



ENERGY CODE COMPLIANCE

First Edition

A Guide for Metal
Building Contractors



1st Edition

***Energy Code Compliance:
A Guide for Metal Building Contractors***



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Cleveland, Ohio 44115

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PREFACE

The MBMA *Energy Code Compliance: A Guide for Metal Building Contractors* is a synthesis of all of the pertinent information on how to design, construct, and maintain metal buildings to be energy efficient.

Most municipalities in the United States have adopted an energy code. This guide is a resource for informing building owners, architects, specifiers, contractors, builders, and metal building manufacturers about the compliance options for satisfying the building envelope provisions of these energy codes.

The use of this guide is totally voluntary. Each building manufacturer or architect and/or engineer retains the prerogative to choose its own design and commercial practices and the responsibility to design its building systems to comply with applicable specifications and contract documents.

Although every effort has been made to present accurate and sound engineering and design information, MBMA assumes no responsibility whatsoever for the application of this information to the design or construction of any specific building system.

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Abbreviations and Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	IBC	International Building Code
ASTM	American Society for Testing and Materials	ICC	International Code Council
Btu	British thermal unit	IECC	International Energy Conservation Code
Btu/h	British thermal unit per hour	LS	Liner System
cfm	cubic feet per minute	MBMA	Metal Building Manufacturers Association
ci	continuous insulation	MBS	Metal Building Systems
CRRC	Cool Roof Rating Council	NAIMA	North American Insulation Manufacturers Association
CZ	Climate Zone	NFRC	National Fenestration Rating Council
DOE	U.S. Department of Energy	psf	pounds per square foot
EIA	Energy Information Administration	PV	Photovoltaic
EIFS	exterior insulation finishing system	R	thermal resistance
F	Fahrenheit	SHGC	solar heat gain coefficient, dimensionless
FC	Filled Cavity	Solar Reflectance	Solar Reflectance
ft	foot	SR	Solar Reflectance Index
ft²	square foot	SSR	standing seam roof Thermal Emittance
ft³	cubic foot	TE	through fastened roof
Guide	Energy Design Guide for Metal Building Systems	TFR	thermal transmittance
h	Hour	U	Underwriters Laboratories Inc.
h x ft² x °F/Btu	hour square foot degree Fahrenheit per British thermal unit	UL	Visible Light Transmittance
HVAC	Heating, Ventilation and Air Conditioning	VLT	Visible Transmittance
		VT	Visible Transmittance

Chapter 1 Design Responsibilities – Building and Energy Codes

The building contractor is responsible for conveying the requirements for and compliance with any pertinent local codes based on the approved set of construction documents.

This would include the required structural design codes and loads. The architect and/or engineer will identify all applicable building codes, energy codes, zoning codes, or other regulations suitable to the construction project, including the metal building system.

While not a recommended practice, if the end customer does not retain an architect or engineer of record, it is the responsibility of the end customer to specify the design criteria to be used for the metal building system including all applicable design loads. The contractor works with the end customer to obtain order and specifications in order to erect the metal building system, as specified by the contract documents.

The building contractor is responsible for interpreting all aspects of the end customer's specifications and incorporating the appropriate specifications, design criteria, and design loads into the order documents submitted to the manufacturer. The building contractor is defined as the party that orders and purchases the metal building system from the manufacturer for resale. The building contractor is an independent contractor and is not an agent for the manufacturer.

Since many non-structural building components play a significant role in energy efficiency and energy code compliance, the overall building envelope design must include any performance criteria that are required in order to comply with energy codes. The building contractor generally supplies the building insulation as specified by the owner's design professional.

It is the responsibility of the end customer, architect, engineer or mechanical contractor to design, specify and assure that adequate provisions are made for ventilation, heating, air conditioning, condensation, insulation, and the lighting or daylighting necessary to meet any energy codes or energy conservation requirements.

It is important for the end customer, architect, and mechanical contractor to consider all of these items that impact energy consumption to achieve the best overall cost-effective goal of reducing energy consumption. Focusing on only one or two design aspects without regards to the others can lead to an inefficient and more costly building solution.

Chapter 2 Energy Code Fundamentals

In the United States, the International Code Council's International Energy Conservation Code (IECC) and ASHRAE Standard 90.1 *Energy Standard for Buildings Except Low-Rise Residential Construction* are the most common energy code and energy standard adopted by states or jurisdictions with state modifications. Some states do develop their own energy code, such as California for example.

2.1 Commercial Energy Code Adoption Status

The level of building energy code stringency, adoption and enforcement varies across the United States. The Department of Energy (DOE) provides the status of energy codes and standards adopted across the United States, as well as a drop-down list menu to view the energy code details for a particular state at www.energycodes.gov/status-state-energy-code-adoption. The Building Codes Assistance Project, <http://bcapcodes.org/> is another resource for this information. For the purposes of this chapter, we will focus on the 2009, 2012, and 2015 IECC and its referenced ASHRAE 90.1 energy standards.

The IECC and ASHRAE Standard 90.1 provides provisions for building envelope, HVAC, service water heating, power, lighting and appliances. This contractor's resource guide will focus solely on describing the building envelope provisions and how this might apply to metal building systems.

2.2 Energy Code Compliance

The IECC is the national model energy code that is often adopted as the state or jurisdictional energy code. For typical commercial projects, the IECC will be the basis for code compliance. This is primarily due to the wide acceptance and familiarity of the International codes within the building code community and because the IECC is written in enforceable code language that is consistent and coordinated with the other building and residential adopted codes.

The IECC is a relatively short and straightforward code. It is able to accomplish its brevity by referencing ASHRAE Standard 90.1 as an alternative compliance path for buildings that are unusual or if the architect and/or engineer desires to pursue trade-offs between different building components. Various versions of the IECC references specific editions of ASHRAE Standard 90.1 as summarized in [Table 2.2-1](#). There are no constraints for an architect and/or engineer when choosing one document over the other, unless the jurisdiction so states, so either is acceptable for

Table 2.2-1: ASHRAE Standard 90.1 MB Insulation Assembly References

IECC	ASHRAE 90.1
2009 IECC	ASHRAE 90.1-2007
2012 IECC	ASHRAE 90.1-2010
2015 IECC	ASHRAE 90.1-2013

showing compliance regardless of the building complexity. The contractor should check with the local jurisdiction. It is important to note that when the architect and/or engineer selects either document, the user is not permitted to “mix and match” criteria within the same project. The intention of providing the alternate compliance path is that the entire project must show compliance to the provisions of either document. More recent editions of the IECC make it clearer that the architect and/or engineer cannot choose the least stringent parts of the two documents to create a hybrid design. In addition, many jurisdictions allow the use of *COMcheck* to demonstrate compliance. *COMcheck* is a commercial building code software tool that provides a method for verifying a building meets the energy code provisions, which is discussed in Chapter 6.

Energy codes include mandatory requirements which must be met, along with compliance options such as the prescriptive method, envelope trade-off method and the energy cost budget method.

2.2.1 Prescriptive Building Envelope Option

The prescriptive method is the easiest to comply with for a metal building system, as it is not necessary to know what mechanical systems or lighting is going to be used in order to provide a building envelope that is insulated to the prescriptive requirements. However, the prescriptive method may not be the most cost-effective method, because trade-offs are not permitted, and the prescriptive requirements may have to be exceeded due to available products or assemblies. In effect, all of the envelope components and building systems must individually exceed the prescriptive requirements when in fact a less costly compliance path is probably available when looking at the overall performance of the building. However, prescriptive simply is not an option due to overriding structural issues, like purlin spaces closer than allowed.

2.2.2 Building Envelope Trade-Off Option

The building envelope trade-off approach provides much greater flexibility to the architect and/or engineer over a prescriptive method, but only applies to the envelope components of the building. This method also allows the use of certain components that, by themselves, may not comply with the prescriptive requirements. This is allowed because other components of the building envelope would need to have higher performance levels, and the resulting building performs the same or better than the one designed using the prescriptive approach for each component. This may provide the best compliance option for a metal building system, because it permits the flexibility to trade off envelope components.

2.2.3 Energy Cost Budget Method (ASHRAE Standard 90.1)

The energy cost budget (ECB) method is a more rigorous analysis, performed with the assistance of a computer model usually approved by either the energy standard or the

authority having jurisdiction. It is the only method that evaluates the theoretical expected energy consumption of a proposed building versus a building that satisfies the minimum requirements.

A performance method offers the most design flexibility and gives the architect and/or engineer an energy budget that is not to be exceeded for the sum of the building's components and systems. With this approach, the architect and/or engineer has complete control over the entire building, including mechanical systems, lighting and the building envelope. This more sophisticated analysis will usually require an energy consultant to be retained to compare all of the various scenarios, but it will likely result in the best overall optimization of the systems that affect energy consumption for a project.

This is the only compliance method that allows for trade-offs between mechanical and lighting systems and the building envelope. For example, it may be more cost effective to include daylighting plus light controls and more efficient HVAC systems than to provide more insulation in the building envelope. However, for a typical project utilizing a metal building system, the decisions on insulating the envelope may have to be made prior to the mechanical and lighting design.

2.3 Building Envelope Applicable Requirements

The building envelope applicable requirements depend on the spaces that are heated and cooled within the building and on the geographic location (climate zone). The interior surface can also be included in the building envelope requirements if it separates a conditioned space from an unconditioned space or encloses a semiheated space. [Figure 2.3-1](#) from ASHRAE Standard 90.1, illustrates different conditioned spaces within a building.

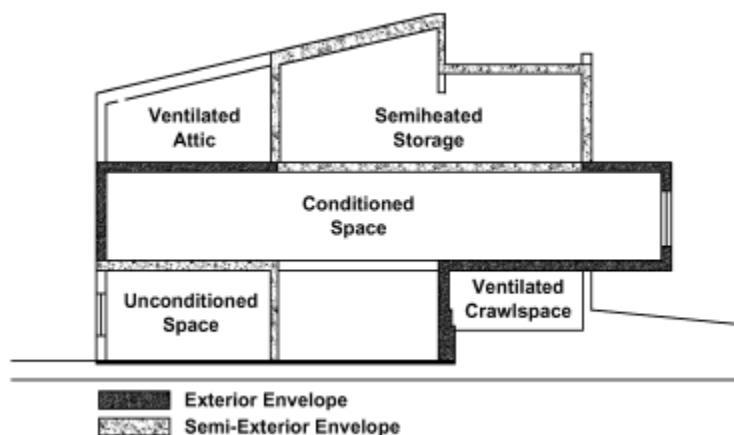


Figure 2.3-1: ASHRAE Standard 90.1-2013

©ASHRAE, www.ashrae.org. 2013 ASHRAE Standard 90.1

2.3.1 Space Conditioning Categories

The building envelope requirements apply provisions for various space conditioning types, which are not defined quite the same in the IECC and ASHRAE Standard 90.1.

2.3.1.1 IECC Space Conditioning Types

The IECC defines a space as either a conditioned space or low energy space.

- Conditioned Space - Area or room within a building being heated or cooled greater than or equal to 3.4 Btu/hr/ft² of floor area.
- Low Energy Building - A building, or portions thereof, that are not considered a conditioned space and that has a peak design rate of energy usage less than 3.4 Btu/hr/ft² of floor area. A low-energy building or portions thereof is exempt from the building thermal envelope provisions.

2.3.1.2 ASHRAE Standard 90.1 Space Conditioning Types

ASHRAE Standard 90.1 defines a space as conditioned, semiheated or unconditioned.

- Conditioned Space - a cooled spaced or heated space as defined further below:
 - Cooled Space - an enclosed space within a building that is cooled by a cooling system whose sensible output capacity exceeds 5 Btu/hr/ft² of floor area.
 - Heated Space - an enclosed space within a building that is heated by a heating system whose output capacity relative to the floor area is greater than or equal to the criteria in [Table 2.3-1](#).

- Note, ASHRAE Standard 90.1-2013, Addendum *a*, modifies the heated space criteria to be more stringent (see [Table 2.3-2](#)), thereby incorporating more buildings in the conditioned space category. A municipality has the option to adopt addenda or simply refer to the full-published version of the standard.

Heating Output, Btu/hr/ft ²	Climate Zone
5	1 and 2
10	3
15	4 and 5
20	6 and 7
25	8

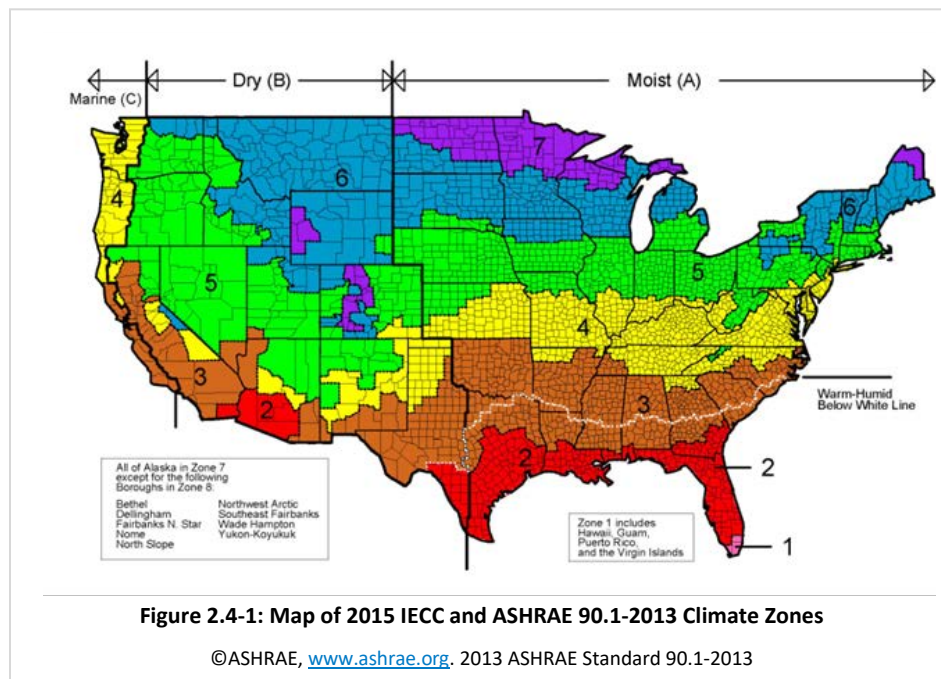
- Semiheated Space - an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/hr/ft² of floor area but is not a conditioned space.
- Unconditioned Space - an enclosed space within a building that is not a conditioned space or a semiheated space. This is similar to the IECC's low-energy building and is therefore exempt from the building thermal envelope provisions. However, there are insulation requirements when the common wall or ceiling is between an unconditioned space and a conditioned space, as specified in ASHRAE Standard 90.1 Section 5.5.2.

Table 2.3-2: ASHRAE Standard 90.1 Heated Space Criteria - Addendum a - 90.1-2013

Climate Zone	Heating Output, Btu/hr/ft ²
1	>5
2	>5
3A, 3B	>9
3C	>7
4A, 4B	>10
4C	>8
5	>12
6	>14
7	>16
8	>19

2.4 Climate Zones

Most of the building envelope requirements can vary by climate zone. Both the IECC and ASHRAE Standard 90.1 use the same climate zone map, as shown in [Figure 2.4-1](#). For ease of enforcement, these climate zones are segmented by county. Thus, all buildings in a given county will have the same requirements. The IECC and ASHRAE Standard 90.1 provide a table of county listings with the assigned climate zone. However, be aware that the jurisdiction adopting or modifying these energy codes may specifically define what climate zone(s) the jurisdiction is subject to as part of their adopted code.



The climate zones range from Climate Zone 1 (hot) through Climate Zone 8 (very cold). These climate zones also have a letter designation A, B and C, where A is moist (humidity levels may be higher), B is dry, and C is marine (moderate temperatures with a summer dry season).

2.4.1 Opaque Envelope Surfaces

For the opaque envelope surfaces, i.e., walls and roofs, energy codes have insulation requirements that are based on space conditioning type and construction type, one of which includes metal building roof and walls. The insulation requirements are defined in terms of “R-value” for the minimum insulation or as a U-factor, which is representative of the envelope assembly. Additional requirements for the opaque envelope surfaces may include the type of roof installed in the warmer climate zones, such as cool roof provisions as described below.

2.4.1.1 R-value and U-factor Defined

Thermal resistance (R) is a measure of a material's ability to impede heat flow. Thermal resistance is often expressed using the term “R-value.” Most insulation materials make use of “dead air” spaces within the material to maximize R-value. The effectiveness of dead air spaces in impeding heat flow is dependent upon temperature. Therefore, R-value should be measured at a standard temperature. The Federal Trade Commission established guidelines in 1976 that set the standard comparison temperature to 75°F.

Thermal transmittance (U) is the total rate that heat will flow through a given “assembly” as opposed to a single insulating material. An assembly may consist of many components that have differing levels of thermal conductance and includes the effects of dead air spaces and surface air film resistances. Thermal transmittance is often expressed using the term “U-factor.” Determining an assembly U-factor can be accomplished by testing the constructed assembly in a hot box apparatus, as defined by ASTM C 1363, *Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus* (ASTM, 2011).

U-factors can also be estimated through finite element computer modeling, by calculation methods or a combination of these. ASHRAE Standard 90.1-2013 includes U-factor calculation methods for single and double layer systems. In the future, ASHRAE Standard 90.1 will incorporate calculation methods for filled cavity and liner type system. These insulation systems and others are defined below.

2.4.1.2 Metal Building Insulation Assemblies

Common metal building roof and wall insulation assemblies listed in the energy codes are noted as one of the following: single layer, double layer, filled cavity (FC) and liner system (LS). Continuous insulation (ci) may be used independently or in combination with any one of the listed insulation assemblies noted above. The prescriptive opaque R-

value table lists specific insulation assemblies that are assumed to meet the prescribed U-factor of a metal building roof or wall with a footnote that references the metal building roof and wall insulation descriptions noted in ASHRAE Standard 90.1, Normative Appendix A, Sections A2.3 or A3.2. [Table 2.4-1](#) below summarizes the insulation descriptions out of the 2007, 2010 and 2013 versions of ASHRAE Standard 90.1. However, each version of the standard refines the definition of the assemblies along with noting the position of each layer of insulation.

