0.113
	Mass/7.0≤ HC<15.0	0.330	0.430	0.430	0.430	0.430
	Mass/15.0≤HC	0.360	0.650	0.690	0.650	0.410
	Other	0.102	0.110	0.110	0.102	0.102
Residential High-rise	R-value	19	11	11	13	13
	U-factor					
	Wood frame	0.074	0.110	0.110	0.102	0.102
	Metal frame	0.183	0.224	0.224	0.217	0.217
	Metal building	0.061	0.123	0.123	0.113	0.113
	Mass/7.0≤ HC<15.0	0.330	0.430	0.430	0.430	0.430
	Mass/15.0≤HC	0.360	0.650	0.690	0.650	0.410
	Other	0.074	0.110	0.110	0.102	0.102
Public School Buildings	R-value	13	13	13	13	13
	U-factor					
	Wood frame	0.102	0.102	0.102	0.102	0.102
	Metal frame	0.261	0.261	0.261	0.261	0.261
	Metal building	0.061	0.061	0.061	0.061	0.061
	Mass/7.0≤ HC<15.0	0.330	0.330	0.330	0.330	0.330
	Other	0.102	0.102	0.102	0.102	0.102

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Joint Appendix IV. There are six classes of wall constructions: wood frame, metal frame, metal building walls, medium mass, high mass, and other (Figure 3-13). The “other” category is used for any wall type that does not fit into one of the other five wall classes. The following bullets give more information.

- **Wood-framed walls.** As defined by the International 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). Joint Appendix IV, Table IV.9 has data for conventional wood-framed walls and Table IV.10 has data for SIPS panels.

- **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. The U-factor criteria are higher for metal-framed walls (compared to wood-framed walls) because the metal framing members are more conductive. From Joint Appendix IV, Table IV.11 has data for metal-framed walls.
- **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 IV.16 from Joint Appendix IV has data for metal building walls.
- **Low mass walls.** Low mass walls have a heat capacity (HC) greater or equal to 7.0 but less than 15.0 Btu/ºF-ft². See the definition below for heat capacity. From Joint Appendix IV, Tables IV.12 and IV.13 have U-factor, C-factor, and heat capacity data for hollow unit masonry walls, solid unit masonry and concrete walls, and concrete sandwich panels.
- **High mass walls** have an HC equal to or greater than 15.0 Btu/ºF-ft². See Joint Appendix IV for HC data on mass walls.
- **Spandrel panels and glass curtain walls**. See Joint Appendix IV, Table IV.15 for U-factor data.

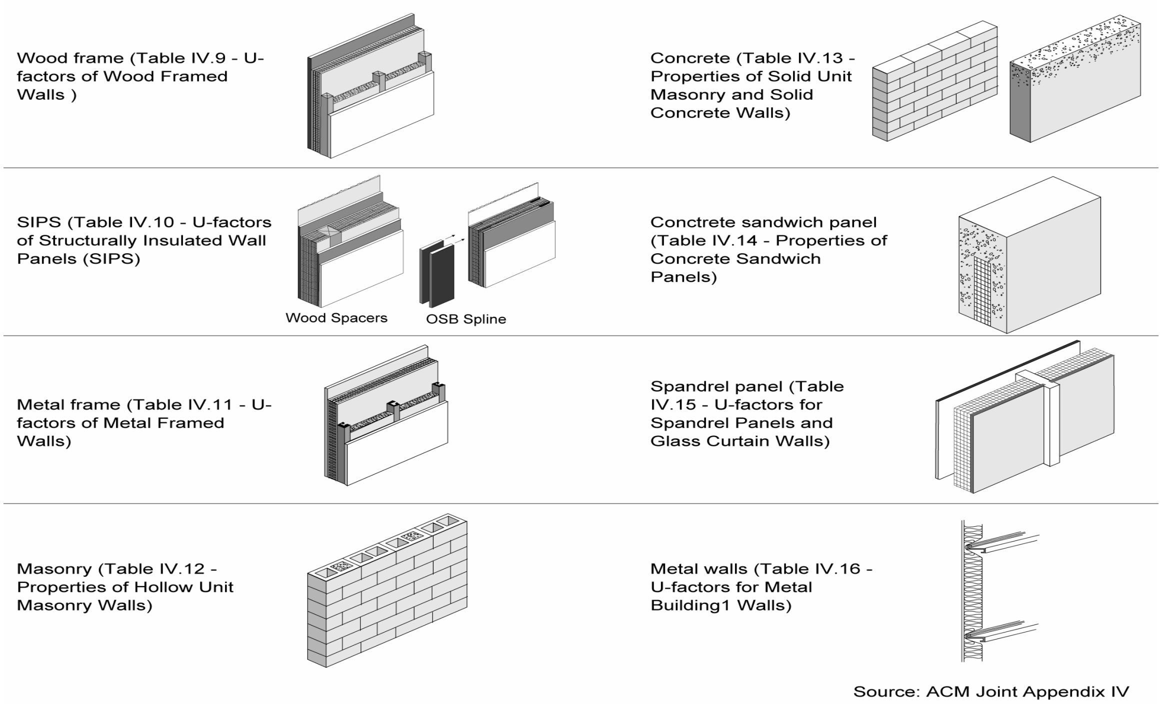


Figure 3-13 – Classes of Wall Constructions.

Demising Walls

§143(a)3 and §143(a)5

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

Exterior floors and insulated soffits can meet the prescriptive requirements by either installing the required R-value of insulation or using a construction that meets the U-factor criteria (Table 3-12). The R-value alternative may be used for either metal-frame or wood-frame construction.

For nonresidential buildings, R-19 is required for floor insulation in the cold regions (zones 1 and 16) and R-11 is required in the other climate zones. 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/ºF-ft².

Table 3-12 – Floor/Soffit Requirements

Summary from Standards Tables 143-A and 143-B

Floor/Soffit		Climate Zones				
Space Type	**Criterion**	1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value or	19	11	11	11	11
	U-factor					
	Mass/7.0≤HC	0.090	0.139	0.139	0.090	0.139
	Other	0.048	0.071	0.071	0.071	0.071
Residential High-rise	R-value	19	11	11	11	11
	U-factor					
	Mass/7.0≤HC	0.090	0.139	0.139	0.090	0.090
	Other	0.048	0.071	0.071	0.071	0.071
	Raised concrete R-value	8	*	*	*	*
Relocatable Public School Buildings	R-value	19	19	19	19	19
	U-factor	0.048	0.048	0.048	0.048	0.048
	Wood-frame	0.107	0.107	0.107	0.107	0.107
	Metal-frame	0.261	0.261	0.261	0.261	0.261
	Metal Building	0.061	0.061	0.061	0.061	0.061
	Mass/7.0≤HC	0.330	0.330	0.330	0.330	0.330
	Other	0.102	0.102	0.102	0.102	0.102

** Required insulation levels for concrete raised floors are R-8 in Climate Zones 2, 11, 13, and 14; R-4 in Climate Zones 12 and 15, and none in Climate Zones 3 through 10.*

For high-rise residential buildings and hotel/motel guest rooms, R-19 floor insulation is required for the cold regions (zones 1 and 16) and R-11 is required in the other climate zones. For relocatable public school buildings, R-19 is required in all climate zones. 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 and high-rise residential concrete raised floors with HC ≥ 7.0 using U-factor for compliance from Joint Appendix IV, Table IV.25, are equivalent to R-8 continuous insulation in climate zones 1, 2, 10 through 13, and 16; and R-4 in climate zones 3 through 9, 14 and 15. The performance method of compliance for high-rise residential concrete raised floors is based on the U-factors in Standards Table 143-B.

Insulation levels for high-rise residential concrete raised floors using R-value for compliance are R-8 continuous insulation underneath in climate zones 1, 2, 11, 13, and 14; and R-4 in climate zones 12 and 15, with no insulation required in Climate zones 3 through 10.

Table IV.25 from Joint Appendix IV is used with mass floors while Tables IV.20 through IV.24 are used for non-mass floors. See also Figure 3-14.

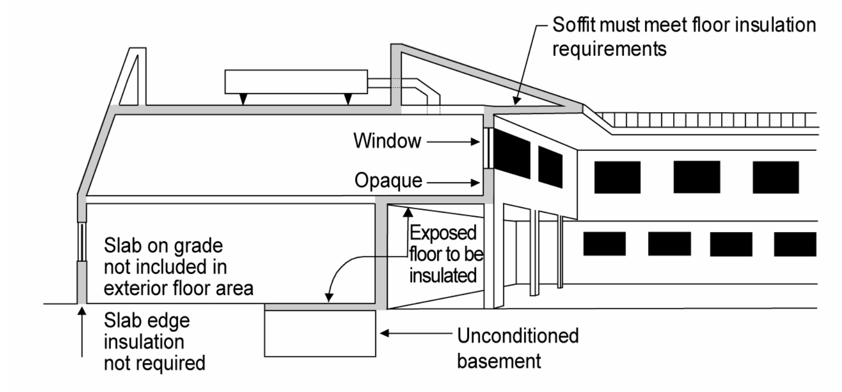


Figure 3-14 – Requirements for Floor/Soffit Surfaces

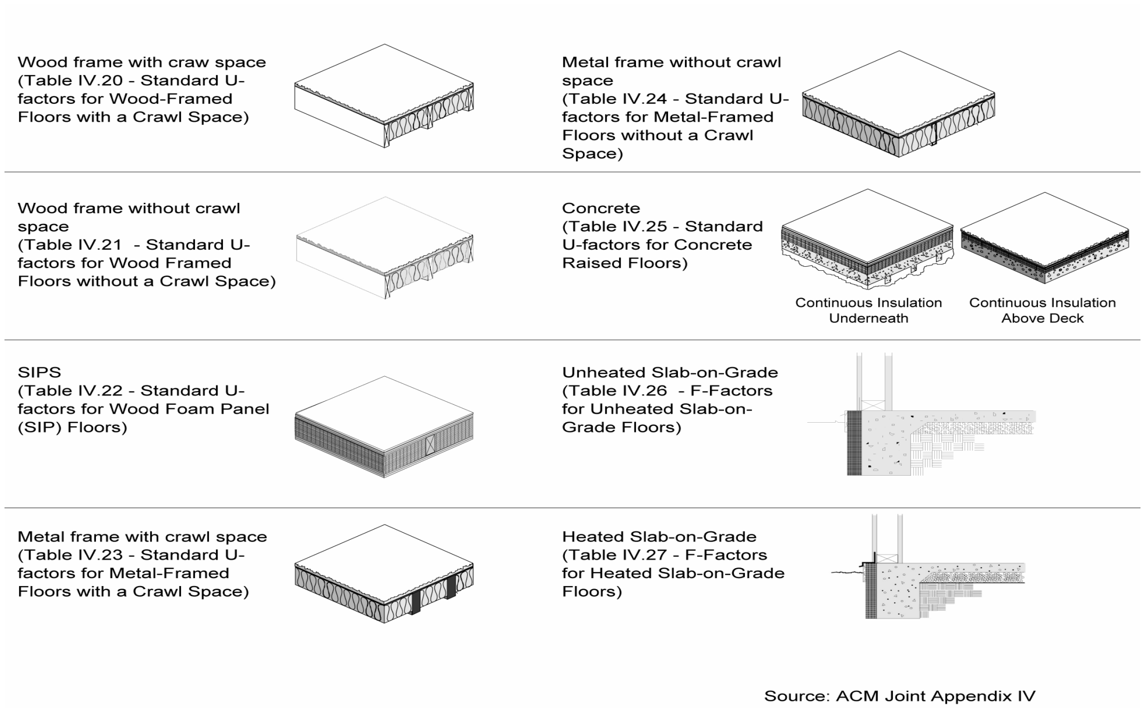


Figure 3-15 – Classes of Floor Constructions.

Exterior Doors

§143(a)7

There are no prescriptive requirements for exterior doors. Glazing in doors, however, must be included in all fenestration calculations. When glazing exceeds one-half of the area of the door, it is defined as a window 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 can 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 IV.28 from Joint Appendix IV has U-factors for exterior doors.

3.4 Cool Roofs

The term “cool roof” refers to an outer layer or exterior surface of a roof that has high solar reflectance and high emittance and reduces heat gain into a building. 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. 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, while surfaces with high emittance allow heat to escape through radiation to the sky.

There are several ways to achieve the high emittance required to qualify as a cool roof. One of the best methods 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 such as modified bitumen or a mineral cap sheet. Metal roofs can qualify as cool roofs by using an industrial grade coating that has high reflectance and high emittance.

3.4.1 Mandatory Measures

The mandatory measures require that cool roofs be tested and labeled by the Cool Roof Rating Council and that liquid applied products meet minimum standards for performance and durability. Note that installing cool roofs is *not* a mandatory measure.

Rating and Labeling

§10-113

When cool roofs are used for compliance, they must be tested and labeled by the Cool Roof Rating Council (CRRC). 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 reflectance and emittance.

The minimum label size and font size of the CRRC label are shown below (Figure 3-16). Please note that the CRRC label (an example of which is shown below) may only be used in accordance with CRRC program guidelines.

CRRC COOL ROOF RATING COUNCIL SM	Initial Weathered Solar Reflectance 0.00 Pending Thermal Emittance 0.00 Pending Rated Product ID XXXXX Licensed Manufacturer ID XXXXX Classification Production Line
Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary. Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.	

Figure 3-16 – Sample CRRC Label

Performance Requirements for Field Applied Liquid Coatings

§118(i)3, Table 118-C

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 an emittance below 0.75, which is the minimum rating for prescriptive compliance. The overall envelope approach is typically used to achieve compliance with these coatings.

This class of field-applied liquid coatings must be manufactured in accordance with ASTM D2824[4] Standard Specification for Aluminum-Pigmented Asphalt Roof Coatings, Nonfibered, Asbestos Fibered, and Fibered without Asbestos, or ASTM D6848, Standard Specification for Aluminum Pigmented Emulsified

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[4] 1.1 This specification covers asphalt-based, aluminum roof coatings suitable for application to roofing or masonry surfaces by brush or spray.

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

1.3 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.

Asphalt Used as a Protective Coating for Roofing, and installed in accordance with ASTM D3805[5], Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings. ASTM D2824, Standard Specification for Aluminum-Pigmented Asphalt Roof Coatings, Nonfibered, Asbestos Fibered, and Fibered without Asbestos, covers asphalt-based aluminum roof coatings suitable for application to roofing or masonry surfaces by brush or spray.

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 must be manufactured to contain no less than 20% Portland cement and meet the requirements of ASTM D822[6], *Standard Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings*. When installed over a rock or gravel surface, the coating must be applied at a thickness of at least 200 dry mils (5 mm). The coatings must be applied at a minimum thickness of 30 mils (0.8 mm) when installed on a mineral cap sheet surface and 40 mils (1 mm) when installed over a metal surface.

Other Field-Applied Liquid Coatings

Other field-applied liquid coatings include elastomeric and acrylic based coatings. These coatings must be applied with a minimum thickness of 20 dry mils (0.5 mm) across the entire surface and be tested to meet a number of performance and durability requirements as specified in Table 118-C of the Standards.

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[5] 1.1 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.

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

1.3 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.

[6] 1.1 This guide is intended for the evaluation of clear and pigmented coatings designed for use on rigid or semirigid plastic substrates. Coated film and sheeting are not covered by this guide.

1.2 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.

3.4.2 Prescriptive Requirements

§143(a)1.A.

The prescriptive requirements call for a cool roof in all low-slope applications for nonresidential buildings. A low-slope roof is defined as a surface with a pitch less than or equal to 2:12. The requirements do not apply to residential buildings or to hotel/motel guest rooms.

A qualifying cool roof must have an initial reflectance of 0.70 or greater and an initial emittance of 0.75 or greater. However, the emittance may be lower and the reflectance higher such that equivalent performance is achieved. For lower emittance values, calculate the required reflectance as follows:

Reflectance = 0.70 + 0.34 * (0.75 - $\epsilon_{initial}$)

Where $\epsilon_{initial}$ is initial emittance. (See Figure 3-17.)

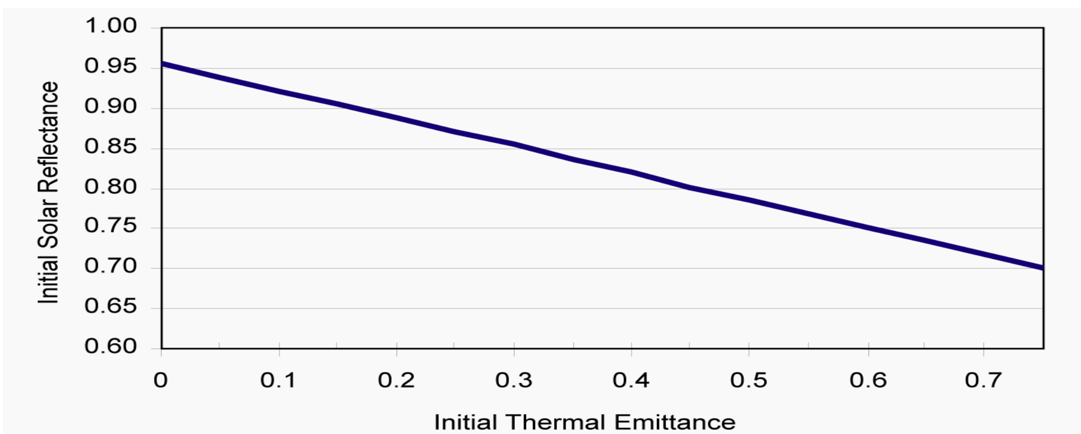


Figure 3-17 – Tradeoffs between Cool Roof Reflectance and Emittance
A cool roof may comply with an emittance lower than 0.75 as long as the reflectance is higher. This graph shows the relationship.

Example 3-7

Question

According to the provisions of the 2005 Title 24 Energy Standards, are cool roofs optional or mandatory for nonresidential buildings?

Answer

Cool roofs are optional; however, they are included on the model buildings (also called the "standard buildings") that establish the energy budget for nonresidential buildings with low-sloped roofs. This means that cool roofs are required if the owner or developer uses the prescriptive envelope component method of compliance for a building with a low-sloped roof. Cool roofs are not required for the prescriptive approach for high-sloped roofs. There are compliance option credits for high-slope nonresidential roofs and roofs on other building types.

Example 3-8

Question

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

Answer

It depends on if and how they are being used for energy compliance. If you are using the prescriptive envelope component approach, the answer is yes; the roof must be certified and labeled by CRRC for nonresidential low-sloped roofs. However, to receive compliance credit using the prescriptive overall envelope approach or the performance approach, obtain a CRRC certification, OR use a default reflectance of 0.10. That is, the answer to the question is no if you use the default reflectance for a particular roofing material. (The default reflectance is different for roofs other than low-sloped nonresidential roofs; see Question 3-15.)

Example 3-9

Question

When re-roofing with gravel, must the roof meet cool roof requirements? Is CRRC certification required?

Answer

Not necessarily. Roof recoverings allowed by the California Building Code do not have to meet the cool roof 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 3-10

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 may it qualify for the exception discussed in the previous question?

Answer

No, the two roofs are not equivalent and therefore the gravel roof over existing cap sheet may not qualify for the exception.

Example 3-11

Question

Do the Title 24 Energy Standards address high-slope residential roofs? In other words, do shingles need to be certified to meet emittance of 0.30? What about high-slope apartment complexes that are residential but not single family homes?

Answer

The Standards offer compliance credits for these other roofs. The same reflectance, emittance and coating performance requirements apply for these other roofs if they are to receive credit. Roofing materials such as asphalt shingles need to be CRRC certified to meet required emittance and reflectance levels. Note that clay or cement roofing tiles have to meet a reflectance of only 0.40 to gain compliance credit for high-sloped roofs on low-rise residential buildings.

Example 3-12

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 can be used to establish cool roof product qualification in Title 24 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 3-13

Question

Is aged reflectance a consideration in the cool roof requirements?

Answer

No, compliance is based strictly on initial reflectance.

Example 3-14

Question

Can the reflectance and emittance requirements of Energy Star Cool Roofs be substituted for the Title 24 Energy Standards requirements?

Answer

No. At this time, Energy Star Cool Roofs have only reflectance requirements and no emittance requirements, so Energy Star Cool Roofs do not automatically qualify as cool roofs under Title 24. Only cool roofs certified by CRRC qualify as cool roofs under Title 24 at this time.

Example 3-15

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 Title 24 Energy Standards?