Table 2.4-1: Metal Building Insulation Descriptions

Roofs	Description (adapted from ASHRAE Standard 90.1-2007, 2010 & 2013, Section A2.3)
Single Layer ^{a,b}	Standing seam roof with single layer of faced fiber glass insulation batts draped perpendicular over the purlins. A thermal spacer block is placed above the purlin/batt and the roof deck is secured to the purlins.
Double Layer ^{a,b}	Standing seam roof with two layers of fiber glass insulation layers. The first R-value is for faced fiber glass insulation batts draped over the purlins. The second R-value is for unfaced fiber glass insulation batts installed parallel to the purlins. A thermal spacer block is placed above the purlin/batt and the roof deck is secured to the purlins.
Filled Cavity ^c (FC)	Standing seam with filled cavity fiber glass insulation. The first rated R-value of insulation represents faced or unfaced insulation installed between the purlins. The second rated R-value of insulation represents unfaced insulation installed above the first layer, perpendicular to the purlins and compressed when the metal roof panels are attached. A supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of insulation. A minimum R-5 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.
Liner System ^c (LS)	Standing seam roof with liner system fiber glass insulation. A continuous membrane is installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins. For multilayer installation, the last rated R-value of insulation is for unfaced insulation draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required unless compliance is shown by the overall assembly U-factor.
Continuous Insulation (ci)	Continuous Insulation. For assemblies with continuous insulation the continuous insulation is installed above or below the purlins, uncompressed and uninterrupted by framing members.
Walls	Description (adapted from ASHRAE Standard 90.1-2007, 2010 & 2013, Section A3.2)
Single Layer	Single layer of faced fiber glass batt insulation compressed between the metal wall panels and the girt.
Double Layer	Double layer of fiber glass batt insulation. The first rated R-value of unfaced fiber glass insulation is compressed between the metal wall panels and the girt. The second rated R-value of faced fiber glass insulation is installed from the inside and covers the girts.
Continuous Insulation (ci)	For assemblies with continuous insulation, the continuous insulation is installed on the outside or inside the girts, uncompressed and uninterrupted by the framing members.

- a. Single and double layer systems: Minimum Thermal Spacer Block R-value: R-5 (2009 IECC, 2012 IECC, ASHRAE Standard 90.1-2007), R- 3.5 (2015 IECC, ASHRAE Standard 90.1-2010), R-3 (ASHRAE Standard 90.1-2013).
- b. ASHRAE Standard 90.1-2013 further defines the standing seam roof clip to provide a minimum 1.5-inch distance between the top of the purlins and the underside of the metal roof panels.
- c. FC - Filled cavity system: Minimum Thermal Spacer Block R-value: R-3.5 (2009 IECC, 2012 IECC, ASHRAE Standard 90.1-2007, ASHRAE Standard 90.1-2010), R-5 (2015 IECC, ASHRAE Standard 90.1-2013).

2.4.1.3 Cool Roof Provisions

Cool roof provisions were incorporated in the energy codes first in ASHRAE Standard 90.1-2007 edition then in the 2012 IECC edition. Since that time, these provisions have evolved as new editions of ASHRAE Standard 90.1 and the IECC were published.

Cool roof performance is a function of two radiative properties: solar reflectance and thermal emittance, as shown in [Figure 2.4-2](#). These two properties define how “cool” a roof product is. Both properties are part of the energy balance at the roof surface. The sun’s energy strikes a roof surface with ultraviolet, visible and infrared energy. In turn, the roof reflects or absorbs and reemits this energy depending upon how the energy is spread across the spectrum.

Solar reflectance is the number reported for solar reflectance for a roof product is a decimal number less than one that represents the fraction of the total solar energy that is reflected off the roof. For example, “high” reflectance materials, such as white painted metal roofing, have values of around 0.70, or 70 percent. That is, the roof absorbs only 30 percent of the energy from the sun.

Thermal emittance is a decimal number less than one that represents the fraction of heat energy that is re-radiated in the near infrared energy spectrum from a material to its surroundings. The greater emissivity value, the greater the ability of a surface to cool itself through radiative heat loss. For example, low emittance products such as unpainted Galvalume™, have values around 0.10.

These parameters are determined primarily by test and are critical measurements for municipalities that are concerned with the phenomenon known as the “urban heat island” effect. They also impact the energy performance of a building, although how and to what extent varies greatly by construction, occupancy and climate.

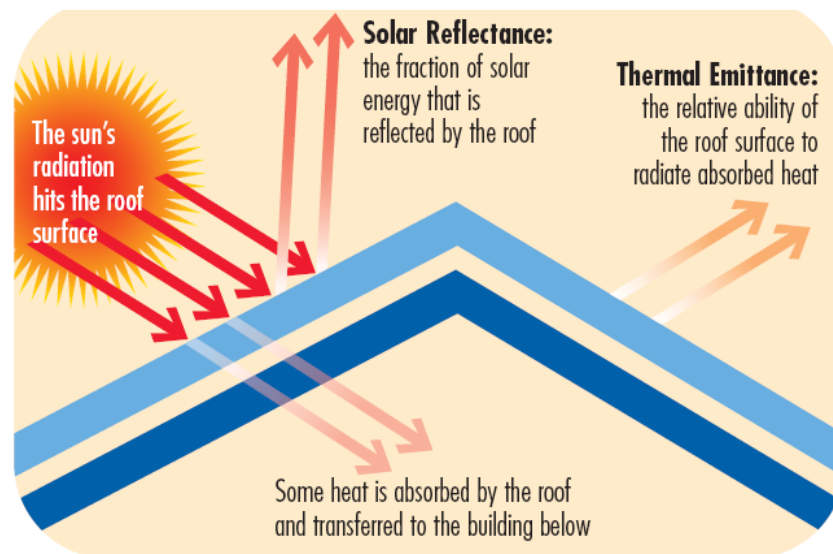


Figure 2.4-2: Solar Reflectance and Thermal Emittance Concept (Source: CRRC)

It is also important to understand how these parameters change over time. Therefore, some standards require that Solar Reflectance and Thermal Emittance be tested after exposure to the outdoor elements for a certain period of time. This exposure is generally done in multiple locations for three years, then the specimens are collected, and the test results averaged. The resulting values are generally referred to as “Aged” values.

Another method used to define a cool roof is the solar reflectance index (SRI). SRI is a method to obtain an index for relative surface temperature with respect to a standard white (SRI = 100) and a standard black (SRI = 0) under standard solar, ambient conditions and wind speed. The SRI calculation is based on the measured reflectance and emittance. Some codes provide an alternate SRI requirement for defining a cool roof if that is preferred over using individual requirements for reflectance and emittance. SRI values may be aged or initial depending upon the input values.

2.4.1.3.1 Cool Roof Rating Council

The Cool Roof Rating Council (CRRC) was established in 1998 as an independent nonprofit educational organization of manufacturers, government institutions, laboratories, regulatory agencies, trade associations and utilities that has established accurate and credible methods for evaluating and labeling the initial and aged solar reflectance and thermal emittance (radiative properties) of roofing products and to disseminate the information to all interested parties.

The centerpiece of the CRRC is the Product Rating Program (CRRC-1). It includes:

- Licensed Sellers who are roofing product manufacturers who obtain official ratings through the CRRC for various roof products
- Independent (AITL) and Participating Manufacturing (AMTL) Accredited Testing Laboratories that report Solar Reflectance and Thermal Emittance values according to CRRC-approved ASTM test methods
- A recognizable trademarked label for communicating radiative property data to all end-users
- A random sampling program to monitor ongoing field compliance with Label claims.

For the three-year aged ratings, product samples are exposed for three years at CRRC Approved Test Farms. The results are published in the CRRC Rated Product Directory, which is available to the public at no cost at <http://www.coolroofs.org>. The directory can be searched by material type, manufacturing company, radiative properties and slope. There are over 1,000 roofing products listed in the Directory, with over 140 being metal roofing. There are a growing number of code bodies, standards and green building rating systems requiring cool roofs or referencing the CRRC’s Product Rating Program.

The MBMA has been an active member in the CRRC since its founding and has worked with the CRRC through the Cool Metal Roofing Coalition. Metal Building Manufacturers can supply roof systems in a wide range of profiles and supplied in thousands of colors. Rating each material would be onerous, as well as prohibitively expensive. As a result, the CRRC adopted the Color Family Program which is a pre-defined range of Hunter “L,” “a,” and “b” color values that establishes the color space for a CRRC predefined set of seventeen (17) colors, as shown in [Figure 2.4-3](#).

	Color Family	Hunter “L” range	Hunter “a” range	Hunter “b” range	Default SR	Default TE
1	Red	17 to 29	+7 to +36	0 to +15	0.25	0.83
2	Terra Cotta	20 to 38	+15 to +30	+6 to +16	0.35	0.83
3	Bright Red	23 to 38	+35 to +49	+10 to +48	0.35	0.83
4	Beige/Off-White	59 to 86	-5 to +5	-3 to +23	0.55	0.83
5	Tan	51 to 86	-2 to +7	+6 to +21	0.45	0.83
6	Dark Blue	13 to 33	-7 to +6	-25 to -2	0.25	0.83
7	Med to Light Blue	34 to 55	-12 to -3	-25 to -8	0.32	0.83
8	Dark Brown	17 to 30	-1 to +9	0 to +10	0.25	0.83
9	Med to Light Brown	25 to 58	-2 to 17	+5 to +26	0.32	0.83
10	Dark Green	18 to 45	-20 to -3	-25 to +11	0.25	0.83
11	Med to Light Green	24 to 70	-20 to 0	-25 to +11	0.32	0.83
12	White	76 to 89	-3 to +2	-3 to +10	0.65	0.83
13	Bright White	>85	-3 to +1	-3 to +6	0.70	0.83
14	Black	<26	-1.5 to +1.5	-1.5 to +1.5	0.25	0.83
15	Dark Gray	24 to 42	-4 to +2	-8 to +4	0.25	0.83
16	Med to Light Gray	40 to 77	-4 to +3	-3 to +8	0.35	0.83
17	Pearlescent Colors	25 to 75	-15 to 17	-15 to 24	0.35	0.75

Figure 2.4-3: CRRC Color Families and Characteristics, CRRC-1, December 6, 2017 Version

2.4.2 Fenestration

Windows, translucent panels, and skylights are evaluated as to their overall impact on the energy efficiency of the building envelope. They are evaluated as an assembly, and take into account the geographic location (climate zone), type of fenestration element (i.e., window or skylight), the glazing material (i.e., plastic or glass), the framing material (i.e., metal or non-metal), the ratio of glazed area to wall or roof area, the orientation (north or non-north facing), and for skylights, whether a curb is utilized with the assembly.

The two properties of fenestration assemblies that are evaluated are the thermal transmission (U-factor) and the solar heat gain. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation. The measure of the ratio of the solar heat gain entering the space through the fenestration assembly to the incident solar radiation is the solar heat gain coefficient (SHGC).

Energy codes stipulate the prescriptive requirements for fenestration assemblies, giving the maximum U-factor and the maximum SHGC for the applicable fenestration assembly. These properties of a given fenestration assembly can be determined by the established test methods given in the governing energy code. Some codes require that a third party, such as the National Fenestration Rating Council (NFRC), certify these properties. However, conservative default values are typically provided in the energy standard, in order to permit the use of fenestration assemblies that have not been tested and/or rated.

2.4.2.1 National Fenestration Rating Council (NFRC)

The NFRC is an organization that provides independent verification of U-factor, SHGC (solar heat gain coefficient) and VLT (visible light transmittance) ratings of fenestrations (windows and skylights). This rating organization certifies the test facilities that are qualified to conduct independent testing of windows and skylights. They also inspect the manufacturing facilities to assure that fenestration is being properly labeled and they maintain a database of rated products. The NFRC label as shown in [Figure 2.4-4](#) is the required evidence that a given window or skylight has the required maximum U-factor and SHGC as described on the building plans.

 National Fenestration Rating Council CERTIFIED	Sky Windows, Inc. DHOX Double Hung Window CPD#999-N-000 Vinyl Frame • Dual Glazed Low E		
	ENERGY Performance		
<ul style="list-style-type: none"> • Energy Savings will depend on your specific climate, house and lifestyle • For more information, call Sky Windows, Inc. 1-800-555-1511 or visit NFRC's web site at www.nfrc.org. 			
Technical Information			
Residential Products			
U-Factor 0.37	Solar Heat Gain Coefficient 0.32	Visible Transmittance 0.53	Air Leakage CFM/ft .2
Nonresidential Products			
U-Factor 0.32	Solar Heat Gain Coefficient 0.33	Visible Transmittance 0.54	Air Leakage CFM/ft .2
<small>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product energy performance. NFRC ratings are determined for a fixed set of environmental conditions and specific product sizes.</small>			

Figure 2.4-4: Sample NFRC Label

Chapter 3 IECC Building Envelope Compliance

In this chapter, more detail is provided on the specific energy code provisions within the International Energy Conservation Code (IECC).

3.1 IECC Building Envelope Air Leakage Mandatory Requirements

The IECC includes mandatory air leakage requirements for window and door assemblies, building envelope, air barriers, loading dock weather seals, vestibules and recessed lighting.

- Window and door assemblies [2009, 2012, 2015 IECC editions] - the air leakage of windows, sliding or swinging door assemblies shall not exceed the air leakage values noted in [Table 3.1-1](#). Site-constructed windows and doors that are weather-stripped or sealed are exempted.
- Building envelope sealing - In the 2009 IECC, it states the "openings and penetrations in the building envelope shall be sealed with caulking materials or closed with gasketing systems compatible with the construction materials and location. Joints and seams shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials spanning joints between construction materials shall allow for expansion and contraction of the construction materials." The 2012 and 2015 IECC refined this language further with more descriptive language as it relates to continuous air barrier installation and key areas to seal joints and seams.
- Air barriers - The 2012 introduced new language that requires a continuous air barrier to be provided throughout the building thermal envelope. However, air barriers are not required in Climate Zones 1, 2 and 3 if complying with the 2012 IECC. The 2015 IECC refined this exception to only apply to Climate Zone 2B.

The 2012 IECC provides air barrier compliance options for the opaque building envelope to provide one of the following:

- Materials with an air permeability no greater than 0.004 cfm/ft² under a pressure differential of 75 Pascals when tested in accordance with ASTM E 2178. There is a list of 16 deemed to comply materials, one of which is "sheet steel" that would allow the use of metal roof and wall cladding common to metal building envelopes.
- Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft² under pressure differential of 75 Pascals when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283.
- Building to have a whole building air leakage test not to exceed 0.40 cfm/ft² at a pressure differential of 75 Pascals in accordance with ASTM E 779 or an equivalent method approved by the code official.

The 2015 IECC further refined the use of this whole building air leakage test option to be an alternative if one chooses not to comply with all other air leakage provisions (i.e., air leakage requirements for window and door assemblies, building envelope, air barriers, loading dock weather seals, vestibules and recessed lighting).

- Loading dock weather seals - The 2009, 2012 and 2015 IECC all require the cargo doors and loading dock doors to be equipped with weather seals to restrict infiltration when vehicles are parked in the doorway.
- Vestibules - The 2009, 2012 and 2015 IECC requires an enclosed vestibule for public access in Climate Zones 3 through 8 with doors that open directly into space greater than 3,000 square feet.
- Recessed lighting - The 2009, 2012 and 2015 IECC requires the sealing of recessed lights to limit air leakage between conditioned and unconditioned spaces.

Table 3.1-1: Air Leakage of Fenestration

Fenestration Assembly	cfm/ft ²	Test Procedure
Windows, sliding doors, swinging doors	0.20	AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400
Skylights - with condensation weepage openings	0.30	
Skylights - all other	0.20	
Curtain walls and storefront glazing	0.06	NFRC 400 or ASTM E283 at 1.57 psf
Commercial glazed swinging entrance doors, revolving doors	1.00	
Garage doors	0.40	ANSI/DASMA 105, NFRC 400, or ASTM E283 at 1.57 psf
Rolling Doors	1.00	
High-speed doors ^a	1.30	

a. Introduced in the 2015 IECC

3.2 IECC Prescriptive Method for Metal Building Insulation

The IECC prescriptive envelope requirements provide a simplified compliance option for standard construction assemblies for conditioned buildings, which includes metal

building roof and wall insulation levels by climate zone. Buildings that are not heated or cooled are not included in the scope of IECC for conditioned buildings and are not required to satisfy the requirements for the building thermal envelope. It is important to note that the IECC does not contain insulation requirements for semiheated buildings, which are common in some metal building applications. For the more appropriate insulation requirements for semiheated building occupancy types, refer to the ASHRAE Standard 90.1 compliance option as outlined in Section 4.1. This may be a more energy efficient choice to consider.

The IECC provides two options for compliance. One option is to install the prescriptive R-value assemblies listed in the R-value table. The referenced R-value table number changes based on which version of the IECC is specified for compliance (i.e., 2009 IECC, Table 502.2(1); 2012 IECC, Table C402.2; and 2015 IECC, Table C402.1.3). The second option is to install an insulation assembly that does not exceed the U-factor specified in the U-factor tables (i.e., Refer to 2009 IECC, Section 502.1.2; 2012 IECC, Section C402.1.2; and 2015 IECC, Section C402.1.4).

The IECC U-factor alternative compliance option allows assemblies outside of those listed in the prescriptive R-value tables mentioned above, as long as the U-factor provided is determined using a hot box test or finite element analysis. This U-factor provided must be less than the maximum U-factor required. The following published resources may be used to comply with the U-factor compliance method:

- ASHRAE Standard 90.1, Normative Appendix A - Metal Building Roof Insulation Assemblies in Table A2.3 and Metal Building Wall Insulation Assemblies in Table A3.2. You are permitted to use a more recent version of ASHRAE Standard 90.1, even if the IECC referenced 90.1 standard is a later edition.
- NAIMA published U-factors for metal building roofs and walls located at www.naima.org.
- Insulation manufacturers test data.

3.2.1 Metal Building Roof Insulation in the IECC

[Table 3.2-1](#) summarizes the metal building roof insulation requirements for the most recent versions of the IECC for all climate zones and non-residential applications. The IECC points to the appropriate version of ASHRAE Standard 90.1, Appendix A, for the metal building insulation assembly descriptions, as described in [Table 2.4-1](#). By reviewing the assembly descriptions and the metal building roof insulation values contain in Appendix Table A2.3, one can derive that all of the IECC prescriptive R-value solutions require a standing seam roof (SSR) with a thermal spacer block with an average purlin spacing of at least 52 inches. The R-value of the thermal spacer block tends to vary based on which version of the IECC is published. For purlin spacing less than 52 inches, the U-factor will need to be determined by other methods as described in Section 4.2.3 for alternative assembly U-factors.

3.2.2 Metal Building Wall Insulation in the IECC

[Table 3.2-1](#) summarizes the metal building wall insulation requirements for the most recent versions of the IECC for all climate zones and non-residential applications. The IECC points to the appropriate version of ASHRAE Standard 90.1, Appendix A, for the metal building insulation assembly descriptions as described in [Table 2.4-1](#). Similarly, by reviewing the assembly descriptions and the metal building wall insulation values contained in Appendix Table A3.2, one can derive all of the IECC prescriptive R-value solutions has the assumption the average girt spacing is at least 52 inches on center. For girt spacings less than 52 inches, the U-factor will need to be determined by other methods as described in Section for alternative assembly 4.2.3 U-factors.

Table 3.2-1: IECC Prescriptive Metal Building Roof Insulation Values (all other category)

Climate Zone		1	2	3	4	5	6	7	8
2009 IECC	Prescriptive R-value	R-19	R-13 + R-13	R-13 + R-13	R-13 + R-13	R-13 + R-13	R-13 + R-19	R-13 + R-19	R-11 + R-19
	Maximum U-factor	0.065	0.055	0.055	0.055	0.055	0.049	0.049	0.035
2012 IECC	Prescriptive R-value	R-19 + R-11LS	R-19 + R-11LS	R-19 + R-11LS	R-19 + R-11LS	R-19 + R-11LS	R-25 + R-11LS	R-30 + R-11LS	R-30 + R-11LS
	Maximum U-factor	0.035	0.035	0.035	0.035	0.035	0.031	0.029	0.029
2015 IECC	Prescriptive R-value	R-19 + R-11LS	R-19 + R-11LS	R-19 + R-11LS	R-19 + R-11LS	R-19 + R-11LS	R-25 + R-11LS	R-30 + R-11LS	R-30 + R-11LS
	Maximum U-factor	0.035	0.035	0.035	0.035	0.035	0.031	0.029	0.029

LS = Liner System

Table 3.2-2: IECC Prescriptive Metal Building Wall Values (all other category)

Climate Zone		1	2	3	4	5	6	7	8
2009 IECC	Prescriptive R-value	R-16	R-16	R-19	R-19	R-13 + R5.6ci	R-13 + R5.6ci	R-19 + R5.6ci	R-19 + R5.6ci
	Maximum U-factor	0.093	0.093	0.084	0.084	0.069	0.069	0.057	0.057
2012 IECC	Prescriptive R-value	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci
	Maximum U-factor	0.079	0.079	0.079	0.052	0.052	0.052	0.052	0.052
2015 IECC	Prescriptive R-value	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci
	Maximum U-factor	0.079	0.079	0.079	0.052	0.052	0.052	0.052	0.052

ci = Continuous insulation.

3.2.3 Cool Roofs in the IECC

The 2009 IECC does not include any recognition of cool roofs as summarized in Section [2.4.1.3](#). Therefore, to take advantage of this, one must use ASHRAE Standard 90.1-2007 building envelope compliance option that is permitted in the IECC. The 2012 IECC, Section C402 included cool roof provisions in the building envelope prescriptive provisions, which were further refined in the 2015 IECC.

3.2.3.1 Cool Roofs in the 2012 IECC

In the 2012 IECC, Section C402.2.1.1, low-sloped roofs, with a slope less than 2 units vertical and 12 units horizontal, directly above cooled conditioned spaces in Climate Zones 1, 2 and 3 must comply with one or more of the options summarized in [Table 3.2-3](#). There are exceptions to the cool roof requirements if portions of roofs include or are covered by:

- Photovoltaic systems or components.
- Solar air or water heating systems or components.
- Roof gardens or landscaped roofs.
- Above-roof decks or walkways.
- Skylights.
- HVAC systems, components, and other opaque objects mounted above the roof.
- Shaded by permanent features of the building or adjacent buildings during the peak sun angle of the summer solstice.
- Ballasted roof portions with minimum stone ballast of 17 pounds per square foot or with 23 pounds per square foot of pavers.
- Roofs where a minimum of 75% of the roof area meets a minimum of one of the exceptions above.

Table 3.2-3: Minimum Cool Roof Options - 2012 IECC^a

Comply with 1 or more:	Option 1	Option 2	Option 3	Option 4
Low Slope >2:12	3-Year Aged SR ^b of 0.55 and 3 Year Aged TE ^c of 0.75	Initial SR ^b of 0.70 and Initial TE ^c of 0.75	3-Year Aged SRI ^d of 64	Initial SRI ^d of 82

SR = Solar Reflectance, TE = Thermal Emittance, SRI = Solar Reflectance Index

a. The use of area-weighted averages to meet these requirements shall be permitted. Materials lacking initial tested values for either SR or TE, shall be assigned both an initial SR of 0.10 and an initial TE of 0.90. Materials lacking 3-year aged tested values for either SR or TE shall be assigned both a 3-year aged SR of 0.10 and a 3-year aged TE of 0.90.

b. SR tested in accordance with ASTM C 1549, ASTM E 903 or ASTM E 1918.

c. TE tested in accordance with ASTM C 1371 or ASTM E 408.

d. SRI shall be determined in accordance with ASTM E 1980 using convection coefficient of 2.1 Btu/hr x ft² x °F. Calculation of aged SRI shall be based on aged tested values of SR and TE. Calculations of initial SRI shall be based on initial tested values of SR and TE.

3.2.3.2 Cool Roofs in the 2015 IECC

The 2015 IECC, Section C402.3, includes refined the cool roof provisions noted in Section [3.2.3.1](#) above. The provisions still apply to low-sloped roofs, with a slope less than 2 units vertical and 12 units horizontal, directly above cooled conditioned spaces in Climate Zones 1, 2 and 3. However, the cool roof provisions summarized in [Table 3.2-4](#) have been limited to 3-year aged values only. The exceptions to the cool roof requirements in the 2015 IECC are based on if portions of roofs include or are covered by:

- Photovoltaic systems or components.
- Solar air or water heating systems or components.
- Roof gardens or landscaped roofs.
- Above-roof decks or walkways.
- Skylights.
- HVAC systems, components, and other opaque objects mounted above the roof.
- Shaded by permanent features of the building or adjacent buildings during the peak sun angle of the summer solstice.
- Ballasted roof portions with minimum stone ballast of 17 pounds per square foot or with 23 pounds per square foot of pavers.
- Roofs where a minimum of 75% of the roof area meets a minimum of one of the exceptions above.

Table 3.2-4: Minimum Cool Roof Options - 2015 IECC^a

Comply with 1 or more:	Option 1	Option 2
Low Slope >2:12	3-Year Aged SR ^b of 0.55 and 3 Year Aged TE ^c of 0.75	3-Year Aged SRI ^d of 64

SR = Solar Reflectance, TE = Thermal Emittance, SRI = Solar Reflectance Index

a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year aged tested values for either SR or TE shall be assigned both a 3-year aged SR in accordance with Section C402.3.1 and a 3-year aged TE of 0.90.

b. Aged SR tested in accordance with ASTM C 1549, ASTM E 903, ASTM E 1918 or CRRC-1.

c. Aged TE tested in accordance with ASTM C 1371, ASTM E 408, or CRRC-1

d. SRI shall be determined in accordance with ASTM E 1980 using convection coefficient of 2.1 Btu/hr x ft² x °F. Calculation of aged SRI shall be based on aged tested values of SR and TE.

The 2015 IECC, Section C402.3.1, provides Equation 4-3 to allow aged solar reflectance to be calculated in the event that the data is unavailable.

$$R_{aged} = [0.2 + 0.7(R_{initial} - 0.2)] \quad (2015 \text{ IECC, Equation 4-3})$$

where:

R_{aged} = The aged solar reflectance.

$R_{initial}$ = The initial solar reflectance determined in accordance with CRRC-1 standard.

3.2.3.3 Fenestration

The prescriptive requirements for the thermal properties of fenestration (maximum U-factor and SHGC) are provided for vertical elements (windows) and horizontal elements (skylights) in the IECC. The requirements tend to vary based on the version of the IECC being referenced. To qualify to use the prescriptive provisions, the area of windows must be less than 30%-40% of the above-grade wall area and the area of skylights must be less than 3% of the roof area. Vertical fenestration window to wall ratio is more refined in the 2012 and 2015 editions of the IECC, as well as the minimum skylight fenestration area.

The addition of window shades or projections can significantly lower or eliminate the solar heat gain coefficient (SHGC) requirements. For example, in the 2009 IECC Table 502.3, if the projection factor (ratio of the horizontal projection to the glazing height being shaded) is at least 0.25, there is no prescriptive SHGC requirement for climate zones 4 through 8. However, in the 2012 IECC there was a SHGC adjustment factor based the projection factor, as well as the orientation of the windows (i.e., 45 degrees of true north or all other orientations). Furthermore, the prescriptive table C402.4 in the 2015 IECC incorporated the adjustment factor into the contents of the table based on window orientation. The architect or design professional will specify the projection factor on the construction documents and note the prescriptive U-factor and SHGC for the fenestration products. As a result, this resource document will not provide the detailed provisions included in the energy code to determine the project factor (PF) and the corresponding SHGC needed.

Each of the versions of the IECC includes exceptions to the values located in the building envelope fenestration maximum U-factor and SHGC requirement tables. Refer to the appropriate version of the IECC for more information.

[Table 3.2-5](#) summarizes the IECC the U-factors and SHGC values for the prescriptive building envelope vertical and horizontal fenestration components.

Table 3.2-5: IECC Prescriptive Building Envelope Fenestration Maximum U-factor and SHGC Values

Climate Zone		1	2	3	4	5	6	7	8								
2009 IECC	Non-Metal Vertical Frames with or without metal reinforcement or cladding (U-factor)																
		1.20	0.75	0.65	0.40	0.35	0.35	0.35	0.35								
	Metal Vertical Frames with or without thermal break (U-factor)																
	Curtain Wall/Storefront	1.00	0.70	0.60	0.50	0.45	0.45	0.40	0.40								
	Entrance Doors	1.20	1.10	0.90	0.85	0.80	0.80	0.80	0.80								
	All other ^a	1.20	0.75	0.65	0.55	0.55	0.55	0.45	0.45								
	SHGC - all frame types																
	PF < 0.25	.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45								
	0.25 ≤ PF < 0.50	0.33	0.33	0.33	NR	NR	NR	NR	NR								
	PF ≥ 0.50	0.40	0.40	0.40	NR	NR	NR	NR	NR								
	Skylights																
	U-factor	0.75	0.75	0.65	0.60	0.60	0.60	0.60	0.60								
SHGC	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR									
2012 IECC	Vertical Frames (U-factor)																
	Fixed Fenestration	0.50	0.50	0.46	0.38	0.38	0.36	0.29	0.29								
	Operable Fenestration	0.65	0.65	0.60	0.45	0.45	0.43	0.37	0.37								
	Entrance Doors	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77								
	SHGC - all frame types																
	U-factor	0.75	0.65	0.55	0.50	0.50	0.50	0.50	0.50								
SHGC ^b	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR									
2015 IECC	Vertical Frames (U-factor)																
	Fixed Fenestration	0.50	0.50	0.46	0.38	0.38	0.36	0.29	0.29								
	Operable Fenestration	0.65	0.65	0.60	0.45	0.45	0.43	0.37	0.37								
	Entrance Doors	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77								
	SHGC - all frame types																
	Orientation	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N
	PF < 0.20	0.25	0.33	0.25	0.33	0.25	0.33	0.40	0.53	0.40	0.53	0.40	0.53	0.45	NR	0.45	NR
	0.20 ≤ PF < 0.50	0.30	0.37	0.30	0.37	0.30	0.37	0.48	0.58	0.48	0.58	0.48	0.58	NR	NR	NR	NR
	PF ≥ 0.50	0.40	0.40	0.40	0.40	0.40	0.40	0.64	0.64	0.64	0.64	0.64	0.64	NR	NR	NR	NR
	SHGC - all frame types																
U-factor	0.75	0.65	0.55	0.50	0.50	0.50	0.50	0.50	0.50								
SHGC	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR									

NR = No requirement. PF = Project Factor.

a. All others includes operable windows, fixed windows and non-entrance doors.

b. Refer to 2012 IECC, Section C402.3.3.1 for SHGC adjustment multipliers for PF greater than 0.20.

3.3 IECC Performance Method

3.3.1 IECC Trade-Off Method Path to ASHRAE Standard 90.1

The commercial building provisions of the IECC do not specifically mention an envelope trade-off option, but the IECC does refer to the ASHRAE Standard 90.1, which does allow the trade-off method. The COMcheck software has the ability to utilize various versions of the IECC in order to perform trade-offs, if the software was approved by the jurisdiction having authority. For more information on how to use COMcheck, refer to [Chapter 6](#).

3.3.2 IECC Whole Building Energy Performance Method

The IECC provides a total building performance method for compliance in Section 506 of the 2009 IECC and in Section 407 of the 2012 and 2015 IECC. This method compares energy usage between a standard reference building and the proposed building. The standard building is a defined construction type. For example, the roof is assumed to be with insulation entirely above the deck with a corresponding U-factor. The proposed building would be based on the selected construction and insulation. This is different from most standards in where the standard building is assumed to be of the same construction as the proposed building, but with the prescriptive requirements for that construction type.

Chapter 4 ASHRAE Standard 90.1 Building Envelope Compliance Methods

4.1 ASHRAE Standard 90.1 Building Envelope Air Leakage Mandatory Requirements

ASHRAE Standard 90.1 includes mandatory air leakage provisions for the building envelope, fenestration and doors assemblies, materials and assembly of materials in the building envelope, loading dock weather seals, and vestibules. Air leakage requirements in ASHRAE Standard 90.1 has become more stringent in each passing version of the standard. The information below attempts to summarize the requirements from one version of the standard to another. Future versions of the standard will begin to incorporate whole building air leakage options for the architect and/or engineer and the contractor to adhere to. In the meantime, the focus is more so on at the material level.

4.1.1 Continuous Air Barrier - Building Envelope

ASHRAE Standard 90.1-2007 Section 5.4.3.1 building envelop installation requirements were limited to simply sealing all openings around the building envelop by means of caulking, gasketing and weather stripping to minimize air leakage. No air leakage limits were noted as it relates to how leaking individual materials, assembly of materials or the whole building are permitted. The standard summarized the following areas of the buildings to seal, whether it was in a conditioned or semiheated space in all climate zones:

- joints around fenestration and door frames
- junctions where walls, floors and roofs intersect
- openings at penetrations of utility services through roofs, walls and floors
- site-built fenestration and doors
- building assemblies used as ducts or plenums
- joints, seams and penetrations of vapor retarders
- all other openings in the building envelope

ASHRAE Standard 90.1-2010 expanded Section 5.4.3.1 continuous air barrier provisions, which was carried forward into ASHRAE Standard 90.1-2013 edition with no additional modifications. Expanded provisions included (1) newly defined exceptions to the installation requirements, (2) information for the architect and/or engineer to incorporate into the construction documents, and (3) minimum air permeance based on ASTM E 2178, "Standard Test Method for Determining Air Leakage of Air Barrier Assemblies."

- Semiheated spaces in Climate Zones 1 through 6, and single wythe concrete masonry buildings in Climate Zone 2B are exempt from the continuous air barrier requirements.
- Air barrier are required to be designed and noted in the following manner:
 - The construction documents must note all air barrier components of each assembly included in the building envelope or clearly identified.
 - Air barrier components involving joints, interconnections and penetrations must be detailed appropriately, this includes lighting fixtures installed on the building envelope.
 - All surfaces of the building envelope (lowest floor, walls, ceiling/roof) must have a continuous air barrier.
 - The design of the continuous air barrier must take into account positive and negative pressures caused by wind, stack effect and mechanical ventilation.
- Either the opaque materials or assemblies must be tested in accordance with ASTM E 2178 to meet a minimum air permeance rate under a pressure differential of 75 Pascals.
 - Single layer materials with an air permeance not exceeding 0.004 cfm/ft², or
 - Assembly of materials with an air permeance not exceeding 0.040 cfm/ft².

As it relates to single layer materials, ASHRAE Standard 90.1 calls out 13 materials that are deemed to comply with the air permeance of not exceeding 0.004 cfm/ft², one of which is "sheet steel" common to metal building envelopes. An example of sheet steel would be the metal roof and wall panels.

- Whole building air leakage limitations were not included in ASHRAE Standard 90.1-2013; however, the 2016 edition will include language similar to what is included in the 2015 IECC at an air permeance rate not exceeding 0.400 cfm/ft².

4.1.2 Fenestration and doors

The air leakage for fenestration and doors shall be determined in accordance to the testing standards listed in the various editions of the ASHRAE Standard 90.1 and determined by a nationally accreditation organization (i.e., NFRC). The products shall be labeled and certified by the manufacturer with the appropriate thermal performance values. The term fenestration applies to products such as windows, skylight and doors that are more than one-half glass in area.