Answer

No, you cannot claim to have a cool roof and you cannot claim higher energy credits if your roof does not meet the coating performance requirements of Title 24 for field-applied coatings.

Example 3-16

Question

Is the default reflectance for a non-CRRC certified/labeled roof or for one that doesn't meet the coating performance requirements different for nonresidential low-sloped roofs than for other roofs?

Answer

Yes, the default reflectance for nonresidential low-sloped roofs is 0.10 and for other roofs is 0.30.

Example 3-17

Question

Aren't cool roofs expensive?

Answer

Not necessarily. Our research shows that the cost of a cool roof compared to a non-cool roof can be the same (no difference in price) or slightly higher per square foot for the cool roof, depending on lots of particulars. Our analyses showed cool roofs to be cost-effective over the life cycle of the roofing material in all 16 of California's climate zones.

Example 3-18

Question

With a reflective, emissive roof (a cool roof), does a building lose the advantage of solar heat gain through the roof in the cold months? Will my heating bills increase?

Answer

In some months in some climate zones, the sun's heat could provide some heat gain into the building through a low-sloped roof. Taking that gain away with a cool roof still results in a net gain in comfort and energy bills over the course of a year, because the hot-weather benefits of reducing air conditioning needs generally outweigh (in some cases, GREATLY outweigh) the solar gain in winter. In some buildings with a cool roof, there may be a slight increase in the need for space heating in the colder months.

Example 3-19

Question

How does a product get CRRC cool roof certification?

Answer

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

Example 3-20

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 3-21

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.

3.5 Infiltration and Air Leakage

3.5.1 Fenestration and Doors

See in Section 3.2.1.

3.5.2 Joints and Openings

§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

Table 143-C
ACM Manual Appendix ND

Public school building design is defined by two prescriptive requirements, listed in Tables 143-A and 143-C of the Standards, covering climate-specific 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 and lighting power requirements in §146. For additional design requirements, refer to §143 and Nonresidential ACM Manual Appendix ND. 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 (ACM Manual Appendix ND). Also see §141(d), §149(b)2 NOTE, and Nonresidential ACM Manual Table N2-1 for public school buildings requirements.

§141(d) Performance

Relocatable Public School Buildings. 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 Nonresidential ACM Manual, 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 can not 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 Nonresidential ACM Manual. The manufacturer/builder shall meet the requirements for identification labels specified in section 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 to be allowed to be installed, i.e., the building with the same proposed design energy features is rotated in 30 degree increments and shall comply in each case. Approved compliance 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 Approach

§143(b)

The overall envelope 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 has two parts, and both parts must be met: overall heat loss and overall heat gain. The overall heat loss accounts for the insulating qualities of the building and sets a maximum rate of conductive heat transfer through the building envelope. The requirements are more stringent in more extreme climate zones than in mild climate zones. The overall heat gain accounts for the area of windows and skylights and their ability to block solar heat gains, thereby reducing cooling loads on the building. Cool roofs are also accounted for in the overall heat gain calculations. The heat gain requirements are more stringent in warmer climate zones.

A standard design value and a proposed design value are calculated for both the overall heat loss and the overall heat gain. The standard design building complies with the exact requirements of the prescriptive approach. The standard values are compared to the proposed values calculated from the actual envelope design. If the proposed values do not exceed the standard values, 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.

3.7.1 Overall Heat Loss

There are two parts to the overall heat loss calculation. The first is to calculate the standard building heat loss; this becomes the standard that must be met. The second is to calculate the proposed building heat loss, which is compared to the standard to show that it does not exceed the standard building heat loss.

There are five steps to calculating the standard building heat loss:

Step 1 - Calculate areas of each type of envelope assembly (walls, windows, roofs, etc.). If glazing exceeds the maximum allowed area, calculate window adjustment factors as directed on part 1 of form ENV-3-C.

Step 2 - Adjust window areas of the standard building if the window areas of the proposed building exceed the maximum areas allowed in §143 (b) of the Standard.

Step 3 - 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 4 - Determine allowed U-factors from the prescriptive envelope criteria in Standards Tables 143-A, 143-B, or 143-C.

Step 5 - Multiply the U-factors and adjusted areas for each building envelope component. The UA values are heat loss rates, in Btu/h-ºF. Add the UA values to determine the standard building heat loss.

Each step is described below in greater detail.

Step 1 - Calculate Areas

First, identify each type of assembly in the building envelope. In a complex building, there could be many. 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.

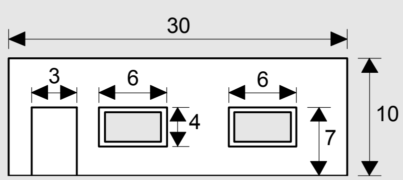
Next, calculate the areas of each assembly. All dimensions are taken at the exterior surface of the assembly. The sum of all the vertical surface areas is the gross exterior wall area (walls, windows, doors). The exterior wall area is the opaque wall area only (no doors). The window wall ratio is the total window area in the gross exterior walls, divided by the gross exterior wall area.

In the case of windows, the area is based on the rough opening dimensions. For most buildings, the actual window area is used to calculate the standard building heat loss.

Example 3-22

Question

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



Answer

The gross exterior wall area is 30 x 10 = 300 ft^2. The door area is 3 x 7 = 21 ft^2. The window areas are 6 x 4 = 24 ft^2 each, or 48 ft^2 total. The exterior wall area is the gross minus doors and windows, or 300 ft^2 - 21 ft^2 - 48 ft^2 = 231 ft^2.

Step 2 - Adjust Fenestration Areas

The standards have additional limitations on the maximum allowable window area. Window area adjustment is required for either of the following conditions:

- Window wall ratio is greater than 40%, 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 heat loss.

The first adjustment is for buildings with very large window area. If the actual window wall ratio is greater than 40%, then an area equal to 40% of the gross wall area is used to calculate the standard building heat loss. Alternatively, for buildings with substantial display perimeter areas (see Section 3.1.2), an area equal to six ft high by the length of the display perimeter is calculated. If this value is greater than 40% of the gross exterior wall area, then it is used in the standard envelope heat loss calculation ("AGi" of the standard heat loss equation, Equation 143-B in the Standard).

The second limitation is on west window wall area. The maximum allowable west window area is the greater of 40% 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.

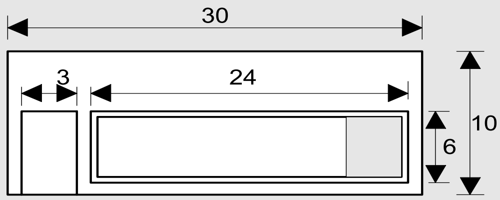
If *both* of the conditions above apply, then two separate adjustments are made: one for the west wall window area and another for the other orientations. The standard west wall window area is set to the larger of 40% of the west wall area or 6 times the display perimeter. The window area for the north, east and south orientations is scaled down proportionate to the window area on that orientation. For example, if the total window area on the north, east and south orientations is 45% of the exterior wall area for those 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 below).

If either of these adjustments is made to the standard window area, the exterior wall area is also adjusted (see above). Skylights are treated similarly. The actual skylight area or the rough opening area will be used to calculate the standard envelope heat loss. If the skylight is site-built (as in the case of large atrium roofs, malls, or other applications) and its shape is three-dimensional (not flat), then the area is the actual surface area, not the opening area. If the skylight area is larger than 5% of the gross exterior roof area (roof doors not included for the standard building), then an area equal to 5% 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% (or the actual skylight area if less than 10% of the gross roof area).

Example 3-23

Question

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



Answer

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

Example 3-24

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 100ft^2. The east and north walls have window areas of 148 ft^2 each. What window area adjustment is required, if any, to the standard design?

Answer

The building gross exterior wall area is 1200 ft^2. The total window area is 144 + 100 + 148 + 148 = 540 ft^2. The building WWR is 540/1200 = 0.45, or 45%. The window areas need adjustment.

The west window area is 40% of the west wall area, or 120 ft^2, as in the example above. The combined window area for the north, east and south orientations is 148 + 148 + 100 = 396 ft^2. The combined WWR for the north, east and south orientations is 396/900 = 0.44. The allowed combined window area for these three walls is 0.40 x 900 = 360 ft^2. Then, the adjusted window areas are:

North, east walls: 148/396 x 360 = 134.5 ft^2 each

South wall: 100/396 x 360 = 90.9 ft^2

As a check, the sum of the adjusted window areas should match the maximum allowed window area: 134.5 + 134.5 + 90.9 = 360 ft^2. Note that the south wall window area must be decreased, even though the south window area is only 33% 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 300ft^2.

Step 3 - Determine Minimum Required Skylight Area

This step applies only for large enclosed spaces with a floor area greater than 25,000 ft^2, a ceiling height of at least 15 ft, and a lighting power density (LPD) of at least 0.5 W/ft^2. Refer to Section 3.2.4 and §143(c) of the Standards for details.

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 building heat loss.

Step 4 - Determine Allowed U-factors

The allowed U-factors are taken from the prescriptive envelope criteria in Standards Tables 143-A, 143-B, or 143-C, depending on the occupancy type. These are the same values discussed under the envelope component approach in the Section 3.3. It is necessary to differentiate wall assembly types and floor/soffit assembly types. The U-factor requirements depend on framing type and heat capacity of the wall or the floor/soffit. In the case of heavier construction assemblies, the heat capacity must be calculated before the allowed U-factor can be determined. For skylights, the type of skylight (glass with curb, glass without curb, plastic with curb) determines the U-factor requirement as shown in Tables 143-A, 143-B, and 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 5 - Multiply and Add

Once the areas and allowed U-factors are determined for each assembly, then the standard building heat loss can be calculated. For each assembly, the U-factor (U) and area (A) are multiplied together; the result is known as the UA product for the assembly. If any of the areas were adjusted, then the adjusted areas are used in this calculation. These UA products are added to obtain the total UA product for the building, which is the standard building heat loss.

The standard building heat loss has units of Btu/hr-°F, and it describes the amount of heat lost per hour through the building envelope for every degree Fahrenheit of temperature difference between inside and outside, under steady state heat flow conditions.

Once the standard building heat loss rate is determined, the proposed design's heat loss rate can be calculated and the two can be compared. If the proposed heat loss rate does not exceed the standard, then the envelope complies with the heat loss criteria.