Doors commonly are broken down into two categories: swinging and non-swinging. Man doors are considered swinging doors, for example. Non-swinging door examples are sliding doors, upward acting garage doors, sectional doors and roll-up doors. Table 4.1-1 summarizes the fenestration air leakage values noted in various sections and tables within the 2007, 2010 and 2013 versions of ASHRAE Standard 90.1.

Table 4.1-1: ASHRAE Standard 90.1 Air Leakage of Fenestration

Fenestration Assembly	cfm/ft ²		
	2007 ^{a,b}	2010 ^b	2013 ^b
Windows, sliding doors, swinging doors	0.40	0.20 ⁱ	0.20 ⁱ
Skylights - with condensation weepage openings	0.40	0.30 ^e	0.30 ^e
Curtain walls and storefront glazing	0.40	0.06 ^d	0.06 ^d
Glazed swinging entrance doors, revolving doors	1.00	1.00 ^c	1.00 ^c
Nonswinging opaque doors	0.40	0.40 ^{f,g,h}	0.40 ^{f,g,h}
Nonswinging doors intended for vehicular access, high-speed door	-	-	1.30 ^j

- a. Determined in accordance with NFRC 400 with an air leakage not to exceed 1.0 cfm/ft² for glazed swinging entrance doors and for revolving doors and 0.4 cfm/ft² for all other products. Garage doors air leakage rate determined in accordance with ANSI/DASMA 105 or NFRC 400.
- b. Field-fabricated fenestration and doors are exempt.
- c. Tested at a pressure of at least 1.57 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283.
- d. Tested at a pressure of at least 1.57 psf in accordance with NFRC 400, or ASTM E283.
- e. Tested at a pressure of at least 1.57 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283; or 0.5 cfm/ft² when tested at a pressure of at least 6.24 psf in accordance AAMA/WDMA/CSA 101/I.S.2/A440.
- f. Tested at a pressure of at least 1.57 psf in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.
- g. Nonswinging opaque doors includes roll-up, metal coiling, sliding, and all other doors that are not swinging.
- h. Metal coiling doors in semi-heated spaces in Climate Zones 1 through 6 are exempt.
- i. Tested at a pressure of at least 1.57 psf in accordance with AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283; or 0.5 cfm/ft² when tested at a pressure of at least 6.24 psf in accordance AAMA/WDMA/CSA 101/I.S.2/A440.
- j. Introduced in ASHRAE 90.1-2013. Doors with minimum opening rate of 32 inch per second, tested at a pressure of a least 1.57 psf in accordance with ANSI/DASMA 105, NFRC 400, or ASTM E283.
- k. Products list below are exempt if the building has a whole building air leakage rate of 0.4 cfm/ft² if tested at a pressure of at least 1.57 psf when tested in accordance with ASTM E779.

4.1.3 Loading Dock Weather Seals

The 2007, 2010 and 2013 versions of ASHRAE Standard 90.1 Section 5.4.3.3 all include the same language whereby requiring weather seals on cargo and loading dock doors in Climates 4 through 8. The weather seals are intended to restrict infiltration when vehicles are parked in the doorway.

4.1.4 Vestibules

ASHRAE Standard 90.1 Section 5.4.3.4 requirements for vestibules is more detailed than that included in the IECC, with a number of exceptions spelled out. Refer to the language in ASHRAE Standard 90.1 for more information on air leakage requirements of vestibules.

4.2 ASHRAE Standard 90.1 Prescriptive Method for Metal Building Envelope

ASHRAE Standard 90.1 prescriptive envelope requirements are similar to that of the IECC, as explained in Section 3.2 above. The difference between the IECC and ASHRAE Standard 90.1 prescriptive building envelope options is that the ASHRAE Standard 90.1 includes semiheated space provisions as described in Section 2.3.1.2 above. ASHRAE Standard 90.1 provides a simplified compliance option for standard construction assemblies for conditioned buildings, semiheated buildings and some provisions for unconditioned buildings, of which includes metal building roof and wall insulation levels by climate zone.

Buildings that include a common wall or ceiling separating an unconditioned space from a conditioned space needs to comply with the semiheated space provisions included in the building envelope insulation and fenestration requirements noted in Tables 5.5-1 through 5.5-8 for the appropriate climate zone.

ASHRAE Standard 90.1 provides two options for compliance. One option is to install the prescriptive R-value assemblies listed in Tables 5.1-1 through 5.5-8 for the appropriate climate zone. The second option is to install an insulation assembly that does not exceed the U-factor specified in the above-mentioned tables.

The U-factor alternative compliance option allows other insulating assemblies outside of those listed in the prescriptive tables mentioned above, as long as the U-factor provided is determined using a hot box test or finite element analysis. This U-factor provided must be less than the maximum U-factor required. The following published resources may be used to comply with the U-factor compliance method:

- ASHRAE Standard 90.1, Normative Appendix A - Metal Building Roof Insulation Assemblies in Table A2.3.3 and Metal Building Wall Insulation Assemblies in Table A3.2.3 You are permitted to use a more recent version of ASHRAE Standard 90.1.
- In order to use the roof insulation assemblies listed in Table A2.3.3 and Table A3.2.3, the average purlin and girt spacing for systems with compressed insulation is at least 52 inches on center. Although this is not specifically called out in the 2007 and 2010 versions of ASHRAE Standard 90.1, the ASHRAE Standard 90.1-2013 does specify this limitation. Furthermore, ASHRAE Standard

90.1-2013 does provide new calculation methods in Appendix A9.2 to account for different secondary member spacings.

- NAIMA published U-factors for metal building roofs and walls located at www.naima.org.
- Insulation manufacturers test data.

4.2.1 Metal Building Roof Insulation in the ASHRAE Standard 90.1

[Table 4.2-1](#) summarizes the metal building roof insulation requirements for conditioned spaces (also known as non-residential) for the most recent versions of ASHRAE Standard 90.1 for all climate zones. [Table 4.2-2](#) summarizes the metal building roof insulation requirements for semiheated spaces. All of the prescriptive R-value solutions require a standing seam roof (SSR) with a thermal spacer block with an average purlin spacing of 60 inches, as called out in the 2010 and 2013 versions of ASHRAE Standard 90.1. The R-value of these thermal spacer blocks tends to vary from R-3 to R-5 based on which version of the standard is published and type of insulation installed, as summarized in [Table 2.4-1](#) above.

4.2.2 Metal Building Wall Insulation in the ASHRAE Standard 90.1

[Table 4.2-3](#) summarizes the metal building wall insulation requirements for the non-residential spaces for the most recent versions of ASHRAE Standard 90.1 for all climate zones. [Table 4.2-4](#) summarizes the metal building wall insulation requirements for the semiheated spaces. ASHRAE Standard 90.1-2010 introduced using continuous insulation in the metal building wall system in combination with fiberglass. This was later amended in ASHRAE Standard 90.1-2013 with using only continuous insulation, prescriptively, in the wall system. One still has the option to use the U-factor method and select other systems listed in Appendix A or use other published resources.

4.2.3 Alternate Assembly U-Factors for Metal Building Roof and Wall Insulation

ASHRAE Standard 90.1 Appendix A9 and the IECC include additional options to choose insulation assemblies. These options are either finite element modeling or hot box testing in conformance with ASTM C 1363, *Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus*.

The 2013 version of ASHRAE Standard 90.1 expanded Appendix A9 to include a calculation method for single and double layer systems, as defined in Section A9.4.5 Metal Building U-Factor Equations. The metal building manufacturer or the design professional will be able to assist with using these calculation methods.

Table 4.2-1: ASHRAE Standard 90.1 Prescriptive Metal Building Roof Insulation Values (Nonresidential)

Climate Zone		1	2	3	4	5	6	7	8
90.1-2007	Prescriptive R-value	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-13 + R-19
	Maximum U-factor	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.049
90.1-2010	Prescriptive R-value	R-19	R-13 + R-13	R-13 + R-13	R-13 + R-13	R-13 + R-13	R-13 + R-19	R-13 + R-19	R-11 + R-19LS
	Maximum U-factor	0.065	0.055	0.055	0.055	0.055	0.049	0.049	0.035
90.1-2013	Prescriptive R-value	R-10 + R-19FC	R-10 + R-19FC	R-10 + R-19FC	R-11 + R-19LS	R-11 + R-19LS	R-11 + R-25LS	R-11 + R-30LS	R-11 + R-11 + R-25LS
	Maximum U-factor	0.041	0.041	0.041	0.037	0.037	0.031	0.029	0.026

LS = Liner System

Table 4.2-2: ASHRAE Standard 90.1 Prescriptive Metal Building Roof Insulation Values (Semi-Heated)

Climate Zone		1	2	3	4	5	6	7	8
90.1-2007	Prescriptive R-value	NR	R-6	R-10	R-10	R-10	R-10	R-10	R-16
	Maximum U-factor	1.280	0.167	0.097	0.097	0.097	0.097	0.097	0.072
90.1-2010	Prescriptive R-value	R-6	R-10	R-10	R-10	R-13	R-16	R-16	R-19
	Maximum U-factor	0.167	0.097	0.097	0.097	0.083	0.072	0.072	0.065
90.1-2013	Prescriptive R-value	R-10	R-16	R-16	R-19	R-19	R-19 + R-19	R-11 + R-19LS	R-11 + R-19LS
	Maximum U-factor	0.115	0.096	0.096	0.082	0.082	0.060	0.037	0.037

NR = no insulation requirement
FC = Filled Cavity

Table 4.2-3: ASHRAE Standard 90.1 Prescriptive Metal Building Wall Insulation Values (Nonresidential)

Climate Zone		1	2	3	4	5	6	7	8
90.1-2007	Prescriptive R-value	R-13	R-13	R-13	R-13	R-13	R-13	R-19	R-13 + R-13
	Maximum U-factor	0.113	0.113	0.113	0.113	0.113	0.113	0.065	0.057
90.1-2010	Prescriptive R-value	R-16	R-16	R-19	R-19	R-13 + R-5.6ci	R-13 + R-5.6ci	R-19 + R-5.6ci	R-19 + R-5.6ci
	Maximum U-factor	0.093	0.093	0.084	0.084	0.069	0.069	0.057	0.057
90.1-2013	Prescriptive R-value	R-9.8ci	R-9.8ci	R-9.8ci	R15.8ci	R-19ci	R-19ci	R22.1ci	R-25ci
	Maximum U-factor	0.094	0.094	0.094	0.060	0.050	0.050	0.044	0.039

ci = continuous insulation

Table 4.2-4: ASHRAE Standard 90.1 Prescriptive Metal Building Wall Insulation Values (Semi-Heated)

Climate Zone		1	2	3	4	5	6	7	8
90.1-2007	Prescriptive R-value	NR	R-6	R-6	R-10	R-11	R-13	R-13	R-13
	Maximum U-factor	1.280	0.167	0.167	0.134	0.123	0.113	0.113	0.113
90.1-2010	Prescriptive R-value	R-13	R-13	R-13	R-13	R-13	R-13	R-13	R-13
	Maximum U-factor	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
90.1-2013	Prescriptive R-value	NR	R-13	R-13	R-13	R-9.8ci	R-9.8ci	R-13ci	R15.8ci
	Maximum U-factor	0.352	0.162	0.162	0.162	0.094	0.094	0.072	0.060

NR = no insulation requirements
ci = continuous insulation

4.2.4 Cool Roofs in ASHRAE Standard 90.1

Cool roofs provisions in ASHRAE Standard 90.1 have evolved over the past few editions of the standard. The IECC uses the common term "cool roof," while ASHRAE Standard 90.1 simply refers to roofs with minimum solar reflectance and thermal remittance. If the metal building project uses the prescriptive building envelop option, and not the performance route, then the cool roof provisions must be addressed based on the language provided if the building does not meet one of the exceptions. Like the IECC, the cool roof provisions in ASHRAE Standard 90.1 are limited to Climate Zone 1 through 3 as stated in Section 5.5.3.1.1, however each version of the standard modifies when these provisions apply and if there is a reduction in the amount of roof insulation needed. Roofs over a semiheated space or roofs over a conditioned space that is not cooled are exempt from the cool roof requirements for all versions of the standard.

4.2.4.1 Cool Roofs in ASHRAE Standard 90.1-2007

In ASHRAE Standard 90.1-2007, Section 5.5.3.1.1, a reduction in roof insulation is permitted based on the values in Table 5.5.3.1 if the roofs in Climate Zones 1 through 3 meets the solar reflectance of 0.70 and a minimum thermal emittance of 0.75, or a minimum solar reflective index of 82.

Table 4.2-5: Cool Roof Provisions - ASHRAE Standard 90.1-2007

Climate Zone	Prescriptive Roof Insulation R-Value		Cool Roof Insulation R-Value ^e		Options
1	R-19	or	R-13	if	SR = 0.70 ^{a,d} and TE = 0.75 ^{a,d} or SRI = 82 ^c
2	R-19		R-13		
3	R-19		R-16		

SR = Solar Reflectance, TE = Thermal Emittance, SRI = Solar Reflectance Index

a. SR tested in accordance with ASTM C 1549, ASTM E 903 or ASTM E 1918.

b. TE tested in accordance with ASTM C 1371 or ASTM E 408.

c. SRI shall be determined in accordance with ASTM E 1980.

d. SR and TE shall be determined by Cool Roof Rating Council CRRC-1 Product Rating Program, or similar, and shall be labeled and certified by the manufacturer.

e. Excludes roofs over ventilated attics, or roofs over semiheated spaces, or roofs over conditioned spaces that are not cooled spaces.

4.2.4.2 Cool Roofs in ASHRAE Standard 90.1-2010

In ASHRAE Standard 90.1-2010, Section 5.5.3.1.1, roofs in Climate Zones 1 through 3 are permitted to increase the roof insulation levels found in Table 5.5.3.1.1 or use the values in Tables 5.5-1 through 5.5-3 by meeting either the minimum 3-year aged solar reflectance of 0.55 and a minimum 3-year aged thermal emittance of 0.75, or a minimum solar reflectance index of 64. Exemptions applicable to common metal buildings to the cool roof provisions are: roofs where a minimum of 75% of the roof area is shaded or covered by PV panels; steep-sloped roofs (<2:12), low-slope metal building roofs in Climate Zones 2 and 3, and roofs over semiheated spaces. Other exemptions are listed in the standard.

Table 4.2-6: Cool Roof Provisions - ASHRAE Standard 90.1-2010

Climate Zone	Without Cool Roof Provisions Insulation R-Value		Prescriptive Roof Insulation R-Value ^e		Options
1	U-0.028 R-35	or	U-0.065 R-19	if	3-Year SR = 0.55 ^{a,b} and 3-Year TE = 0.75 ^{a,b} or 3-Year SRI = 64 ^c
2			U-0.055 R-13 + R-13		
3			U-0.055 R-13 + R-13		

SR = Solar Reflectance, TE = Thermal Emittance, SRI = Solar Reflectance Index

a. SR tested in accordance with ASTM C 1549, or ASTM E 1918.

b. TE tested in accordance with ASTM C 1371 or ASTM E 408.

c. SRI shall be determined in accordance with ASTM E 1980.

d. SR and TE shall be determined by Cool Roof Rating Council CRRR-1 Product Rating Program, or similar, and shall be labeled and certified by the manufacturer.

4.2.4.3 Cool Roofs in ASHRAE Standard 90.1-2013

In ASHRAE Standard 90.1-2013, Section 5.5.3.1.1, roofs in Climate Zones 1 through 3 are permitted to increase the roof insulation levels found in Table 5.5.3.1.1 or use the values in Tables 5.5-1 through 5.5-3 by meeting either the minimum 3-year aged solar reflectance of 0.55 and a minimum 3-year aged thermal emittance of 0.75, or a minimum solar reflectance index of 64. Exemptions applicable to common metal buildings to the cool roof provisions are: roofs where a minimum of 75% of the roof area is shaded or covered by PV panels; steep-sloped roofs (<2:12), low-slope metal building roofs in Climate Zones 2 and 3, and roofs over semiheated spaces. Other exemptions are listed in the standard.

4.2.5 Fenestration

The prescriptive requirements for the thermal properties of fenestration (maximum U-factor and SHGC) are provided for vertical elements (windows) and horizontal elements (skylights) in ASHRAE Standard 90.1. The requirements tend to vary based on the version of the standard being referenced. To qualify to use the prescriptive provisions, the area of windows must be between 0%-40% of the above-grade wall area and the area of skylights must be between 0%-5% the roof area. Vertical fenestration window to wall ratio is more refined in the 2010 and 2013 editions of ASHRAE Standard 90.1, as well as the skylight fenestration area. For a summary of the prescriptive measures, please refer to Tables 4.2-8 through 4.3-12 below.

Table 4.2-7: ASHRAE Standard 90.1-2007 Prescriptive Fenestration - Nonresidential

Climate Zone	1	2	3	4	5	6	7	8									
ASHRAE Standard 90.1-2007	Non-Metal Vertical Frames with or without metal reinforcement or cladding (U-factor)																
		1.20	0.75	0.65	0.40	0.35	0.35	0.35	0.35								
	Metal Vertical Frames with or without thermal break (U-factor)																
	Curtain Wall/Storefront	1.20	0.70	0.60	0.50	0.45	0.45	0.40	0.40								
	Entrance Doors	1.20	1.10	0.90	0.85	0.80	0.80	0.80	0.80								
	All other ^b	1.20	0.75	0.65	0.55	0.55	0.55	0.45	0.45								
	Vertical Window SHGC - all frame types^a																
	All Window Types	0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45								
	Skylights																
	Type	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC
	Curb, Glass, 0-2% of Roof	1.98	0.36	1.98	0.36	1.17	0.39	1.17	0.49	1.17	0.49	1.17	0.49	1.17	0.68	0.98	NR
	Curb, Glass, 2.1-5% of Roof	1.98	0.19	1.98	0.19	1.17	0.19	1.17	0.39	1.17	0.39	1.17	0.49	1.17	0.64	0.98	NR
	Curb, Plastic, 0-2% of Roof	1.90	0.34	1.90	0.39	1.30	0.65	1.30	0.65	1.10	0.77	0.87	0.71	0.87	0.77	0.61	NR
	Curb, Plastic, 2.1-5% of Roof	1.90	0.27	1.90	0.34	1.30	0.34	1.30	0.34	1.10	0.62	0.87	0.58	0.87	0.71	0.61	NR
w/o Curb, 0-2% of Roof (all)	1.36	0.36	1.36	0.36	0.69	0.39	0.69	0.49	0.69	0.49	0.69	0.49	0.69	0.64	0.58	NR	
w/o Curb, 2.1-5% of Roof (all)	1.36	0.19	1.36	0.19	0.69	0.19	0.69	0.39	0.69	0.39	0.69	0.49	0.69	0.64	0.58	NR	

NR = No requirement.

a. SHGC may be reduced if permanent opaque projections shade the window. Use multipliers in Table 5.5.4.4.1.

b. All others include operable windows, fixed windows and non-entrance doors.