The proposed heat loss is calculated the same as the standard, except that the actual areas and U-factors of each assembly are used without adjustment. U-factors for opaque building components are taken from tabulated values in Joint Appendix IV. The U-factors are heat transfer rates for the construction assembly, including the frame, insulation and interior and exterior film coefficients. It is not necessary to calculate the U-factor of opaque doors, as they are ignored in the overall heat loss calculations. Any glazing in doors, however, is considered a window and must be included in all window calculations.

The UA product is calculated for each surface, and these are totaled to arrive at the proposed building heat loss. It has the same units and meaning as the standard building heat loss (see above).

For a complete example of how the standard building heat loss and proposed building heat loss are calculated and compared using the ENV-3-C form, see example 3-25.

3.7.2 Overall Heat Gain

As with the overall heat loss, there are two parts to the overall heat gain calculation. The first part is to calculate the standard building heat gain; this becomes the standard that must not be exceeded. The second part is to calculate the proposed building heat gain; compare this to the standard, and show that the proposed heat gain does not exceed the standard heat gain.

The overall envelope approach allows for tradeoffs for building heat gain. For instance, the 2005 Standards have a prescriptive measure for cool roofs on nonresidential buildings with low-sloped roofs. If the proposed building does not have a cool roof, the designer could compensate for the increased heat gain through the roof by reducing the SHGC of the windows, thereby reducing solar heat gains through fenestration.

Building heat gain occurs from conduction through the opaque and fenestration envelope components and from radiative heat transfer. There are several steps to calculating the standard building heat gain:

Step 1 - Determine the conduction heat gain. This includes heat gain through opaque surfaces and fenestration.

Step 2 - Determine the radiation heat gain through opaque surfaces.

Step 3 - Determine the radiation heat gain through fenestration. The heat gain through windows and skylights is calculated in this step.

Step 4 - Calculate the total building heat gain for the standard building. This is the sum of the heat gains calculated for each of the previous steps.

Step 5 - Add the UA values to determine the standard building heat loss.

Each of these five steps is now described in detail.

Step 1 - Calculate Conduction Heat Gain.

a) Determine Areas. The area of each building envelope component was determined in the standard building heat loss calculation. Window area (and the corresponding wall area) was adjusted when it exceeded the maximum allowed area. The same window area is used for the heat gain calculation, except that it is further broken down by orientation. Each window is assigned to the nearest cardinal orientation: east, west, north and south.

b) Determine U-factors and temperature factors. The U-values for the standard building are determined from the prescriptive envelope requirements and should match the U-factors used in the standard building heat loss equation. The temperature factor (TF) is a temperature difference (in degrees F) representative of the difference between the indoor conditioned space and outdoor design conditions. Standards Table 143-D lists TF values for each climate. Separate values are given based on the heat capacity of the material: constructions with higher thermal capacitance will delay the heat gain to the space until later hours in the day.

c) Calculate conduction heat gain for each component. The conduction heat gain for each building envelope component can be determined by the product AxTFxU. The calculated result has units of energy, Btu/h.

Step 2 - Calculate Radiation Heat Gain from Opaque Surfaces.

The heat gain due to radiation absorbed by the roof is calculated in this step. A portion of the solar radiation absorbed by the roof will be conducted through the envelope to the building space. The 2005 Standards prescriptively require a cool roof for nonresidential buildings with low-sloped roofs. Cool roofs absorb less of the solar energy, thus reducing the heat gain to the space (see Section 3.4).

An effective absorptance is calculated from the initial solar reflectance of the roof coating, $\rho_{Ri,std}$.

This calculation requires the following parameters:

a) Roof absorptance – the standard building must have a cool roof if the roof is low-sloped. The absorptance for the standard design is based on the initial solar reflectance of the roofing product, ρ_{Ristd}. The initial reflectance is 0.7 for low-sloped roofs and 0.3 for high-sloped roofs, high-rise residential buildings, and guest rooms of hotel/motel buildings. The effective absorptance of the standard building's roof is given by:

$$\alpha_{Std} = 1 - (0.2 + 0.7\,[\rho_{Ri,std} - 0.2])$$

$$= 0.94 - 0.7\rho_{Ri,std}$$

This results in an absorptance of 0.45 for low-sloped roofs and 0.73 for high-sloped roofs.

For the proposed design, the roofing product should be tested by the CRRC-1 rating procedure. Refer to Section 3.7.3 for the procedure to determine the proposed building absorptance value.

b) U-factor, area – the roof U-factor for the standard building meets the prescriptive envelope criteria and matches the U-factor used in standard building heat gain equation.

c) Weighting factor, temperature factor – these are taken from Standards Tables 143-E and 143-D, respectively.

d) The product of the absorptance, U-factor, area, temperature factor and solar factor is the roof radiation heat gain for the standard design.

Step 3. Calculate Radiation Heat Gain through Fenestration.

The heat gain through fenestration is calculated for each orientation. This calculation is comprised of the following steps:

a) Relative solar heat gain (RSHG) – the relative solar heat gain is a measure of the window's ability to transmit solar energy into the building. It includes the thermal properties of the glazing and shading effects of permanently attached exterior overhangs. The RSHG for the standard building is taken from the prescriptive envelope criteria, Standards Table 143-A. The value is dependent on the orientation of the glazing and the window-wall ratio (WWR). A higher RSHG is allowed for buildings with low WWR values.

The RSHG for the fenestration in the proposed building is the product of the window's SHGC and the overhang factor (OHF).

b) Area. Glazing area of each orientation is determined. The area for the standard building is adjusted if the total window area exceeds limits defined in §143(b)2 of the Standards.

c) Weighting factor (WF) and solar factor (SF). Solar factor values are taken from Standards Table 143-D, for the appropriate climate zone. Weighting factors in the heat gain equations account for the variation in solar radiation striking windows and skylights by orientation and climate zone. The appropriate values are taken from Standards Table 143-E. For windows, assume light mass value. Weighting factors are identical for the standard building and proposed building.

d) The radiation heat gain through each window is the product of the RSHG, area, weighting factor and solar factor.

Step 4. Calculate Radiation Heat Gain through Skylights.

The radiation heat gain is a product of the solar heat gain coefficient, skylight area, weighting factor (WF) and solar factor. Weighting factor and solar factor have the same values for the standard and proposed buildings.

a) SHGC. 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% and 2.1-5%). This is taken from Standards Table 143-A, 143-B, or 143-C.

b) Skylight area. The skylight area of the standard building is set to match the actual skylight area of the proposed building.

c) Weighting factor. The weighting factor for the skylight is taken from Standards Table 143-E for the appropriate climate zone.

d) Solar factor. The solar factor is dependent on the climate zone and taken from Standards Table 143-D.

The product of the SHGC, area, WF, and SF yields the radiation heat gain through the skylight in Btu/h.

Step 5. Calculate the Total Standard and Proposed Building Heat Gain.

The total heat gain for the standard building is the sum of the heat gains calculated in each of the previous three steps.

Once the standard building heat gain rate is determined, the proposed design heat gain rate is calculated and compared to the proposed heat gain. If the proposed heat gain rate does not exceed the standard, then the envelope complies with the heat gain criteria.

3.7.3 Roof Absorptance Calculation

(This section describes details on a support calculation for a parameter in the standard building heat gain equation and proposed building heat gain equation.)

The Prescriptive Approach in the 2005 Standards includes a cool roof for nonresidential buildings with low-sloped roofs. A rating procedure, CRRC-1, was developed for qualification of cool roofs. There are three cases for low-sloped roofs:

a) The roof is CRRC-1 certified with an initial thermal emittance of at least 0.75 and initial reflectance of at least 0.7.

b) The roof is CRRC-1 certified with an initial thermal emittance less than 0.75.

c) The roof is not CRRC-1 certified.

For the first case, the proposed absorptance is calculated from the initial reflectance by the following equation:

$$\alpha_{prop} = 1 – (0.2 + 0.7 [\rho_{Ri,std} – 0.2]$$

$=0.94 - 0.7\rho_{Ri,std}$

For the second case (b), a tradeoff is allowed between initial emittance and reflectance. A higher initial reflectance will compensate for a lower initial emittance. The absorptance calculation in this case requires two steps. First, the initial reflectance of the proposed design is determined by:

$$\rho_{Ri,prop} = -0.448 + 1.121\ \rho_{init} + 0.524\ \varepsilon_{init}$$

Second, the proposed absorptance, $\alpha_{prop,}$ is calculated by the equation above.

The calculated value of $\rho_{Ri,prop}$ must not be larger than the reflectance of the roofing product or less than 0.10. If the proposed design roofing product used has not been certified and labeled according to the requirements of §10-113 and/or does not meet the requirements of §118 (i) 3, the proposed design initial solar reflectance is 0.10 for nonresidential buildings with low-sloped roofs less than or equal to 2:12 ratio, or 0.30 for nonresidential buildings with high-sloped roofs greater than 2:12 ratio, high-rise residential buildings, and guest rooms in hotel/motel buildings.

For the third case, a default value of the initial reflectance is assumed: 0.1 for low-sloped roofs and 0.3 for high-sloped roofs. This results in a roof absorptance of 0.87 and 0.73 for low-sloped and high-sloped roofs, respectively. The higher absorptance for non-CRRC tested roofs is penalizing, since this will result in a higher value for the radiation absorbed and conducted through the roof.

For the windows on each orientation, the actual area, SHGC, overhang factor, and weighting factor are multiplied together. For skylights, the actual area, SHGC, and weighting factor are multiplied. For roofs, the actual area, U-factor, weighting factor, and absorptance value are multiplied. These are summed to obtain the proposed building's heat gain.

Example 3-25

Question

A building located in climate zone 12 has a roof area of 5,000ft^2. Determine the roof absorptance for: (a) CRRC-1 tested product with a reflectance ρ_{init} of 0.7 and emittance ε_{init} of 0.78, (b) a roof that has not been CRRC-1 tested.

Answer

The proposed absorptance is determined from the equation above.

a. α_{prop} = 1 – (0.2 + 0.7 [$\rho_{Ri,init}$ – 0.2]

α_{prop} = 1 – (0.2 + 0.7 [0.7-0.2]) = 0.45

b. For the roof that has not been CRRC-1 certified, the absorptance default value is 0.87. This results in a radiation heat gain that is nearly double the standard absorptance, α_{std} design of 0.45.

Example 3-26

Question

What roof absorptance value should be used in the proposed design for a single ply roofing product labeled with a CRRC-1 tested reflectance ρ_{init} of 0.8 and tested emittance ε_{init} of 0.4?

Answer

From equation the proposed reflectance, $\rho_{Ri,prop}$ = -0.448 + 1.121 ρ_{init} + 0.524 $\varepsilon_{init,}$ Therefore, $\rho_{Ri,prop}$ =
-0.448 + 1.121 * 0.8 + 0.524 * 0.4 = 0.658. Plugging this value into the absorptance equation α_{prop} = 0.94 – 0.7$\rho_{Ri,prop}$ = 0.479. The calculated a absorptance does not meet the standard absorptance of 0.45. The proposed absorptance must be equal to or less than the standard absorptance value.

Example 3-27

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. 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 slope 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 and the U-factor is 1.19. All of the 5 ft high windows are shaded by overhangs with a 4 ft projection, located at 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 both a lower heat loss and a lower heat gain than a standard building that meets the minimum requirements of the prescriptive standards. Heat loss and heat gain are calculated using the equations from §143(b).

Heat loss for the standard building is 53,948 Btu/h-ºF as shown in the calculations below. The U-factors are taken from Standards Table 143-A. The wall U-factor is based on a metal-framed wall.

HLstd = 162,000x0.224 + 50,000x0.076 + 18,000x0.77

HLstd = 53,948 Btu/h-ºF

Heat loss for the proposed building is 35,830 Btu/h-ºF as shown in the calculations below. The wall and roof U-factors (0.080 and 0.029 respectively) are taken from Joint Appendix IV. The window U-factor of 1.19 is taken from the Default Fenestration U-factor values in Standards Table 116-A.

HLprop = 162,000x0.080 + 50,000x0.029 + 18,000x1.19

HLprop = 35,830 Btu/h-ºF

The proposed building has a lower heat loss than the standard building so the building meets the heat loss portion of the requirements. Next, the heat gain must be compared for both the proposed and standard building.

The heat gain for the standard building is 2,983,370 Btu/h as shown in the calculations below. The SHGC criteria for fenestration is 0.61 for all orientations (see Standards Table 143-A).

1. Calculate the conduction Heat Gain for each component. The conduction heat gain of each component is the product A x U x TF (Thermal Factor). The conduction heat gains in Btu/h are listed below

Component	Standard				Proposed			
	A	U	TF	Gain	A	U	TF	Gain
Walls	16,2000	0.224	27	979,776	16,2000	0.08	27	349,920
Roof	50,000	0.076	27	102,600	50,000	0.029	27	39,150
Windows	18,000	0.77	27	374,220	18,000	1.19	27	578,340
Conduction Gain, Btu/h				**1,456,596**				**967,410**

2. Calculate the radiation heat gain through fenestration. First, the overhang factor (OHF) for the proposed building is determined from Table 3-7, with H/V=4/5=0.8. The window wall ratio = 18,000/180,000 = 0.1 or 10%. The values for the standard and proposed design are listed below. The radiation heat gain for each window is the product *WF x A x RSHG x SF* as indicated in the equation in §143(b).

Standard Building	WF	A	RSHG	SF	Gain
North	0.57	5000	0.61	123	213,836
South	1.30	5000	0.61	123	487,696
West	1.17	4000	0.61	123	351,140
East	0.97	4000	0.61	123	291,116
Radiation Subtotal					**1,343,788**

Proposed Building	WF	A	SHGC	OHF	SF	Gain
North	0.57	5000	0.83	0.80	123	232,765
South	1.30	5000	0.83	0.45	123	298,613
West	1.17	4000	0.83	0.49	123	234,113
East	0.97	4000	0.83	0.49	123	194,094
						959,585

3. Next, calculate the heat gain due to radiation absorbed on the roof. The heat gain is calculated by WF x A x U x α x SF (Solar Factor). The roof absorptance for the standard building is 0.45, based on an initial reflectance of 0.7. Since the proposed building does not have a cool roof, the initial reflectance is 0.1 and the absorptance 0.87. The heat gain due to absorbed radiation at the roof can now be calculated.

	WF	A	U	α	SF	HeatGain
Standard	0.87	50000	0.076	0.45	123	**182,987**
Proposed	0.87	50000	0.029	0.87	123	**134,993**

The total heat gain for the standard and proposed building can now be calculated:

	Standard	Proposed
Conduction Gain	1,456,596	967,410
Radiation Gain	1,343,787	959,585
Absorbed Solar Gain	182,987	134,993
Total	**2,983,370**	**2,061,988**

The heat gain for the proposed building of 2,061,988 Btu/h is less than the standard building heat gain of 2,983,370 Btu/h.

Since both the heat gain and heat loss of the proposed building are less than those for the standard building, the proposed building complies using the overall envelope approach.

3.8 Performance Approach

Under the performance approach, the energy use of the building is modeled by a computer program approved by the Energy Commission. The proposed design has to have TDV energy less than 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 computer programs, 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 7.

The following modeling capabilities are required by all approved nonresidential computer programs. 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 thickness, density, specific heat and conductivity.

3.8.2 Opaque Surface Heat Transfer

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

- Surface areas by opaque surface type.
- Surface orientation and slope.
- Thermal conductance of the surface.
- Surface absorptance. Surface absorptance is a restricted input (except for cool roofs).

Surface absorptance and emittance are variable inputs in the proposed design for roofs to provide a 'cool roof credit'. The roof reference design is set with a non-cool roof surface absorptance. 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.

3.8.3 Fenestration Heat Transfer

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

- Fenestration areas.
- Fenestration orientation and slope.
- Fenestration thermal conductance.
- Fenestration solar heat gain coefficient.

3.8.4 Overhangs

Approved computer programs are able to model overhangs. 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.

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.

3.8.6 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 Standards, 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 7 of this manual.

Here are some relevant definitions:

- An addition is a change to an existing building that increases conditioned floor area and volume. See §149(a)1.
- 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.
- 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).

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 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 Measures (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 Approach.

All additions must also comply with §143 (c), Minimum Skylight Area for Large Enclosed Spaces in Low-Rise Buildings.

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 Approach.

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) 1 A and B and are reproduced below. Note that the 2005 Standards include the first-ever requirements related to cool roofs when roofs on existing buildings are replaced [§149 (b) 1 B].

§149 (b) 1 A. Alterations to the building envelope other than those subject to 149 (b) 1 B shall:

i. When there are no changes to fenestration area, meet the requirements of Section 143 (a) for the altered component; or

EXCEPTION to Section 149 (b) 1 A (i): When only a portion of an entire building's fenestration is replaced, or 50 ft^2 or less of fenestration area is added, compliance may be shown with Section 149 (b) A (i) except that the solar heat gain coefficient requirement of Section 143 is not required.

ii. Neither increase the overall heat gain nor increase the overall heat loss of the building envelope.

§149 (b) 1 B. Replacements, recovering or recoating of the exterior surface of existing nonresidential low-sloped roofs shall meet Subsection i or ii where more than 50% of the roof or more than 2,000 square feet of roof, whichever is less, is being replaced, recovered or recoated.

i. The roof shall meet the requirements of either 118 (i) 1 or 118 (i) 2; and for liquid applied roof coatings, Section 118 (i) 3, or

ii. The building envelope, which has a roof replacement subject to this requirement, shall comply with Section 143 (b) 3, where

a. the standard building has a solar reflectance which meets the requirements of Section 143 (a) 1 and the other terms in Equation 143-D correspond to the existing building at the time of the application of the permit, and

b. the proposed building has either:

(1.) The solar reflectance of the replacement roof product, as certified and labeled according to the requirements of Section 10-113 and the roof product meets the requirements of Section 118 (i) 3, or

(2.) A solar reflectance of 0.10 if the product has not been certified and labeled and/or does not meet the requirements of Section 118 (i) 3, and

(3.) Has the other improvements to the building envelope necessary to comply.

EXCEPTION to Section 149 (b) 1 B: Roof recoverings allowed by the CBC are not required to meet Section 149 (b) 1 B when all of the following occur:

1. The existing roof has a rock or gravel surface, and
2. The new roof has a rock or gravel surface, and
3. There is no removal of existing layers of roof coverings of more than 50% of the roof or more than 2,000 square feet of roof, whichever is less; and
4. There is no recoating with a liquid applied coating; and
5. There is no installation of a recover board, rigid insulation or other rigid, smooth substrate to separate and protect the new roof recovering from the existing roof.

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); 3.4.2, Prescriptive Requirements (Cool Roofs); and 3.7 Overall Envelope Approach.

3.10 Compliance Documentation

3.10.1 ENV-1-C: Certificate of Compliance

The ENV-1-C Certificate of Compliance form has two parts. Both parts must appear on the plans (usually near the front of the architectural drawings). A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department 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.

ENV-1-C Part 1 of 2

Project Description

1. PROJECT NAME is the title of the project, as shown on the plans 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. PROJECT ADDRESS is the address of the project as shown on the plans and known to the building department.

4. PRINCIPAL DESIGNER - ENVELOPE is the person responsible for the preparation of the building envelope plans, and who signs the STATEMENT OF COMPLIANCE (see below). The person’s telephone number is given to facilitate response to any questions that arise.

5. DOCUMENTATION AUTHOR is the person who prepared the energy compliance documentation and who signs the STATEMENT OF COMPLIANCE. The person’s telephone number is given to facilitate response to any questions that arise.

6. ENFORCEMENT AGENCY USE is reserved for building department record keeping purposes.

General Information

1. DATE OF PLANS is the last revision date of the plans. If the plans are revised after this date, it may be necessary to re-submit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.

2. BUILDING CONDITIONED FLOOR AREA has specific meaning under the energy Standards. Refer to Section **1.7.15** for a discussion of this definition.

3. CLIMATE ZONE is the official climate zone number where the building is located. Refer to California Climate Zone Description (Joint Appendix II) for a listing of cities and their climate zones.

4. BUILDING TYPE is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the Nonresidential Standards are designated "Nonresidential" here. It is possible for a building to include more than one building type, in which case check all applicable types here. See Section **1.7.15** for the formal definitions of these occupancies.

For relocatable public school buildings, special conditions apply. The relocatable can comply with either a specific climate zone or all climate zones.