Table 4.2-8: ASHRAE Standard 90.1-2007 Prescriptive Fenestration - Semiheated

Climate Zone	1	2	3	4	5	6	7	8									
ASHRAE Standard 90.1-2007	Non-Metal Vertical Frames with or without metal reinforcement or cladding (U-factor)																
		1.20	1.20	1.20	1.20	1.20	0.65	0.65	0.65								
	Metal Vertical Frames with or without thermal break (U-factor)																
	Curtain Wall/Storefront	1.20	1.20	1.20	1.20	1.20	0.60	0.60	0.60								
	Entrance Doors	1.20	1.20	1.20	1.20	1.20	0.90	0.90	0.90								
	All other ^a	1.20	1.20	1.20	1.20	1.20	0.65	0.65	0.65								
	Vertical Window SHGC - all frame types																
	All Window Types	NR	NR	NR	NR	NR	NR	NR	NR								
	Skylights																
	Type	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC
	Curb, Glass, 0-2% of Roof	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.30	NR
	Curb, Glass, 2.1-5% of Roof	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.30	NR
	Curb, Plastic, 0-2% of Roof	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.10	NR
	Curb, Plastic, 2.1-5% of Roof	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.10	NR
w/o Curb, 0-2% of Roof (all)	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	0.81	NR	
w/o Curb, 2.1-5% of Roof (all)	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	0.81	NR	

NR = No requirement.

a. All others includes operable windows, fixed windows and non-entrance doors.

Table 4.2-9: ASHRAE Standard 90.1-2010 Prescriptive Fenestration - Nonresidential

Climate Zone		1	2	3	4	5	6	7	8								
ASHRAE Standard 90.1-2010	Non-Metal Vertical Frames with or without metal reinforcement or cladding (U-factor)																
		1.20	0.75	0.65	0.40	0.35	0.35	0.35	0.35								
	Metal Vertical Frames with or without thermal break (U-factor)																
	Curtain Wall/Storefront	1.20	0.70	0.60	0.50	0.45	0.45	0.40	0.40								
	Entrance Doors	1.20	1.10	0.90	0.85	0.80	0.80	0.80	0.80								
	All other ^b	1.20	0.75	0.65	0.55	0.55	0.55	0.45	0.45								
	Vertical Window SHGC - all frame types^a																
	All Window Types	0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45								
	Skylights																
	Type	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC
	Curb, Glass, 0-2% of Roof	1.98	0.36	1.98	0.36	1.17	0.39	1.17	0.49	1.17	0.49	1.17	0.49	1.17	0.68	0.98	NR
	Curb, Glass, 2.1-5% of Roof	1.98	0.19	1.98	0.19	1.17	0.19	1.17	0.39	1.17	0.39	1.17	0.49	1.17	0.64	0.98	NR
	Curb, Plastic, 0-2% of Roof	1.90	0.34	1.90	0.39	1.30	0.65	1.30	0.65	1.10	0.77	0.87	0.71	0.87	0.77	0.61	NR
	Curb, Plastic, 2.1-5% of Roof	1.90	0.27	1.90	0.34	1.30	0.34	1.30	0.34	1.10	0.62	0.87	0.58	0.87	0.71	0.61	NR
w/o Curb, 0-2% of Roof (all)	1.36	0.36	1.36	0.36	0.69	0.39	0.69	0.49	0.69	0.49	0.69	0.49	0.69	0.64	0.58	NR	
w/o Curb, 2.1-5% of Roof (all)	1.36	0.19	1.36	0.19	0.69	0.39	0.69	0.39	0.69	0.39	0.69	0.49	0.69	0.64	0.58	NR	

NR = No requirement.

a. SHGC may be reduced if permanent opaque projections shade the window. Use multipliers in Table 5.5.4.4.1.

b. All others include operable windows, fixed windows and non-entrance doors.

Table 4.2-10: ASHRAE Standard 90.1-2010 Prescriptive Fenestration - Semiheated

Climate Zone		1	2	3	4	5	6	7	8								
ASHRAE Standard 90.1-2010	Non-Metal Vertical Frames with or without metal reinforcement or cladding (U-factor)																
		1.20	1.20	1.20	1.20	1.20	0.65	0.65	0.65								
	Metal Vertical Frames with or without thermal break (U-factor)																
	Curtain Wall/Storefront	1.20	1.20	1.20	1.20	1.20	0.60	0.60	0.60								
	Entrance Doors	1.20	1.20	1.20	1.20	1.20	0.90	0.90	0.90								
	All other ^a	1.20	1.20	1.20	1.20	1.20	0.65	0.65	0.65								
	Vertical Window SHGC - all frame types																
	All Window Types	NR	NR	NR	NR	NR	NR	NR	NR								
	Skylights																
	Type	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC
	Curb, Glass, 0-2% of Roof	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.30	NR
	Curb, Glass, 2.1-5% of Roof	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.98	NR	1.30	NR
	Curb, Plastic, 0-2% of Roof	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.10	NR
	Curb, Plastic, 2.1-5% of Roof	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.90	NR	1.10	NR
w/o Curb, 0-2% of Roof (all)	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	0.81	NR	
w/o Curb, 2.1-5% of Roof (all)	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	1.36	NR	0.81	NR	

NR = No requirement.

a. All others include operable windows, fixed windows and non-entrance doors.

Table 4.2-11: ASHRAE Standard 90.1-2013 Prescriptive Fenestration - Nonresidential

Climate Zone		1	2	3	4	5	6	7	8							
ASHRAE Standard 90.1-2013	Vertical Fenestration 0%-40% (U-factor)															
	Nonmetal Framing, All	0.50	0.40	0.35	0.35	0.32	0.32	0.32	0.32							
	Metal Framing, Fixed	0.57	0.57	0.50	0.42	0.42	0.42	0.38	0.38							
	Metal Framing, Operable	0.65	0.65	0.60	0.50	0.50	0.50	0.40	0.40							
	Metal Framing, Entrance Door	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77							
	Vertical Window SHGC - all frame types^a															
	All Window Types	0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45							
	Vertical Window SHGC/VLT - all frame types															
	All Window Types	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10							
	Skylights															
Type	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC
All Types	0.75	0.35	0.65	0.35	0.55	0.35	0.50	0.40	0.50	0.40	0.50	0.40	0.50	NR	0.50	NR

NR = No requirement. SHGC = Solar Heat Gain Coefficient. VT/SHGC = Visible Transmittance/SHGC Ratio
a. SHGC may be reduced if permanent opaque projections shade the window. Use multipliers in Table 5.5.4.4.1.

Table 4.2-12: ASHRAE Standard 90.1-2013 Prescriptive Fenestration - Semiheated

Climate Zone		1	2	3	4	5	6	7	8							
ASHRAE Standard 90.1-2013	Vertical Fenestration 0%-40% (U-factor)															
	Nonmetal Framing, All	0.93	0.93	0.87	0.51	0.45	0.45	0.32	0.32							
	Metal Framing, Fixed	1.20	1.20	1.20	0.73	0.62	0.51	0.38	0.38							
	Metal Framing, Operable	1.20	1.20	1.20	0.81	0.70	0.59	0.44	0.44							
	Metal Framing, Entrance Door	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77							
	Vertical Window SHGC - all frame types^a															
	All Window Types	NR	NR	NR	NR	NR	NR	NR	NR							
	Vertical Window SHGC/VLT - all frame types															
	All Window Types	NR	NR	NR	NR	NR	NR	NR	NR							
	Skylights															
Type	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC	U	SHGC
All Types	1.80	NR	1.80	NR	1.70	NR	1.15	NR	0.98	NR	0.85	NR	0.85	NR	0.85	NR

NR = No requirement. SHGC = Solar Heat Gain Coefficient. VT/SHGC = Visible Transmittance/SHGC Ratio
a. SHGC may be reduced if permanent opaque projections shade the window. Use multipliers in Table 5.5.4.4.1.

4.3 ASHRAE Standard 90.1 Performance Methods

4.3.1 ASHRAE Standard 90.1 Trade-Off Method Path

Section 5.6 of ASHRAE Standard 90.1 provides the option to trade off envelope performance factors of the building envelope components only by using the Department of Energy (DOE) COMcheck software for commercial buildings. ASHRAE Standard 90.1 Normative Appendix C includes the parameters by which the COMcheck software is based off. The COMcheck software has the ability to utilize various versions of the ASHRAE Standard 90.1 standard in order to perform trade-offs, if the software was approved by the jurisdiction having authority. For more information on how to use COMcheck, refer to [Chapter 6](#).

4.3.2 ASHRAE Standard 90.1 Energy Cost Budget Method

Section 11 of ASHRAE Standard 90.1 defines the energy cost budget (ECB) method as an alternative to the prescriptive provisions of the standard. The ECB method is also an alternative to the trade-off method, where by the ECB method utilizes more advanced computer software program that analyses the entire building, including the mechanical and lighting systems using software programs such as DOE-2 or BLAST. This method is commonly used by energy code consultants to run the proprietary software programs that enables the design energy costs of the proposed building to not exceed the energy cost budget of the baseline building.

Chapter 5 Insulating Metal Building Systems

In this Chapter, the various methods available to insulate a metal building system will be reviewed.

5.1 Understanding R-values and U-factors

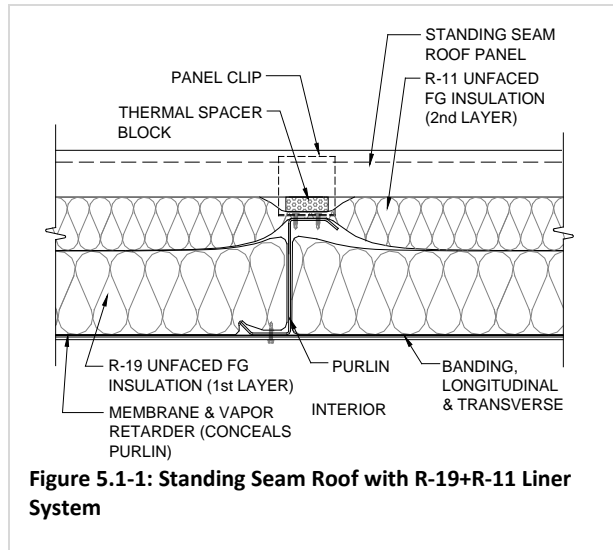
The energy codes primarily focus on U-factors to tell the whole story to account for actual heat flow through the “entire insulated assembly” (i.e., framing members, compressed insulation, fasteners, etc.), not just measuring the heat flow through a “single-layer” of material. Technically, the U-factor is equal to the inverse of the R-value ($U=1/R$). However, this does not apply when insulation is installed in a building. The inverse of the U-factor is referred to as the “effective R-value” of the assembly that includes various products, each having their own specific R-values. The lower the U-factor the better the thermal performance.

Cavity Filled Fiberglass Metal Building Roof Example

The prescriptive assemblies listed in both the IECC and ASHRAE Standard 90.1 account for metal building roof and wall construction. For example, in ASHRAE Standard 90.1-2013, a metal building roof in Climate Zone 5 to meet a U-factor of U-0.037 could use a R-19 + R-11 Liner System. This is not the same as simply specifying an R-30 fiberglass insulation system. By doing so would be incorrect. The effective R-value of this system would be an R-27 ($1/U-0.037$). This reduction in R-value highlights heat flow bypassing or thermally short-circuiting the fiberglass through the purlins. See [Figure 5.1-1](#) below.

In order to meet the U-0.037, the roof assembly would need to be constructed in the following manner (see also ASHRAE Standard 90.1-2013, Table 5.5-5, Section A2.3.2.4, Section A2.3.3, and Table A2.3.3):

The R-11 unfaced fiberglass is installed perpendicular to the purlins and compressed between the purlins and a standing seam roof (SSR) with roof clips and the purlins being spaced at least 52 inches with a minimum R-3 thermal spacer block. Furthermore, the U-factor takes into account the uncompressed, unfaced R-19 insulation resting on top of the continuous membrane that is secured to the bottom of the purlins by way of metal banding.

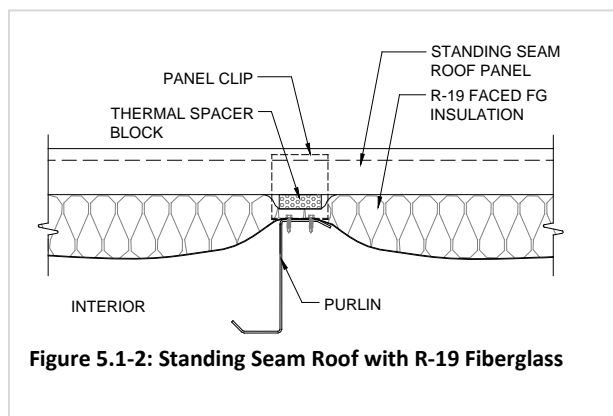


Single-Layer Metal Building Roof Example

This reduction in effective R-value may be better explained looking at a single-layer of fiberglass insulation material. Take for example a semiheated space in Climate Zone 5. Per ASHRAE Standard 90.1-2013, a metal building roof with R-19 fiberglass insulation has an assigned U-factor of U-0.082 or an effective R-value of R-12 ($1/U-0.082$). See [Figure 5.1-2](#) below.

In order to meet the U-0.082, the roof assembly would need to be constructed in the following manner (see also ASHRAE Standard 90.1-2013, Table 5.5-5, Section A2.3.2.1, Section A2.3.3, and Table A2.3.2):

The R-19 faced fiberglass is installed perpendicular to the purlins and compressed between the purlins and a standing seam roof with R-3 spacer blocks. The base assembly is the same as above.



5.2 Common Methods for Insulating a Metal Building

Some of the most common ways to insulate a metal building are described in the following sections, which include fiberglass, continuous insulation, fiberglass plus continuous insulation, and insulated metal panel systems. The architect and/or engineer and the general contractor are often the entities who make decisions regarding the selection of the insulation system with input from the building owner.

5.2.1 Fiberglass Systems

In roof applications, either a standing seam roof (SSR) or a through-fastened roof (TFR) would be installed over the insulation and secured to the purlins. Standing seam metal roofs provide greater thermal efficiency than through-fastened roofs because the roof clips provide more space and less compression of the insulation at the purlin. Thermal spacer blocks (TSBs) are installed in most standing seam roof applications between the metal roof panels and the insulation. The materials commonly used for TSBs are expanded polystyrene foam and polyisocyanurate foam. The thermal spacer blocks fulfill two purposes:

- They improve the thermal performance by reducing the conduction of energy through the roof purlins.
- They fill the space between the roof panels and the purlins, which is created by the standoff clips which in turn provides some support to the panel.

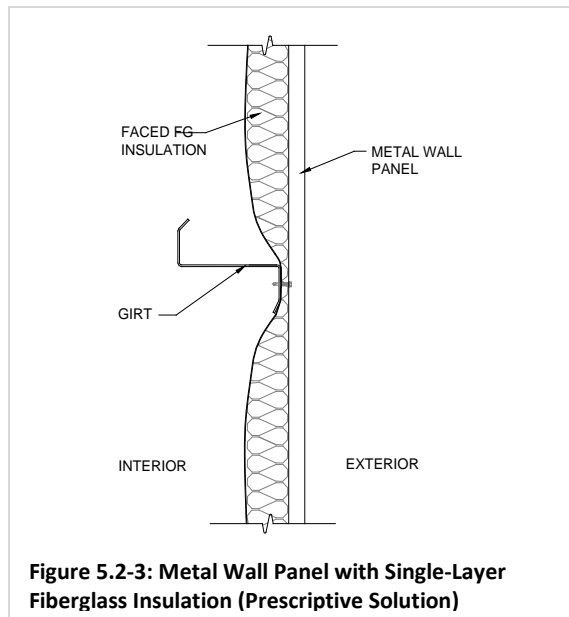
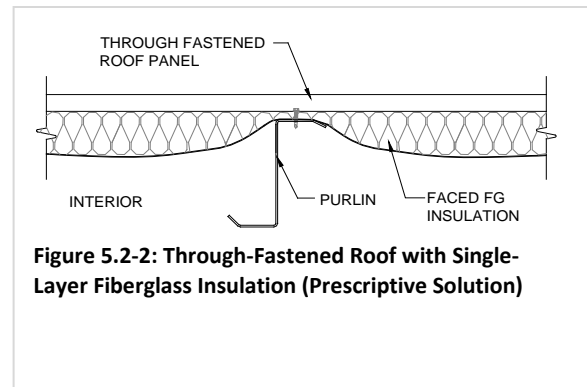
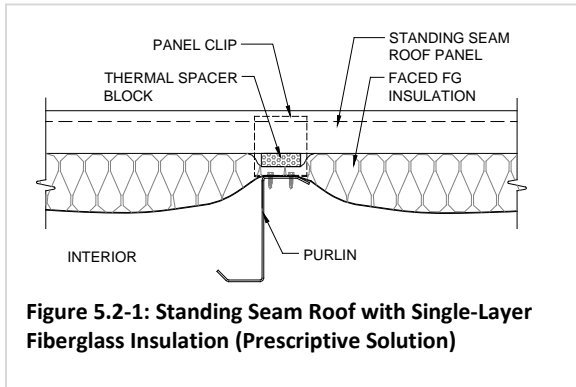
The thermal spacer blocks are typically about 3 inches wide, 3/4 to 1 inch thick, and are installed along the length of the purlin in between the roof clips. Common R-values used in the energy codes for these thermal spacer blocks ranges from R-3, R-3.5 to R-5.