If it complies with all climate zones, then the prescriptive requirements in Standards §143(a)8 and Table 143-C apply to the Standard building. If the overall envelope compliance method is used, then one copy of the form ENV-3-C must be completed for each of the 12 orientations and three climate zones (14, 15, and 16, see NRAM Manual appendix ND or Section 3.6, Public School Buildings of this manual), to demonstrate compliance in all climates.

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

- NEW CONSTRUCTION should be checked for all new buildings, newly conditioned space or a stand-alone addition submitted for envelope compliance.
- 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 Section **1.7.12**.
- ALTERATION should be checked for alterations to existing building envelopes. See Section **1.7.11**.
- UNCONDITIONED should be checked when the building is not intended as conditioned space, or when the owner chooses to defer demonstrating envelope compliance until such time as the space conditioning system permit application is submitted. See Section **1.7.8** for a full discussion. The building department 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.

2. METHOD OF COMPLIANCE indicates which method is being used and documented with this submittal:

- COMPONENT for the envelope component method. Form ENV-2-C must be included in the compliance documentation.
- OVERALL ENVELOPE for the overall envelope method. Form ENV-3-C must be included in the compliance documentation.

Statement of Compliance

The Statement of Compliance 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 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; check the appropriate box that describes the signer's eligibility. See **2.3.3** for applicable text from the Business and Professions Code.

Envelope Mandatory Measures

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.

Nonresidential Energy Standards Compliance (Title 24, Part 6, Ch. 1)

Envelope Mandatory Measures

Installed Insulating Material shall have been certified by the manufacturer to comply with the California Quality Standards for Insulating Material.

All Insulating Materials shall be installed in compliance with the flame spread rating and smoke density requirements of Sections 2602 and 707 of the UBC.

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.

Site Constructed Doors, Windows and Skylights shall be caulked between the unit and the building, and shall be weather-stripped (except for unframed glass doors and fire doors).

Manufactured Doors and Windows installed shall have air infiltration rates certified by the manufacturer per §116(a)1. Manufactured fenestration products must be labeled for U-factor according to NFRC procedures.

Demising Wall Insulation (R-13) shall be installed in all opaque portions of framed walls (except doors).

ENV-1-C Part 2 of 2

The information on Part 2 summarizes the information about the building envelope that can be readily verified by the building department field inspector. This form should be included on the plans. Alternatively, the information may be incorporated into construction assembly and glazing schedules on the plans, provided it is complete and in substantially the same format as this form.

Opaque Surfaces

1. SURFACE TYPE - Provide a name or designator for each unique type of opaque surface. 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. CONSTRUCTION TYPE - List the general type of construction for each opaque surface type. The entry should be descriptive, as it is used by the field inspector to distinguish between the various assemblies.

3. AREA - List the gross surface area of the surface type.

4. U-FACTOR - List the U-factor of the surface type from the Joint Appendix IV (e.g. 0.049).

5. AZIMUTH - The plan azimuth is determined by an observer standing outside the building looking at the front elevation. For example, the front of the building is zero degrees, left side of the building is 90°, the right side is 270°, and the back is 180°.

6. TILT – The tilt of an opaque surface is expressed in terms of degrees, 0=horizontal facing up, 90=vertical, 180=horizontal facing down.

7. CONDITION STATUS – Indicate the Opaque Surface Type by entering N for New, E for Existing, or A for Altered.

8. JOINT APPENDIX IV REFERENCE – List the cell table reference for the proposed assembly (e.g., table cell reference is IV.9 C25).The reference number indicates the Joint Appendix IV table number, column and row for the specified assembly and insulation.

9. LOCATION/COMMENTS - Use to provide further description for each surface type. Again, it should be descriptive to assist in locating and inspecting the assembly.

10. NOTE TO FIELD - This column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Example 3-28

Question

A 2x8 wood frame wall with studs 24" o.c. contains R-19 cavity insulation and continuous insulation rated R-5. What is the U-value for this assembly, and what reference is required? What compliance method(s) can be used with this assembly?

Answer

The assembly is found in Joint Appendix IV Table IV.9 for wood frame walls. The U-factor for this insulation level is 0.049, and the table cell reference is IV.9 C25. This U-value is used for the proposed assembly. Since the U-factor is smaller than the prescriptive requirement, either the Component method or Overall Envelope method may be used.

Fenestration Surfaces

If this box is checked, provide an NFRC label certificate or the Energy Commission DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE FORM, FC-1; see Section 3.2.1.

1. FENESTRATION TYPE – Provide a designator for each unique type of window (i.e., metal, vinyl, thermal block window, skylight, clear, tinted, reflective, low-e, etc.) in Column A.

2. AREA - Indicate the total ft^2 of all of the fenestration with the same characteristics in Column B.

3. AZIMUTH - The plan Azimuth is determined by an observer standing outside the building looking at the front elevation. The front of the building is zero degrees, left side of the building is $90^{o,}$ the right side is 270^{o}, and the back is 180^{o}. Enter value in Column D.

4. U-FACTOR - Indicate the maximum U-factor for windows using the Energy Commission's default U-factors (See Section 3.2.5), ACM Manual Appendix NI Default Table 116-A, or the NFRC label certificate. Enter the value in Column E.

5. U-FACTOR TYPE – Enter the U-factor type by entering D for CEC Default Table (see Standards Tables 116-A), A for ACM Manual Appendix Default Table, or N for NFRC Label in Column F.

6. FENESTRATION SHGC - Indicate the maximum SHGC for windows using the Energy Commission's default U-factors (See Section 3.2.5), the center of glass SHGC, or the NFRC label certificate SHGC value and enter the value in Column G.

7. SHGC TYPE - List the solar heat gain coefficient (SHGC) of the fenestration product using D for the Energy Commission's Default Table value (see Standards Tables 116-B), C for the manufacturer's center of glass (SHGCc), use the Alternative Calculation Method for Nonresidential Solar Heat Gain Coefficients (ACM Manual Appendix NI) or N for NFRC and enter type in Column H.

8. CONDITION STATUS – Indicate the Fenestration Surface Type by entering N for New, E for Existing, or A for Altered in Column I.

9. LOCATION/COMMENTS - Use to provide further description for each surface type. It should be descriptive enough to assist in locating and inspecting the fenestration.

10. NOTE TO FIELD - This column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Exterior Shading

(Note that 'fins' apply to performance approach only).

1. FENESTRATION NO. - List the number designation on the plans for the fenestration with exterior shading so the exterior shading can be matched to the appropriate window for the shading value in this row.

2. EXTERIOR SHADE TYPE - List the type of exterior shading, limited to devices permanently attached to the building (e.g., shade screens), or structural components of the building (i.e., overhangs and fins). Manually operable shading devices cannot be modeled.

3. SHGC - List the shading coefficient of the shading device.

4. WINDOW - When the shading type is an overhang, list the height and width (in ft) of the window.

5. OVERHANG - For overhangs being used to achieve compliance with prescriptive envelope requirements, list the dimensions (in ft) of the overhang:

- LENGTH - is the distance (in ft) the overhang projects out from the building façade.
- HEIGHT - is the distance, in ft, from the bottom of the window to the bottom of the overhang. To qualify for credit, the bottom of the overhang must be no more than two vertical ft higher than the top of the window (window head).
- LExt. and RExt. - is the length the overhang extends beyond the window on the left and right sides. Credit for an overhang may be taken only if the overhang extends beyond both sides of the window jamb a distance equal to the overhang length.

Minimum Skylight Area for Large Enclosed Spaces

If this box is checked, form ENV-4-C should be included in the compliance documentation. This requirement applies only if the proposed building contains an enclosed space with floor area greater than 25,000 ft^2, a ceiling height greater than 15 feet and an LPD for general lighting of at least 0.5 W/ft^2.

Notes to Field

This space is for building department use only. It may be used by the plan checker to continue or elaborate on notes elsewhere on the form.

3.10.2 ENV-2-C: Envelope Component Method

ENV-2-C Part 1 of 2

This form (ENV-2-C) should be used only when the envelope is shown to comply using the prescriptive envelope component method.

1. PROJECT NAME is the title of the project as shown on the plans, on the ENV-1-C, 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.

Window Area Calculation

This calculation determines whether the window area for the building exceeds the allowable maximum for the envelope component method.

A. DISPLAY PERIMETER - This is multiplied by 6 FT to determine the DISPLAY AREA for glazing limits.

B. GROSS EXTERIOR WALL AREA -This is multiplied by 0.40 to determine the 40% 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.

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 – Proposed window area divided by gross exterior wall area.

West Orientation Calculation

F. WEST 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% 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 – This is the PROPOSED WEST WINDOW AREA divided by the WEST EXTERIOR WALL AREA.

Skylight Area Calculation

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

A. ATRIUM or SKYLIGHT HEIGHT - distance from the floor to the above in FT.

B. If the height distance from the floor to the above is less than or equal to 55 FT then multiply the GROSS ROOF AREA by 5% (0.05) for the STANDARD ALLOWED SKYLIGHT AREA.

C. If the height distance is greater than 55 FT then multiply GROSS ROOF AREA by 10% (0.10) for the STANDARD ALLOWED SKYLIGHT AREA.

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

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

Skylights

SKYLIGHT 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 - Indicate if the glazing includes a curb or not and if made out of plastic. This affects the allowed U-factor and solar heat gain coefficient.

NO. OF PANES - Indicate “2” for double glazed, “1” for single glazed skylights.

U-FACTOR - PROPOSED skylight glazing U-factor is determined as discussed in Section 3.2.5. ALLOWED U-factor is taken from Standards Tables 143-A, 143-B, or 143-C.

SOLAR HEAT GAIN COEFFICIENT - Indicate PROPOSED solar heat gain coefficient. The 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, 143-B, or 143-C, depending on the building occupancy type.

Relocatable Public Schools Buildings

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

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 can not 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 manufacturer/builder shall meet the requirements for identification labels specified in §143 (a) 8.

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 Nonresidential ACM Manual, Appendix ND, assuming the prescriptive envelope criteria in TABLE 143-C.

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

ENV-2-C Part 2 of 2

Cool Roofs

The mandatory measures require that cool roofs be tested through the Cool Roof Rating Council and labeled that liquid applied products meet minimum standards for performance and durability. Note that installing cool roofs is *not* a mandatory measure.

Check the applicable boxes either Option1: CRRC-1 Tested – Initial Thermal Emittance ≥ 0.75 and Intial Solar Reflectance ≥ 0.70 or Option 2: CRRC-1 Tested - Initial Thermal Emittance < 0.75.

Option1 compares the proposed values against the standard values. The standard values are set by the prescriptive approach. If both the proposed values are below the standard then proceed with the Option 2 method. This method is for any products that have an initial thermal emittance < 0.75. The initial solar reflectance must be calculated given the equation

$\rho_{initial} = .70 + [0.34 X (0.75 - \varepsilon_{initial})]$.

The calculated initial solar reflectance becomes the new calculated standard.

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.

Liquid field applied coatings must meet conditions in either Option1 or Option 2 before selecting coatings. Check the applicable box that matches the applied coating or check the “Other” and enter the name and manufacture of the roof coating. The coating must be applied with a minimum dry mil thickness of 20 mils across the entire roof surface and meet minimum requirements listed in §118(i) 3 and Table 118-C.

Opaque Surfaces

1. ASSEMBLY NAME - Provide a name or designator for each unique type of opaque surface. 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. TYPE - Provide the type of assembly (e.g., wood- or metal-frame wall, other floor/soffit, etc.).

3. HEAT CAPACITY - 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.

4. INSULATION R-VALUE - 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. The PROPOSED value is the R-value for the insulation product alone, not the total R-value for the assembly. The MIN. ALLOWED value is taken from Standards Table 143-A, 143-B, or 143-C.

5. ASSEMBLY U-FACTOR - 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-1-C, Part 2 of 2, Opaque Surfaces. The PROPOSED value is taken from tabulated values in Joint Appendix IV. The table cell reference number (column number and row number for the specified assembly and insulation) from Joint Appendix IV should be listed next to the PROPOSED value. . The MAXIMUM ALLOWED value is taken from Standards Table 143-A, 143-B, or 143-C.

Windows

1. 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.

2. ORIENTATION - Indicate orientation of each unique type of window. A window with an overhang and a similar window without an overhang would be different types. If overhangs are not used, similar windows on non-north orientations may be grouped together.

3. U-FACTOR - PROPOSED glazing U-factor is determined from ENV-1-C Part 2 of 2 Fenestration Surfaces. ALLOWED U-factor is taken from Standards Tables 143-A, 143-B, or 143-C.

4. NO. OF PANES - Indicate “2” for double glazed, “1” for single glazed windows.

5. PROPOSED RSHG – Indicate solar heat gain coefficient (SHGC), overhang factor (OHF), and the resulting RSHG.RSHG = SHGCwin x [1 + aH/V + $b(H/V)^2$]) where

H = horizontal distance from window out to bottom of overhang

V = vertical distance from bottom of window to a plane at the same height as the bottom of lower edge of overhang.

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.

If a given window does not have an overhang, then SHGC and RSHG are the same (See Section 3.2.6).

6. ALLOWED RSHG - 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).

3.10.3 ENV-3-C: Overall Envelope Method

This compliance worksheet should be used only when the envelope is shown to comply using the overall envelope method.

1. PROJECT NAME is the title of the project, as shown on the plans, on the ENV-1-C, 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.

ENV-3-C Part 1 of 7

The first part 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 for the standard envelope.

Window Area Calculation

A. DISPLAY PERIMETER - This is multiplied by 6 FT to determine the DISPLAY AREA for glazing limits.

B. GROSS EXTERIOR WALL AREA -This is multiplied by 0.40 to determine the 40% 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.

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 – Proposed window area divided by gross exterior wall area.

West Orientation Calculation

F. WEST 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% 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 – This is the PROPOSED WEST WINDOW AREA divided by the WEST EXTERIOR WALL AREA.

Combined Values 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.

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.

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

O. If D is greater than C, calculate 1 or 2 below, otherwise place a check mark in the box labeled “Check IF NOT APPICABLE” on the Window area adjustment calculations portion of Part 7.

1. If I is less than H, 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.

2. If I is greater than H, Calculate a. and b. below

a. 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).

b. Divide MAXIMUM STANDARD N/E/S AREA (Box M) by PROPOSED N/E/S AREA and enter result into box for N/E/S WINDOW ADJUSTMENT FACTOR (WAF_{nes}).

The WINDOW ADJUSTMENT FACTOR numbers are carried to Part 7 of the form to calculate the adjusted window and wall areas. Upon completion of those calculations, Part 3, Part 4, and Part 6 may be completed.

ENV-3-C Part 2 of 7 Skylight Area Calculation

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

B. 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% (0.05) for the STANDARD ALLOWED SKYLIGHT AREA.

C. If the height distance is greater than 55 FT then multiply GROSS ROOF AREA by 10% (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.

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

1. If the PROPOSED SKYLIGHT AREA is greater than or equal to the STANDARD SKYLIGHT AREA, then divide STANDARD SKYLIGHT AREA by PROPOSED SKYLIGHT AREA and enter result into box for SKYLIGHT ADJUSTMENT FACTOR. Otherwise enter 1.0 in the box for SKYLIGHT ADJUSTMENT FACTOR, the skylight calculations on Part 3, Part 4, and Part 6 can be done without the adjusted skylight or roof areas.

The SKYLIGHT ADJUSTMENT FACTOR is carried to Part 7 of the form to calculate the adjusted skylight and roof areas. Upon completion of those calculations, Parts 3 through 6 may be completed.

ENV-3-C Part 3 of 7 Overall Heat Loss

This form should be used to confirm that the proposed envelope design has an overall heat loss no greater than the standard heat loss for the building.

Overall Heat Loss

A. ASSEMBLY NAME - Provide a name or designator for each unique type of surface under the appropriate heading (e.g., WALLS, ROOFS/ CEILINGS, etc.). 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. For windows and skylights, list the number of panes of glazing; indicate “2” for double-glazed, “1” for single glazed-windows.

Proposed

B. PROPOSED AREA - Enter the actual area, in ft^2, of each assembly. Refer to Joint Appendix I for definitions by type of assembly.

C. PROPOSED HEAT CAPACITY - See Section 3.3.2 and Joint Appendix IV for discussion of how this value is determined. 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 then the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

D. PROPOSED U-FACTOR - Enter the U-factor of the proposed assembly as designed. U-factors are taken from tabulated values in the Joint Appendix IV. The corresponding table cell reference number from Joint Appendix IV should be listed in the next column. U-factors for windows and skylights are from ENV-1-C Part 2 of 2

Note: For Wet Insulation Systems on exterior roofs in Climate Zones 1and 16, the insulating R-value of continuous insulation materials installed above the roof waterproof membrane must be multiplied by 0.8 before choosing the table column for determining assembly U-factor. See the footnotes for Tables IV.1 through IV.7 in the Joint Appendices.

JOINT APPENDIX IV REFERENCE – List the cell table reference for the proposed assembly (e.g. table cell reference is IV.9 C25).The reference number indicates the Joint Appendix IV table number, column number, and row number for the specified assembly and insulation.

E. PROPOSED UA - The numbers in columns B and D are multiplied together and the result entered in this column.

Standard

F. STANDARD AREA - If no window or skylight area adjustments are required (as demonstrated on Part 1 of 7), then the STANDARD AREA is the same as the PROPOSED AREA for each assembly. If adjustments are required, then the adjusted areas of window, wall, skylight and roof are taken from Part 7 of 7.

G. STANDARD U-FACTOR - Enter the U-factor for each assembly type, taken from Standards Tables 143-A, 143-B, or 143-C.

H. STANDARD UA - The numbers in COLUMNS F and G are multiplied together and the result entered in this column.

COLUMNS E and H are totaled at the bottom of the page and the results compared. If the COLUMN E total is no greater than the COLUMN H total, then the overall heat loss requirement has been met.

ENV-3-C Part 4 of 7 Overall Heat Gain from Conduction

The heat gain subtotals from Parts 4 and 5 are added to the subtotal on Part 6 to determine the total standard building heat gain and proposed building heat gain. Part 4 deals with the conduction heat gain through the building envelope.

A. ASSEMBLY NAME - Provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). 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. For windows and skylights, list the number of panes of glazing; indicate “2” for double-glazed, “1” for single-glazed windows.

Proposed

B. PROPOSED AREA - Enter the actual area, in ft^2, of each assembly.

C. TEMPERATURE FACTOR - Enter the temperature factor based on the envelope type and Climate Zone from Standards Table 143-D.

D. PROPOSED HEAT CAPACITY - See Section 3.3.2 and Joint Appendix IV for discussion of how this value is determined. 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 then the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

E. PROPOSED U-FACTOR - Enter the U-factor of the proposed assembly as designed. U-factors are taken from tabulated values in the Joint Appendix IV. The corresponding table cell reference number from Joint Appendix IV should be listed in the next column. U-factors for windows and skylights are from ENV-1-C Part 2 of 2

Note: For Wet Insulation Systems on exterior roofs in Climate Zones 1and 16, the insulating R-value of continuous insulation materials installed above the roof waterproof membrane shall be multiplied times 0.8 before choosing the table column for determining assembly U-factor. See the footnotes for Tables IV.1 through IV.7 in the Joint Appendices.

JOINT APPENDIX IV REFERENCE – List the cell table reference for the proposed assembly (e.g. table cell reference is IV.9 C25).The reference number indicates the Joint Appendix IV table number, column and row for the specified assembly and insulation.

F. HEAT GAIN - The numbers in COLUMNS B, C, and E are multiplied together and the result entered in this column. The result is a heat gain in Btu/h for that building component.

Standard

G. STANDARD AREA - If no window or skylight area adjustments are required (as demonstrated on Part 1 of 7), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 7 of 7.

H. STANDARD U-FACTOR - Enter the U-factor for each assembly type, taken from Standards Tables 143-A, 143-B, or 143-C of the Standards for the appropriate climate zone.

I. TEMPERATURE FACTOR - Enter the temperature factor based on the envelope type and climate zone from Table 143-D of the Standards (same as C).

J. HEAT GAIN - The numbers in COLUMNS G, H, and I are multiplied together and the result entered in this column.

Columns F and J are totaled. These subtotals are entered under ‘Part 6 Subtotal’ in COLUMNS I and M of ENV-3-C Part 6 of 7.

ENV-3-C Part 5 of 7 Overall Heat Gain from Radiation

This part of the form is used to calculate the heat gain due to solar radiation absorbed by the roof for the standard and proposed building envelopes.