ASHRAE Standard 90.1 and the IECC both contain published performance values for draped and compressed fiberglass insulation systems. In addition to the published U-factors found in codes and standards, some manufacturers may provide data from hot box tests or finite element modeling to show compliance for proprietary systems as well as systems not prescriptively found in the code.

5.2.1.1 Single-Layer Compressed Fiberglass Insulation

A single-layer of fiberglass insulation is installed perpendicular to the roof purlins and wall girts and compressed between the panel and the secondary framing member. Typically, the R-values range from R-10 to R-19 can be used as the compressed insulation layer in these assemblies.

These single-layer insulation systems may be used with either through-fastened or a standing seam roof systems, as shown in [Figure 5.2-1](#) and [Figure 5.2-2](#), respectively, as well as, in wall applications with a metal wall panel, as shown in [Figure 5.2-3](#). Once the insulation has been installed, the metal roof or wall panels are secured over the insulation, which compresses the insulation at the framing.



Because the insulation is compressed at the framing, the thermal performance is limited by the insulation thickness that can be installed. For standing seam roof systems, almost all metal building manufacturers provide roof clips that will accommodate R-19 to R-30 fiberglass insulation compressed over purlins.

Current energy code requirements and market demand has reduced the popularity of single-layer fiberglass systems for conditioned metal buildings. Single-layer systems will likely remain an economical option for semiheated metal buildings as defined in ASHRAE Standard 90.1 for such end uses as warehouses, manufacturing and aircraft hangers due

to the cost-effectiveness of the method. However, more stringent energy codes have mandated lower U-factor requirements in the colder climate zones. This has necessitated the need for higher performing single and double-layer cavity filled roof and wall systems (see Section [5.2.2](#)).

As a side note, with any fiberglass insulation system, it is important that the insulation not be excessively compressed. In single-layer roof and wall systems it is important that the insulation be installed properly and not excessively taut, which can affect the expansion of the fiberglass and thermal performance. Table A2.3.3, in the ASHRAE Standard 90.1-2013, shows a reduction (compared to the 90.1-2010 standard) in the thermal performance of draped metal building insulation. This is due to concerns that insulation installers were not adhering to insulation manufacturer's recommendations and were overly compressing the insulation. This is shown in [Table 5.2-1](#) below, which compares the U-factors shown for comparable single-layer draped metal building insulation assemblies, in the ASHRAE Standard 90.1-2010 and 90.1-2013 Standards. Note that lower U-factors mean better thermal performance.

Table 5.2-1: Metal Building Single-Layer Roof Insulation - Reduction in Thermal Performance

Insulation	ASHRAE 90.1-2010	ASHRAE 90.1-2013
R-10	U-0.097	U-0.115
R-16	U-0.072	U-0.096
R-19	U-0.065	U-0.082

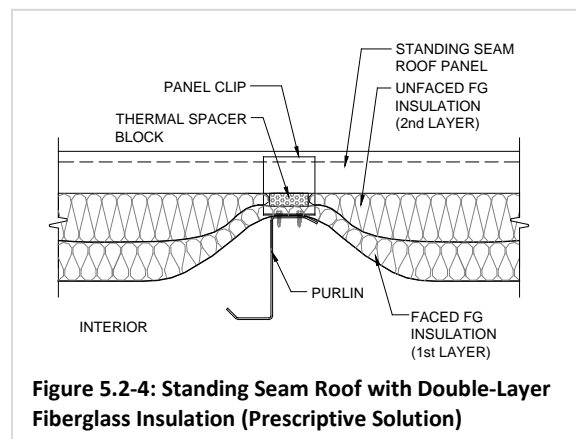
Other factors that can affect the installed performance of draped and compressed insulation in metal buildings are the space between the metal panel and the framing, and the spacing of the framing. For through-fastened roof and wall metal panels, it is assumed the insulation is fully compressed between the panel and secondary framing member. For a standing seam roof, it is assumed that a thermal spacer block is used that rests on top of the draped fiberglass insulation and an attaching clip that offsets the roof from the purlin by about 1.5 inches. This offset, combined with the use of a thermal spacer block, will significantly reduce the heat loss due to insulation compression, resulting in lower U-factors for standing seam roof assemblies. The U-factors shown for metal building roofs and walls in the reference tables of ASHRAE Standard 90.1-2013 appendices are based upon the average purlin or girt spacing of at least 52 inches.

5.2.1.2 Double-Layer Compressed Fiberglass Insulation for Roof Applications

Double-layer drape and fill insulation systems can use any nominal combinations of fiberglass such as R-10 + R-10, R-10 + R-13, R-13 + R13, R-13 + R-19, etc. This system is used in roofs where greater thermal performance than a single-layer system is required.

Different ways have been used to describe or specify double-layer insulation systems. In this Guide, we describe the "first layer" as the first installed layer over the purlin and listed first in the description. The "second layer" is the second installed unfaced fiberglass layer and is listed second in the description. This may differ from how various double-layer systems are described in other standards but will be consistently defined in this manner in this Guide.

Double-layer fiberglass roof insulation systems use a similar method of installation as single-layer roof systems, but with an added layer of unfaced insulation to increase the thermal performance. The most common method is to install the first layer of faced fiberglass blanket perpendicular, over the purlins, and then a second layer of unfaced insulation is installed on top of the first layer, parallel to the purlins (See [Figure 5.2-4](#)). For example, R-13 + R-19 insulation assembly means the R-13 layer is the faced layer over the purlins and the R-19 layer is the second unfaced layer on top and parallel to the purlins.



Similar to the single-layer systems discussed in Section [5.2.2.3](#), there are practical limits on thickness for the first layer because it is compressed over the purlins. The second layer is usually thicker than the first layer. It is important that the insulation installer is thoroughly trained to allow for enough drape in the first layer of insulation so that the second layer of insulation is not overly compressed due to the tension of the facing when the roof panels are installed. To ensure that the installer can accomplish this, the ordered insulation lengths must account for the expected drape. As discussed above, with the assumption made by ASHRAE that the installation of the insulation is not allowing for proper drape, the ASHRAE Standard 90.1-2013 downgraded the thermal performance of double-layer systems as shown in [Table 5.2-2](#).

Table 5.2-2: Metal Building Double-Layer Roof Insulation - Reduction in Thermal Performance

Insulation	ASHRAE 90.1-2010	ASHRAE 90.1-2013
R-10 + R-13	U-0.058	U-0.082
R-13 + R-13	U-0.055	U-0.075
R-13 + R-19	U-0.049	U-0.068

5.2.2 Cavity Filled Insulation Systems

The term “cavity filled” can be generically used to describe any insulation system that is installed in-between structural framing without significant voids. One should refer to specific assembly descriptions in the energy code or product literature with regard to the cavity-filled system being selected or specified. Each type of insulation will have specific performance characteristics in terms of overall U-factor, speed of installation and vapor permeability. These systems are often supported by banding, rigid boards or other means of support attached to the bottom of the roof purlins.

This method has advantages in that it allows for the full depth of the purlin or girt to be filled with insulation and can provide a higher thermal performance than the traditional draped and compressed insulation systems. The purlin or girt depth must be considered when selecting the insulation combination, because the entire cavity should be filled as a best practice to avoid the potential for condensation.

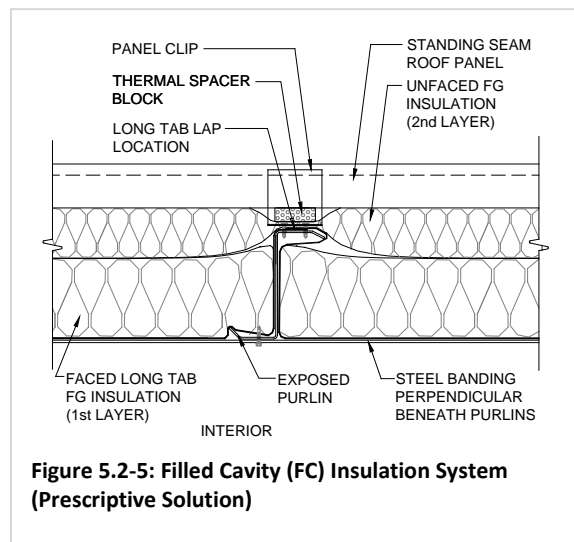
The energy codes include cavity filled roof and wall options for metal buildings. The IECC and the ASHRAE Standard 90.1 labels these systems as "Filled Cavity (FC)" and "Liner Systems (LS)." With the introduction of Addendum 'cp' to modify ASHRAE Standard 90.1-2013, there are two additional cavity filled options for metal building wall assemblies. These cavity filled insulation wall assemblies are labeled as "Single-Layer in Cavity" and "Double-Layer" systems. Each of the four systems is described below.

5.2.2.1 Filled Cavity (FC) for Roof Applications

The Filled Cavity (FC) insulation system utilizes laminated insulation installed in the roof of a metal building. This system is often known as the “long tab and banded system” (see [Figure 5.2-5](#)). The lower layer of insulation arrives at the job site with an integral laminated vapor retarder that has extra vapor retarder material (the “tab”) that extends beyond the fiberglass on both sides. It is important that the purlin depth is known when the insulation is ordered to ensure that the proper tab length is provided. The first layer of insulation is installed parallel to, and between the purlins with the facings down to the inside of the buildings. This layer is supported by steel banding running

perpendicular to the purlins. The tabs should extend alongside of, and over the purlins, where they can overlap the tabs from the adjacent purlin space. The second layer of insulation (typically unfaced) is then installed perpendicular to, and over the purlins filling the cavity. This system works with both through-fastened and standing seam roofs. It provides a finished appearance on the inside, leaving the purlins exposed for easy access by the mechanical trades.

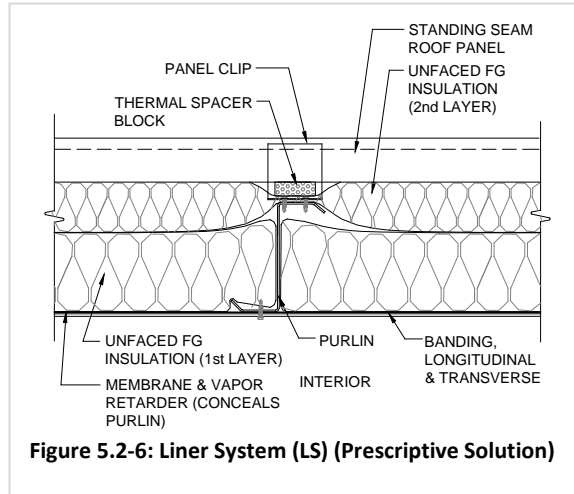
Commonly used systems in conjunction with 8" purlins include: R-19 + R-10, R-19 + R-11, R-19 + R-13, R-25 + R-10, and R-30 + R-11 (for 12" deep purlins), where the first rated layer in the notation is the faced layer, and the second rated layer is the unfaced layer, etc.



5.2.2.2 Liner System (LS) for Roof Applications

There are several proprietary Liner Systems (LS) in the marketplace with slightly different features used to insulate a metal building roof. One type, as shown in [Figure 5.2-6](#) utilizes steel banding installed in a grid pattern under the purlins. A separate vapor retarder membrane liner is then pulled under the purlins and over the bands. The liner and the grid bands are fastened to the bottom of the purlins after the liner is in place. The installer then installs unfaced fiberglass between the purlins on top of the liner. Next, rolls of unfaced fiberglass are placed perpendicular over the purlins, completely filling the cavity. This system works with both through-fastened and standing seam roofs, provides a finished appearance on the inside, and the liner completely covers the purlin, so they are not visible from the inside of the building. The vapor retarder membrane liner must be sealed to all primary structural frames and to any penetrations due to framing braces, and suspended fixtures such as lights, sprinklers, and HVAC ducts must also be sealed.

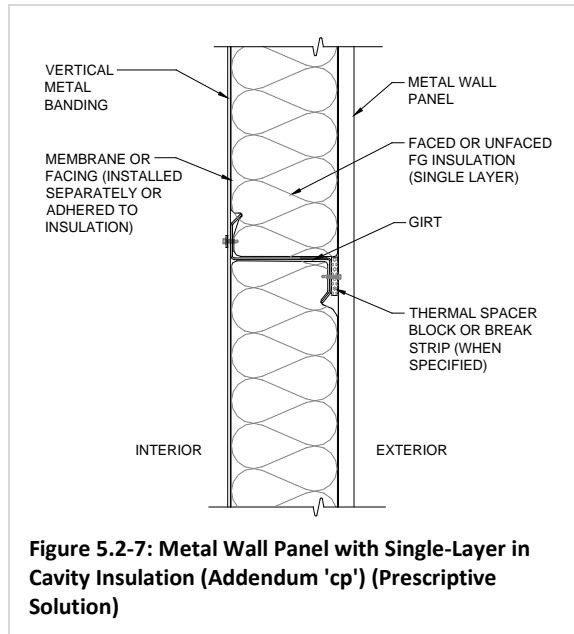
Common roof systems used in conjunction with 8-inch purlins include: R-19 + R-11, R-19 + R-13, R-25 + R-11, and R-30 + R-11 (for 12 inch deep purlins), etc., where the first nominal R-value is the first installed layer (lower) and the second nominal R-value is the final (upper) layer that is compressed at the purlins.



5.2.2.3 Single-Layer in Cavity for Wall Applications

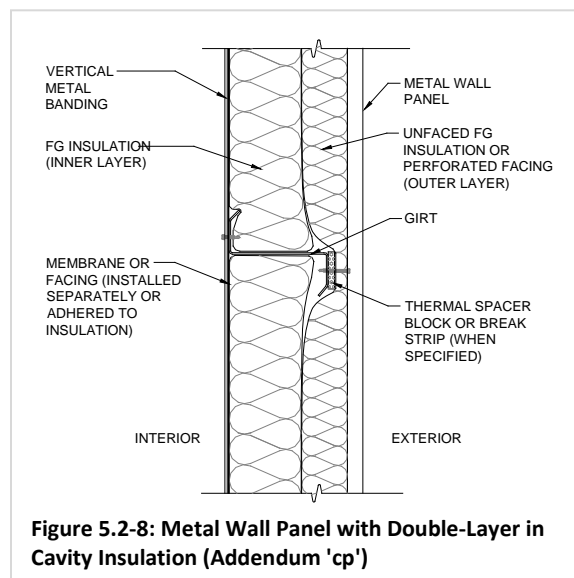
Single-Layer in Cavity is a fiberglass insulation system introduced in 2016 via Addendum 'cp' to the ASHRAE Standard 90.1-2013 version, as illustrated in [Figure 5.2-7](#). This system differs from the commonly used single-layer system described above in that the single-layer wall insulation is either R-25 or R-30 and is installed between the girts. Addendum 'cp' describes this type of system as having the insulation installed in the cavity between the girts, not compressed by the framing. A vapor retarder membrane or facing, installed separately or adhered to the insulation, is installed between the girts to form a continuous layer. A thermal spacer block or thermal break strip between the girts and metal walls panels is required when specified in ASHRAE Standard 90.1 Table A3.2.3 or when recommended by product supplier to meet the intended assembly U-factor. The information contained in this addendum will be a part of the ASHRAE Standard 90.1-2016 published version.

Since the Single-layer in Cavity systems are not compressed between the metal wall panel and the girts, a layer of continuous insulation (ci) may be installed between the girts and the metal wall panel in lieu of thermal spacer blocks or thermal break strip.



5.2.2.4 Double-Layer Cavity Filled for Wall Applications

Historically, double-layer wall insulation systems were described in the ASHRAE Standard 90.1 prior to 2010 version. These systems consisted of two fiberglass layers of insulation, one unfaced layer compressed between the metal wall panel and the girt and a faced layer installed between the girts. These double-layer systems were designated as "Double-Layer of Mineral Fiber" wall systems. In the ASHRAE Standard 90.1-2013 edition, however, these insulation assembly types were removed due to issues with constructability and general lack of use.



In 2016, Addendum 'cp' to the ASHRAE Standard 90.1-2013 was issued that included a new type of double-layer wall insulation system (see [Figure 5.2.8](#)). The double-layer systems have one layer installed between the girts to fill the cavity and one layer compressed between the metal wall panel and the girt. A vapor retarder membrane or facing is installed separately or adhered to the insulation and is installed over the exposed girts to form a continuous layer. The following double-layer combinations are available via Addendum 'cp': R-25 + R-10, R-25 + R-16, R-25 + R-10 with thermal spacer block, and R-30 + R-16. For instance, the R-25 would represent the uncompressed cavity filled layer and the R-10 would represent the compressed layer between the girt and the wall panel. A thermal spacer block or thermal break strip between the girts and metal walls panels may be required when specified in ASHRAE Standard 90.1 Table A3.2.3 or when required by product supplier to meet the listed assembly U-factor. Due to the outer layer of fiberglass insulation being compressed between the girt and the wall panel, it was determined to not include the option to add continuous insulation to Table A3.2.3 for constructability reasons.

5.2.3 Continuous Insulation Systems

Continuous insulation is abbreviated in the IECC and ASHRAE Standard 90.1 as "ci" in the prescriptive tables and 90.1 Appendix Tables A2.3 and A3.2 for metal building roofs and walls, respectively. ASHRAE Standard 90.1-2013 has renumbered these tables as A2.3.3 and A3.2.2. Both the IECC and ASHRAE Standard 90.1 define continuous insulation as "insulation that is uncompressed and continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope." Based on this definition, the continuous insulation may be installed above or below the roof purlins or on the inside or outside portion of the exterior wall girts.

The energy codes and standards are silent on what types of products may be considered "continuous insulation." There are a variety of products that may meet the definition of continuous insulation. Continuous insulation is a form of foam plastic insulation; thereby the International Building Code (IBC) includes provisions in IBC Chapter 26 (see [Section 5.2.3](#) for more information).

Brief descriptions of the various foam plastic insulation product types are noted below. Remember, that if the product does not meet the definition of continuous insulation in order to meet the prescriptive U-factors or R-values called out in the IECC or ASHRAE Standard 90.1, then the product manufacturer will need to provide justification via testing reports or calculations by approved methods that validate the claimed U-factor of the assembly. Products that do not meet the definition of continuous insulation should not be used to comply where the code specifically calls for continuous insulation and should not be entered in software tools as continuous insulation.

It should also be noted that the R-value of foam plastic insulation is dependent upon temperature. Generally, measured R-values are higher at lower temperatures. Therefore, when comparing R-values between systems and manufacturers, be sure the comparison is made at the same temperature. In order to be consistent with the FTC R-value rule, 75°F is commonly used, but other temperatures may be more appropriate depending upon climate, construction and occupancy.

Faced Polyisocyanurate Rigid Foam Board Insulation

The specification that covers the general requirements for polyisocyanurate (polyiso) foam board insulation is ASTM C1289-15, *Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board* (ASTM, 2015). Generally, the R-value per inch for faced polyiso insulation board is about R-6 to R-6.5, as supported by the information provided in ASTM C1289. In any event, energy codes usually specify a required R-value or U-factor, rather than a specific thickness or type of insulation. It is important to verify that the rated R-value of the installed product has been determined in accordance with the appropriate standard for the product type as listed in the IBC.

Polyisocyanurate foams can have a variety of facings and may have additional components added to provide core foam reinforcement. Many rigid insulation board products have an integral vapor retarder laminated during the manufacturing process. These products will generally not require a separate field-applied vapor retarder but will require proper sealing of the board joints in accordance with the board manufacturer's installation instructions. Not all foam products have or qualify as a vapor retarder, so check the manufacturer's specifications to make sure the product qualifies for the specific requirements of a given project.

Unfaced Polystyrene Rigid Foam Board Insulation

The specification that covers the general requirements for polystyrene foam board insulation is ASTM C 578-15b, *Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation* (ASTM, 2015). This product may be in the form of extruded or expanded polystyrene, with an R-value that can range from about R-3 to R-5.4 per inch at 75°F.

Sprayed Polyurethane Foam Insulation

The specification that covers the general requirements for spray-applied polyurethane foam (SPF) insulation is ASTM C1029-15, *Standard Specification for Spray-Applied Cellular Polyurethane Foam* (ASTM, 2015). There are two SPF types, open-cell and closed cell.

- Open-cell SPF has an insulating value of approximately R-3.5 per inch at 75°F and is considered permeable to water vapor.

- Closed-cell SPF has an insulating value of approximately R-6.5 per inch at 75°F and is considered to be water vapor resistant.

Manufacturer's specifications should be reviewed to determine whether a distinct vapor retarder is necessary to comply with project requirements, which can vary depending upon the climate and interior environmental conditions.

In order to meet the definition of a continuous insulation (c.i.) and be compliant with the prescriptive R-values noted in the IECC and ASHRAE Standard 90.1 tables, the layer of SPF must either provide a consistent thickness around the framing members or include a thermal block to short circuit the thermal bridging where the metal panel connects to the framing member. See [Figure 5.2-14](#). If this does not occur, the product manufacturer will need to provide test reports or calculations by approved methods that validate the claimed U-factor of the assembly.

Unlike other forms of foam plastic insulation described in this Section of the Guide, SPF is adhered directly to the surface being applied to with the expectation that the product will not become dislodged over time, thus providing the desired thermal insulating properties that include an air barrier system to minimize air leakage.

Some standing seam roofs are specifically designed for thermal expansion and contraction of metal panels. Applying SPF directly onto such roofs can restrict movement or cause localized separation of the SPF from the metal substrate. Discussions with manufacturers of the SPF product, along with the manufacturers of the metal roof and wall panel products, are important in assuring compatibility and adequate adhesion of these products. This may include compatibility with the published performance of the painted or metallic materials or for expansion and contraction when needed. Proper spraying techniques when applying SPF to the metal roof or wall panels may be necessary to avoid deformation or oil canning since SPF temperatures during the curing process can be as high as 325°F.

SPF should only be installed by trained SPF professionals who understand the installation conditions, safety requirements and proper application techniques for the specific SPF being sprayed. The Air Barrier Association of America (www.airbarrier.org) and the Spray Polyurethane Foam Alliance (www.sprayfoam.org) provide additional information about SPF and their certified installer programs.

Insulated Metal Panels

Insulated metal panels are used in many applications that require high insulating properties and a durable interior liner surface. These panels can be up to 6 inches thick and have excellent R-values to meet the needs of refrigerated warehousing, freezer buildings, and the ever-increasing energy code provisions for thermal insulation.

Insulated metal panels are typically clad with either steel or aluminum. Various manufacturers have different panel profiles and side lap connections. Some use simple side laps with exposed through fasteners. Others use tongue-and-groove systems with hidden fasteners. Some roof systems even have standing seam side laps.

Either the foam fill in these panels can be foamed in place, or they can be a glued laminated sandwich panel. The foam fill for either panel type can vary, which will dictate the assembly performance. Usually the material used in foamed-in-place panels will be polyurethane or polyisocyanurate foam, while sandwich panels are most likely to use polystyrene of varying densities, although polyisocyanurate foam can also be used. In some cases, usually in situations where fire protection ratings are desired, slag wool cores are used to create sandwich panels, which have both thermal and fire resistance properties.

R-values for foamed-in-place panels range from about R-6 to R-8 per inch depending on the panel manufacturer's process. R-values for sandwich panels with laminated polystyrene core range from about R-4 to R-5.5 per inch.

There are several panel configuration options for walls. There are flat, planked, and striated exterior profiles. The R-values available with core systems for both roofs and walls range from about R-13 to R-46 depending on the foam, thickness, and manufacturer. An insulated metal panel may be used to meet the required U-factor specified by the energy code or standard, as long as the product manufacturer provides test reports or calculations by approved methods that validate the claimed U-factor of the assembly.

5.2.3.1 Building Code Fire Safety Requirements for Foam Plastic Insulation

The 2015 International Building Code, Section 2603 Foam Plastic Insulation, has a number of fire safety requirements for all foam plastic insulation products. These provisions would apply to rigid foam boards, SPF, and the cores of the insulated metal panels referenced above. The following outlines the fire safety requirements that may be applicable to metal building system projects:

According to IBC Section 2603.3, all foam plastic products and foam plastic cores of manufactured assemblies shall be tested and have a flame spread index of not more than 75 and a smoke-developed index of not more than 450. ASTM E84-15b or UL 723 are used as the test methods.

Foam plastic products and cores that exceed 4 inches in thickness shall be tested at a minimum thickness of 4 inches and pass the full-scale tests that are referenced in Section 2603.9 using the thickness and density intended for use.

Per IBC Section 2603.4, foam plastic products and foam plastic cores of manufactured assemblies in exterior walls of any height buildings, shall be separated from the interior

of a building by an approved thermal barrier of 1/2 inch gypsum board or an equivalent 15-minute thermal barrier fire protective surface that is tested in accordance with and meets the acceptance criteria of both the temperature transmission fire test and the integrity fire test of NFPA 275.

An exception to the thermal barrier requirements is full scale testing of foam plastic products in accordance with Section 2603.9, such as NFPA 286, FM 4880, UL 1040, or UL 1715, where tests are related to the actual end-use configuration. See additional requirements in Section 2603.5.4, where applicable.

Per Section 2603.5, foam plastic products and foam plastic cores of manufactured assemblies located in the exterior walls of any height shall meet all of the following:

- Meet fire-resistance-rated wall requirements, when required to have a fire rating.
- Meet the thermal barrier requirements of Section 2603.4, with an exception for one-story buildings complying with Section 2603.4.1.4.
- Potential heat requirements, with an exception for Type V and one-story buildings complying with Section 2603.4.1.4.
- Flame spread index of 25 or less and smoke-developed index of 450 or less (in addition to thermal barrier requirements above) per E84 and cannot exceed 4 inches in thickness.
- The exterior wall assembly shall meet NFPA 285, except for one-story buildings complying with Section 2603.4.1.4 or where insulation is covered by not less than 1-inch of masonry or concrete.
- Additional exceptions may apply that are not covered in this Guide.

Section 2603.4.1.4 provides an exception from thermal barriers mentioned above for exterior walls assemblies on one-story buildings. These exemptions may include insulated metal panels or any metal liner panel covering a foam plastic when meeting all of the following requirements:

Installed on a one-story building equipped with an automatic sprinkler system.

The foam plastic has a flame spread index of 25 or less, a smoke-developed index of not more than 450, not more than 4 inches thick.

The foam plastic is covered by a thickness of not less than 0.032-inch-thick aluminum or corrosion-resistant steel having a base metal thickness of not less than 0.016 inch thick.

However, most insulated metal panel manufacturers list their products in compliance with the more stringent requirements of IBC Section 2603.9 through third-party agencies, such as UL and FM Global. In this case, thermal barriers are not required in most exterior wall applications with insulated metal panels.

Although these described code requirements are generally applicable to most metal building applications, other IBC provisions should also be reviewed in light of a specific project. Be sure to verify with the product manufacturer that the product has been properly fire tested and is code compliant for the intended use.

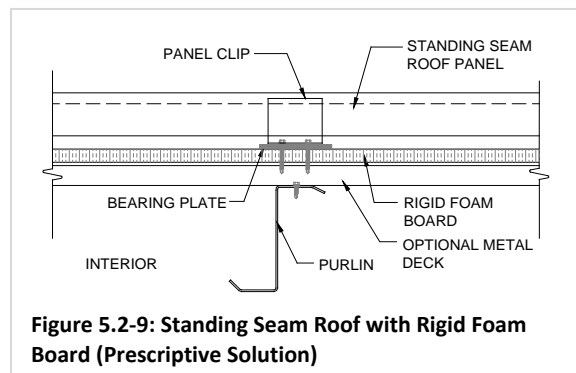
For more information about fire code provisions for other aspects of metal building systems, refer to the MBMA *Fire Resistance Design Guide for Metal Building Systems* (MBMA, 2010).

5.2.3.2 Continuous Insulation Used Independently

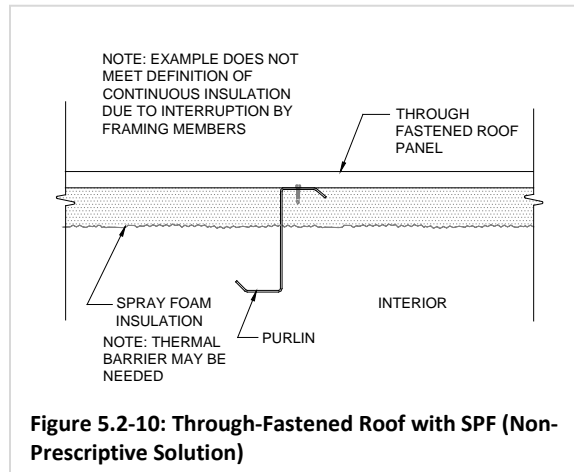
Roof Applications

In order to meet the thermal properties listed in ASHRAE Standard 90.1 Table A2.3 for metal building roofs, one could use the prescriptive continuous insulation (ci) systems described in Sections [5.2.3](#) above, as long as the insulation meets the definition of continuous insulation as defined by both the IECC and ASHRAE Standard 90.1.

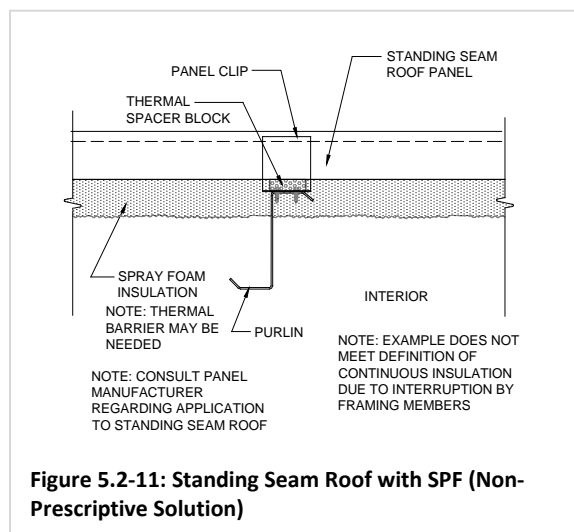
Rigid foam board insulation is typically installed above the purlins in either standing seam or through-fastened roof systems. In the case of standing seam roofs and clips, the roof manufacturer should provide an additional steel bearing plate to support each clip as shown in [Figure 5.2-9](#). The manufacturer can supply supporting documentation and installation details for this case. In the case of through-fastened roofs, the roof manufacturer should be contacted regarding compatibility and fastening techniques for weather resistant performance. The manufacturer can supply supporting documentation and installation details for this case. When rigid insulation systems are used, proper communication is essential to ensure all necessary materials and attachment hardware are ordered.



SPF applications would be to the underside of the standing seam roof or through-fastened roof system and would not meet the prescriptive continuous insulation definition. The through-fastened roof applications, in the IECC and ASHRAE Standard 90.1, do not include a thermal spacer block. This allows the metal roof panel to securely fasten to the purlin to avoid fastener movement that would be caused by a thermal spacer block (i.e., rigid foam board), as shown in [Figure 5.2-10](#).

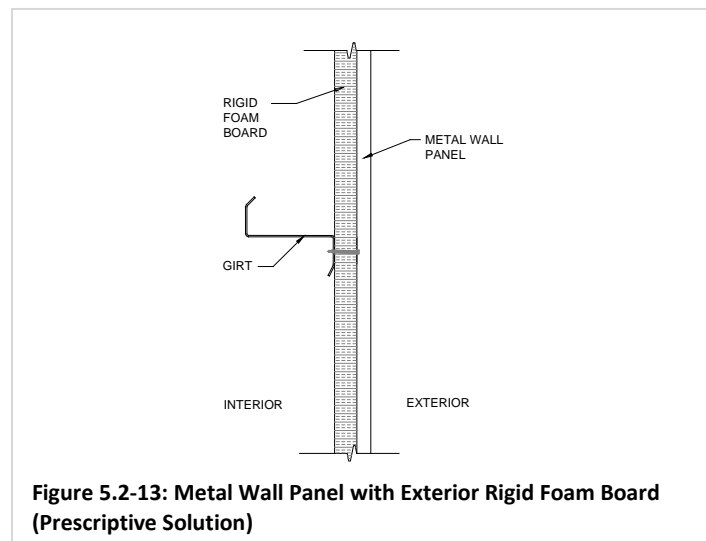
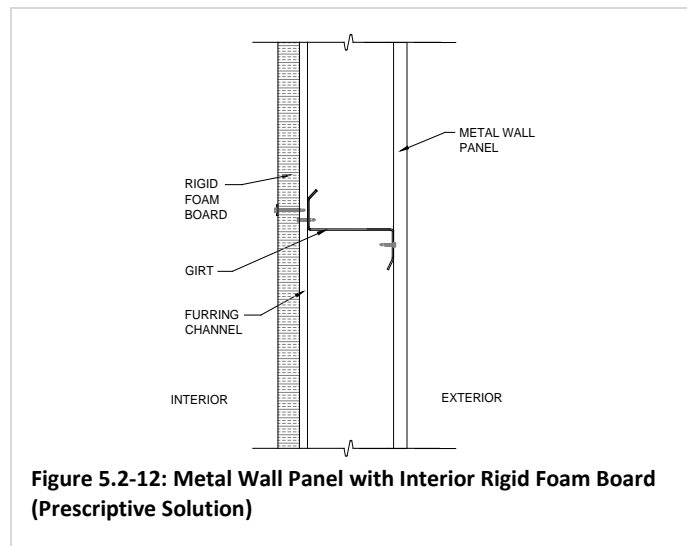


Although, the above cautions the application of SPF on the underside of a standing seam roof, when appropriate the SPF may be used, as illustrated in [Figure 5.2-11](#). A thermal spacer block is typically used with a standing seam roof. However, it is limited to about 1 inch thick (or an R-5). If the prescriptive U-factor and R-value tables permit an R-5 or less in the roof application, then SPF can be applied to meet the low insulation level requirements (such as in Climate Zone 1, Semiheated Spaces, ASHRAE 90.1-2007). Consequently, this would meet the definition of continuous insulation. The prescriptive R-values of a metal building roof greatly increases in the later editions of the energy codes and the various climate zones that would not enable SPF to qualify as a continuous insulation.