Roof Absorptance Calculation

This section determines the roof absorption value for the proposed building. A cool roof certified by the CRRC-1 rating procedure is now required for low-sloped nonresidential buildings.

Case 1 Proposed

1. CRRC-1 Certified? Select *Yes* if the proposed roof has been certified and go to step 2, or if you selected *No* then go to step 8.

2. Is the initial thermal emittance ≥0.75? If yes then go to step 3, or if *No* then go to step 5.

3. Enter the initial reflectance value from CRRC then go to step 4 and insert the value in the equation and calculate.

4. Calculate the proposed absorption and enter the result in Column F.

Case 2 CRRC-1 Tested – Proposed

5. Enter the CRRC initial reflectance and emittance values, go to step 6, enter the values in the equation, and calculate the proposed reflectance.

6. Calculate the proposed reflectance, go to step 7, and enter the value into equation and calculate.

7. Calculate the proposed absorption and enter the results in Column F.

Case 3 Not CRRC-1 Tested – Proposed Default

8. Is the roof a nonresidential low-slope? If yes, the proposed default absorption value is 0.87; if not use 0.73. Enter the value in Column F.

Standard Absorptance Values

When tested in accordance with CRRC-1 - The standard absorptance values α_{std} for Column J are either 0.45 for nonresidential low-sloped roofs or 0.73 for nonresidential high-sloped roofs. The standard absorptance is based on the initial solar reflectance of 0.70 for nonresidential low-sloped roofs and 0.30 for nonresidential high-sloped roofs. See Standards Equation 143-D.

Overall Heat Gain Radiation for Roofs

A. ASSEMBLY NAME - Provide a name or designator for each unique type of roof surface (e.g., Roof-1, Roof-2, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. AREA - Enter the actual area, in ft^2, of each assembly.

C. SOLAR FACTOR - Enter the solar factor for the applicable climate zone from Table 143-D of the Standards.

D. WEIGHTING FACTOR - Enter the appropriate weighting factor based on climate zone and Nonresidential or High-Rise Residential from Standards Table 143-E.

E. PROPOSED U-FACTOR - Enter the U-factor of the proposed assembly as designed. U-factors are taken from a table in Joint Appendix IV, Roofs and Ceiling.

F. PROPOSED ABSORPTANCE (α)- Enter the absorptance of the proposed roof assembly. Use an absorptance from item 8 above for roofs not certified under CRRC-1.

G. PROPOSED HEAT GAIN - The numbers from COLUMNS B, C, D, E, and F are multiplied and entered in this column.

H. AREA (ADJUSTED) - If no skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each roof assembly. If adjustments are required, then the adjusted areas of skylight and roof are taken from Part 6 of 7.

I. STANDARD U-FACTOR - Enter the standard U-factor for each roof assembly, taken from Standards Tables 143-A, 143-B, or 143-C.

J. STANDARD ABSORPTANCE (α) - Enter 0.45 as the absorptance of the standard roof assembly for nonresidential buildings with low-sloped roofs and 0.73 for nonresidential buildings with high-sloped roofs, for high-rise residential buildings, and guest rooms of hotel/motel buildings.

K. STANDARD HEAT GAIN - Multiply COLUMNS C, D, H, I and J and enter the result here.

Columns G and K are totaled. These subtotals are entered under 'Part 5 Subtotal' in COLUMNS I and M of ENV-3-C, Part 6 of 7.

ENV-3-C Part 6 of 7 Overall Heat Gain from Radiation

Overall Heat Gain from Fenestration

This form should be used to calculate the radiation heat gain through fenestration for the standard building and proposed building.

A. WINDOW/SKYLIGHT NAME - Provide a name or designator for each orientation of glazing under the appropriate heading (NORTH, SOUTH, SKYLIGHTS, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. WEIGHTING FACTOR - Enter the weighting factor for each orientation and skylight. The weighting factors are taken from Table 143-E for the appropriate climate zone

C. PROPOSED AREA - The total area of proposed windows and skylights shown on the plans is entered here.

D. SOLAR FACTOR - Enter the solar factor for the applicable climate zone from Standards Table 143-D.

E. PROPOSED SHGC - The proposed solar heat gain coefficient of the glazing.

F.-H. PROPOSED OVERHANG - Indicate the overhang horizontal length (H), the overhang vertical height (V), overhang ratio (H/V) and overhang factor (OHF). Column F includes both (H for horizontal) and (V for vertical). The overhang adjustment does not apply to skylights. Note: if there is no overhang for the window, values for H and V are not required and the OHF is set to 1.

I. PROPOSED TOTAL - Multiply COLUMNS B, C, D, E & H and enter the result here.

J. STANDARD AREA - If no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 6.

K. STANDARD RSHG - This is the maximum relative solar heat gain taken from Standards Tables 143-A, 143-B, and 143-C for the specified window orientation (north or non-north) and the actual fenestration area if actual is less than 40% WWR; otherwise it is set to the RSHG for 40% WWR. The maximum relative solar heat gain coefficient for skylights is taken from the same table, depending on whether the skylight glazing is made of glass or plastic.

L. SOLAR FACTOR - Enter the solar factor for the applicable climate zone from Standards Table 143-D.

M. STANDARD TOTAL - Multiply COLUMNS B, J, K, & L and enter the result here.

COLUMNS I and M are totaled. Totals from COLUMNS F and J from Part 4 of 7 and Part 5 of 7 are carried forward and added to Part 6 and the results compared. If the COLUMN I total is no greater than the COLUMN M total, then the overall heat gain requirement has been met.

ENV-3-C Part 7 of 7 Window Area Adjustment Calculations

If the WINDOW AREA TEST or the SKYLIGHT AREA TEST (Part 1 and 2 of this form) determines that area adjustments are not necessary, check the NOT APPLICABLE boxes. If the tests indicate that adjustments must be made, perform the calculations in the appropriate sections below.

A. 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.

B.-D. AREAS - List the areas (in ft^2). 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 is calculated on the top half of Part 1. This is taken from Part 1 of the ENV-3-C 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 COLUMN F and G are used in COLUMN F of the Overall Heat Loss calculation (Part 3) and Column G of the Overall Heat Gain from Conduction calculation (Part 4) and the values in COLUMN G are used in COLUMNS H of the Overall Heat Gain from Radiation, Opaque Surfaces calculation (Part 5), and values in COLUMN F are used in COLUMN J of the Overall Heat Gain from Radiation, Fenestration Surfaces calculation (Part 6).

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 ft^2). 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 is the skylight adjustment factor calculated on Part 2. 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 totals in COLUMNS E and F are used in COLUMN F of the Overall Heat Loss calculation (Part 3) and in COLUMN G of the Overall Heat Gain from Conduction calculation (Part 4), and values in COLUMN F are used in COLUMN H of the Overall Heat Gain from Radiation, Opaque Surfaces calculation (Part 5), and values in COLUMN E are used in COLUMN J of the Overall Heat Gain from Radiation, Fenestration Surfaces calculation (Part 6).

3.10.4 ENV-4-C Minimum Skylight Area for Large Enclosed Spaces

This form must be filled out if the building contains an enclosed space with a floor area greater than 25,000 ft^2, a ceiling height of greater than 15 feet and an LPD of equal or greater to 0.5 W/ft^2.

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-E of this worksheet. To determine the minimum area based on minimum effective aperture area, fill in steps F-N 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-4-C Part 1 of 2

Minimum Fraction of Daylit Area Method

A. PROPOSED DAYLIT AREA - Enter the proposed daylit area as indicated on the plans schedule and enter the relevant page number of the plans.

B. MINIMUM DAYLIT AREA - Enter the result of the enclosed floor area and multiply by 0.50..

Checks the box if Criteria 1, “Proposed Daylit Area is equal to or greater than Minimum Daylit Area,” is met; otherwise, go to the next criteria section.

C. SKYLIGHT-DAYLIT FRACTION – Select one of the boxes corresponding to the proposed installed LPD of the enclosed space and enter the resulting percentage in the box on the right.

D. MINIMUM SKYLIGHT AREA – The product of B and C is the minimum skylight area to daylit area.

E. PROPOSED SKYLIGHT AREA – Enter the proposed total skylight area in the large enclosed space that matches the plans and include the page from the plans.

Check the box if Criteria 2, ”Proposed skylight area is equal to or greater than minimum skylight area,” is met; otherwise go to next criteria section.

Check the box if Criteria 3, ” Haze rating of skylight glazing or skylight diffuser is greater than 90%,” is met and enter the document and page number with “haze” specification of skylights. Otherwise go to the next criteria section.

Check the box if the large enclosed space complies with Criteria 1, 2, and 3 above.

ENV-4-C Part 2 of 2

Minimum Effective Aperture Ratio

F. PROPOSED DAYLIT AREA - Enter the proposed daylit area as indicated on the plans schedule and enter the relevant page number of the plans.

G. MINIMUM DAYLIT AREA - Enter the large enclosed floor area and multiply by 0.50.

Checks the box if Criteria 1, “Proposed Daylit Area is equal to or greater than Minimum Daylit Area,” is met; otherwise go to next criteria section.

H. MINIMUM EFFECTIVE APERTURE – Select one of the boxes corresponding to the proposed installed LPD of the enclosed space and enter the resulting percentage in the box on the right.

I. SKYLIGHT VISIBLE TRANSMITTANCE (VLT) – Enter the VLT value in this box from manufacturer’s literature.

J. CALCULATE THE WELL CAVITY RATIO – 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.

K. 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).

L. WELL EFFICIENCY – This is determined from the nomograph in Figure 146-A in the Standards. See Chapter 5, Section 5.6 of this manual. Average skylight well wall reflectance and WCR are required.

M. MINIMUM SKYLIGHT AREA – Follow the equation listed on the form to calculate the minimum skylight area by minimum effective aperture.

N. PROPOSED SKYLIGHT AREA – Enter the proposed skylight area in this box. The proposed area must exceed the minimum requirement specified in field D or field E of Part 1 of 2 of this form.

Check the box if Criteria 2, "Proposed skylight area is equal to or greater than minimum skylight area," is met; otherwise go to the next criteria section.

Check the box if Criteria 3, "Haze rating of skylight glazing or skylight diffuser is greater than 90%." Enter the document and page number with haze specification of skylights. Otherwise go to the next criteria section.

Check the box if the large enclosed space complies with Criteria 1, 2, and 3 above (Section 143(c), items 1-3).