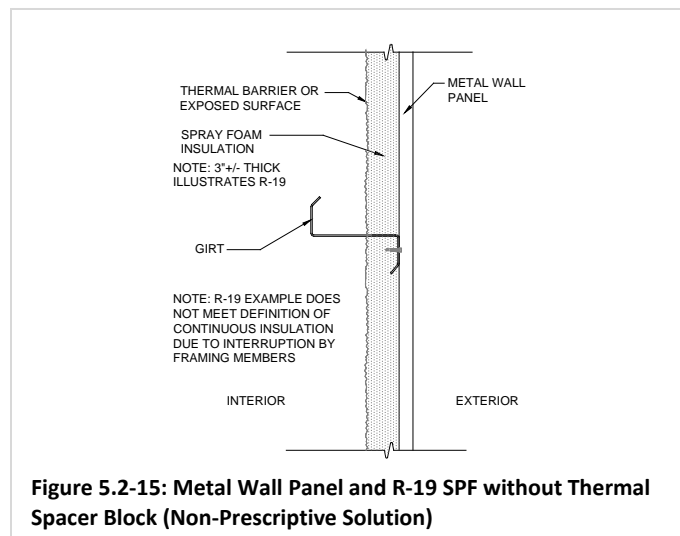
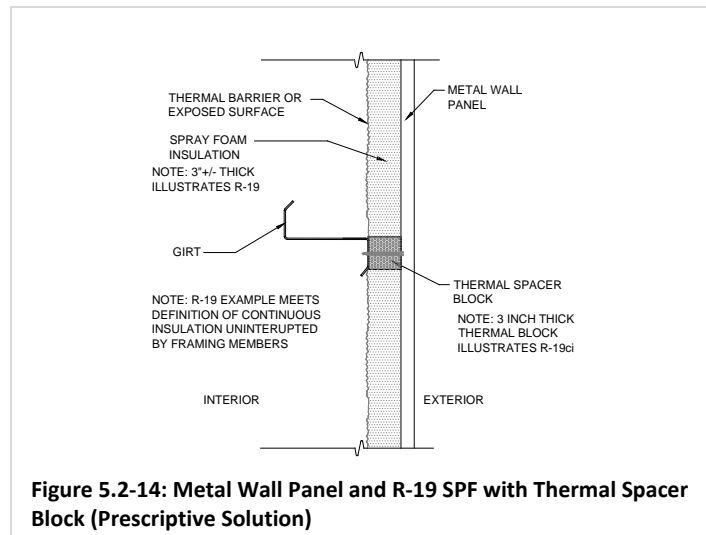
Wall Applications

Wall applications may include a layer of rigid foam insulation installed between the metal wall panel and the girt, as shown in [Figure 5.2-13](#), or on the interior portion of the wall, per [Figure 5.2-12](#), to meet the prescriptive continuous insulation provisions. SPF applications include applying the product to the interior side of the metal wall panel to the specified thickness to meet the intended or required U-factor.



Additionally, a thermal spacer block must be included between the girt and the metal wall panel of the same prescriptive R-value, in order to meet the definition of continuous insulation, as shown in [Figure 5.2-14](#). Another option would be to not include the thermal spacer block and apply the SPF between the framing members, as

shown in [Figure 5.2-15](#), or around the profile of the framing member. However, the SPF supplier would need to validate the intended U-factor based on test reports or approved calculation methods.



Fiberglass plus Continuous Insulation Systems

As previously noted, the IECC and ASHRAE Standard 90.1 prescriptive insulation tables point to ASHRAE Standard 90.1 Appendix A for assembly descriptions or additional insulation systems to meet the U-factor value or to a validated U-factor via testing or approved calculation methods. For discussion purposes of this portion of the Guide, refer you to ASHRAE Standard 90.1-2013 Table A2.3.2, Table A3.2.2 and Addendum ‘cp’ for assembly U-factors for metal building roofs and walls. These tables provide the options to include continuous insulation (ci) systems by themselves or in conjunction

with fiberglass assemblies. Of course, the manufacturer can supply tested assembly U-factors or calculations for a system that deviates from those listed in Tables.

As the adopted version of IECC or ASHRAE Standard 90.1 varies across the country, it is acceptable to reference a more recent published version of the standard to obtain U-factor values for an insulation assembly.

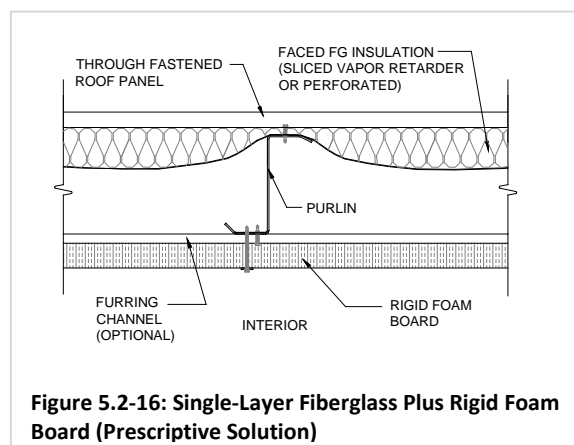
ASHRAE Standard 90.1-2013 Table A2.3.3 for metal building roof assemblies does not combine continuous insulation systems for all fiberglass insulation assemblies, only for the single-layer, double-layer and filled cavity assemblies listed.

ASHRAE Standard 90.1-2013 Table A3.2.2 for metal building wall assemblies only includes the single-layer fiberglass insulation option with continuous insulation in combination. Addendum cp expanded this list to include single-layer in cavity and double-layer fiberglass systems. Continuous insulation may be included with the single-layer in cavity solution but is not shown with the double-layer system.

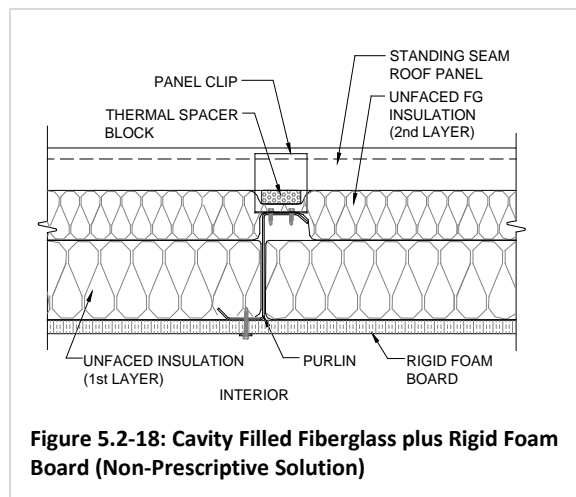
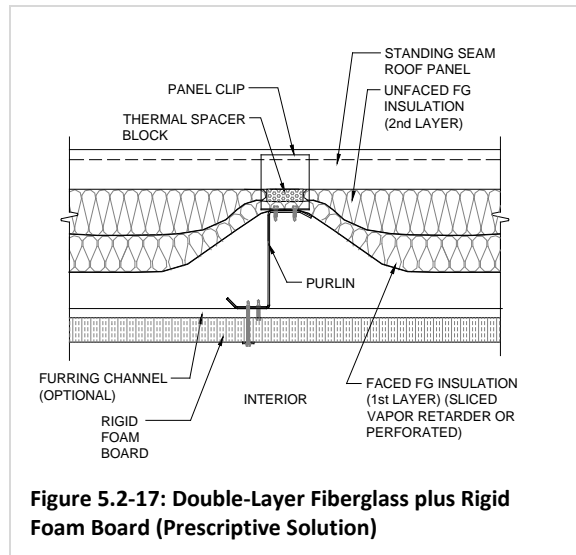
To elaborate further, summarized are the following fiberglass insulation systems in conjunction with continuous insulation below.

Roof Applications

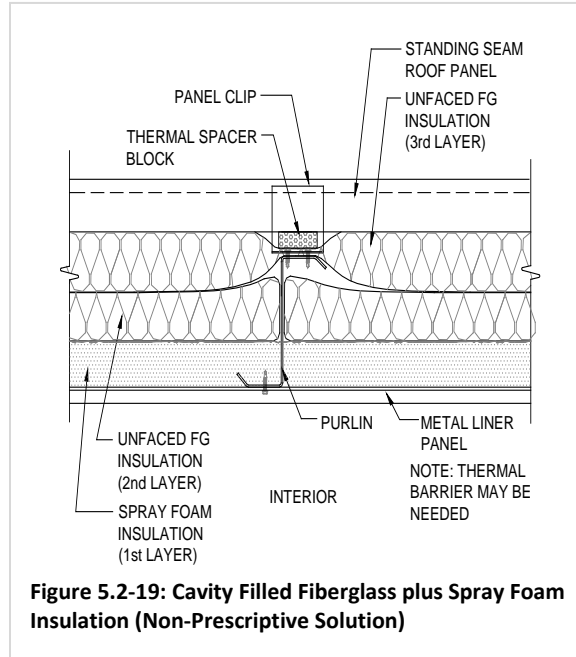
Continuous insulation installed in conjunction with single-layer or double-layer fiberglass systems would typically be installed beneath the purlin, as shown in [Figure 5.2-16](#) and [Figure 5.2-17](#). To avoid condensation issues, it is important that either the faced layer of the fiberglass insulation is cut in a number of locations to allow air to pass through (in retrofit applications) or the layer of fiberglass insulation would have a perforated facing. The reason being is that the continuous insulation layer will be serving as the vapor barrier.



A variation of the filled cavity or liner systems may include rigid foam board attached underneath the purlin in lieu of the banding and vapor retarder systems similar to [Figure 5.2-18](#). For retrofit applications, where a vapor retarder exists, it is important to slice the vapor retarder to avoid condensation issues. Continuous insulation systems that are not continuous across framing members would need to have the product manufacturer provide test reports or calculations by approved methods that validate the intended U-factor of the assembly.

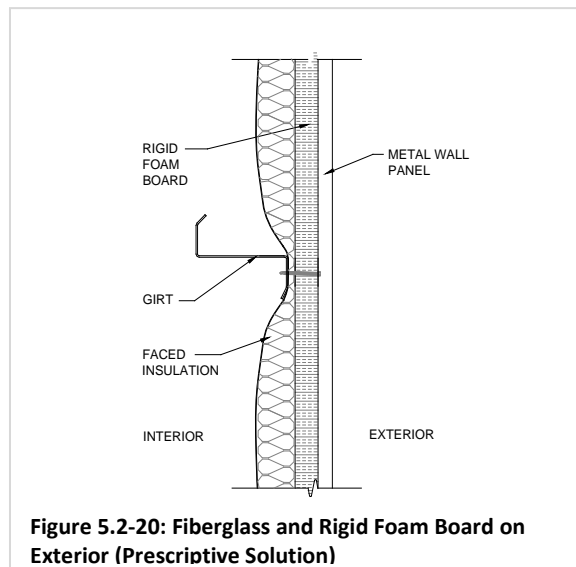


For SPF applications in conjunction with fiberglass in the roof, the SPF provides a layer of insulation applied to the backside of the roof liner panel with the balance of the cavity space filled with fiberglass as shown in [Figure 5.2-19](#). Since the framing member interrupts the SPF, this would not meet the definition of continuous insulation. Thereby, this insulation roof assembly would need to be validated via testing or approved calculation methods.

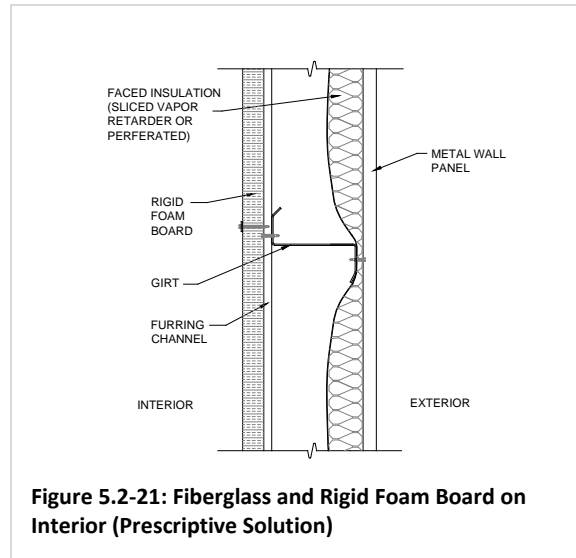


Wall Systems

Wall systems may also include foam board in combination with fiberglass insulation. Prescriptive tables in the IECC and ASHRAE Standard 90.1 include one layer of fiberglass wall insulation plus a layer of continuous insulation (ci), as shown in [Figure 5.2-20](#). The rigid board may also be installed on the interior, as shown in [Figure 5.2-21](#). The 2013 version of ASHRAE Standard 90.1 removed this prescriptive combination and simply called out a layer of continuous insulation (ci) to meet a certain R-value. However, ASHRAE Standard 90.1 Appendix A Table A3.2.2 includes U-factors for these combination systems to refer to, along with the addition of Addendum 'cp'.



For new construction or retrofit projects where the goal is to improve the existing wall insulation performance, the rigid insulation can be installed on the building interior. If the building has existing faced fiberglass insulation that is not planned for removal, it is a good practice to cut or puncture the existing fiberglass insulation facing to prevent the creation of a double vapor barrier in the wall system, as shown in [Figure 5.2-21](#). This practice is intended to reduce the potential for condensation under certain conditions.



It is important for the architect and/or engineer to be aware of the location of any pre-existing vapor retarders for retrofit projects so that actions can be accounted for in the field to ensure they have been properly dealt with. For new construction, the facing of the fiberglass could be perforated to allow air to pass through when continuous insulation is specified on the interior of the girts. In many cases, the insulation board can be installed behind a metal liner panel. This may be desirable for a number of reasons, for instance in an active warehouse or manufacturing facility where the building activity could cause physical damage to the insulation.

For published ASHRAE Standard 90.1 assembly U-factors that account for prescribed fiberglass plus various combinations of continuous insulation, refers to Table A2.3 and Table A3.2 for metal building roofs and walls respectively. Various thicknesses of rigid board can be used, but with a typical minimum of 1 inch. Joints are sealed per the manufacturer's instruction to provide a vapor retarder.

5.2.3.3 Reflective Insulation – Hybrid Systems - Multiple Types

A number of reflective insulation systems are available for use in metal buildings. They differ in the type of material used as a core or substrate to support the reflective surfaces. Some core options include composite products with foams, cellular plastics, and fibrous material. A number of the reflective insulation assemblies that are available provide a continuous layer or layers of thermal resistance that reduces heat transfer through the girts or purlins.

The thermal performance of reflective insulation systems is primarily the result of its core insulation and the enclosed air spaces adjacent to its low-emittance surfaces. The enclosed air space performs best in reducing the radiant component of heat transfer. Core insulation reduces the conductive and convective components. The low-emittance surfaces are formed by aluminum foil or metalized film. It is important that there is an enclosed air space adjacent to the reflective surface in the assembly where specified by the product manufacturer to meet the intended R-value. Reflective air spaces have R-values that depend on the system orientation (heat flow direction), temperatures, and distance across the air space, surface emittance and limited air movement in and out of the enclosed air space as specified in the ASHRAE Handbook of Fundamentals. Without considering these characteristics the performance of the product will not be realized in the field. The air space must be within the air barrier in order to minimize airflow in or out of the air space. The low-emittance surface material is an important design feature of a reflective insulation system because it reduces the thermal radiation across the air space. The low thermal conductivity of air provides resistance to conductive heat transfer. It is important that this surface is not in an environment where it will become dirty or otherwise compromised over time as its low-emittance qualities are crucial to its performance.

Natural convection occurs in air spaces when the heat flow direction is up or horizontal. The amount of natural convection depends on spacing and temperature differentials. All of these features are part of the evaluation process for reflective insulation systems.

Hybrid insulation systems that combine traditional batt/blanket insulation with reflective assemblies can provide added R-value for the cavity region, but most important there is added thermal resistance in the heat flow path through the purlins. Reflective insulation systems are available for installation above the purlins, below the purlins, or in some cases between the purlins. Reflective insulation may be available, perforated with vapor transmitting properties, designed for vapor transmission when required.

The reflective insulation industry offers both stand-alone systems and hybrid systems for use in the wall and roofs of metal buildings. These hybrid systems include using the reflective insulation to the outside or to the inside of the girts or purlins combined with traditional batt/blanket insulation. These hybrid walls or roof systems allow the building contractor to achieve higher R-values requirements.

For additional information on the subject:

- ASHRAE Standard 90.1-2013 Addendum 'ac' includes specific installation information regarding non-reflective and reflective air spaces.
- ASHRAE Standard 90.1-2013 Table A9.4.2-1 Values for Cavity Air Spaces, contains thermal performance values for a variety of assemblies.
- 2013 ASHRAE Handbook of Fundamentals, page 26, contains a description of reflective insulation systems. Furthermore, Table 3, page 26.13, provides additional data on assembly thermal performance values.

Chapter 6 Commercial Compliance Using COMcheck

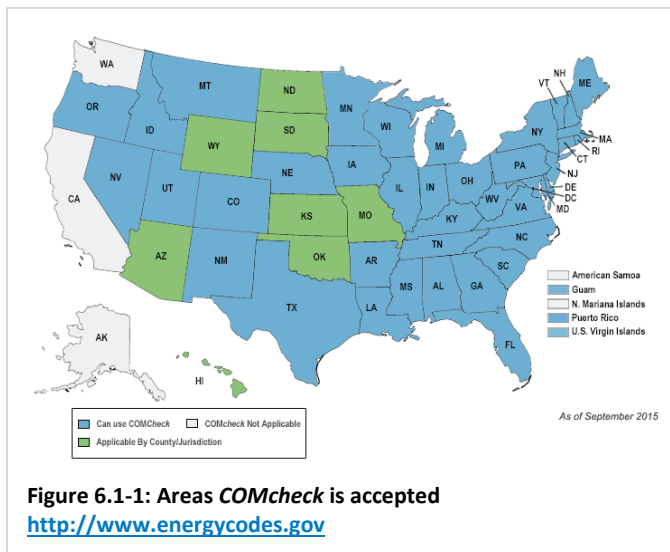
6.1 COMcheck Introduction

COMcheck is a commercial building code performance program that has automated the building code compliance process. The latest version of this COMcheck software is available at <http://www.energycodes.gov>. This software has been developed to simplify the commercial code compliance for IECC, ASHRAE Standard 90.1, and other state specific codes. COMcheck has the ability to address trade-offs within building components (envelope, lighting, or HVAC). On the other hand, this software does not perform a whole building energy analysis and is unable to address trade-offs between different components (i.e., between lighting and envelope).

As shown in [Figure 6.1-1](#), most states can use COMcheck for energy code compliance. Currently, COMcheck supports the IECC versions from 1998 through 2012, ASHRAE Standard 90.1 versions from 1989 through 2013, as well as incorporating many of the individual state amendments to the program. COMcheck is intended to be a simplified nonresidential energy code compliance tool.

The lighting portion of the tool compares the installed lighting power of the spaces against the allowed lighting power. One can define each fixture type, their wattage and their quantity. The program will then calculate the total wattage and compare against the total wattage allowance.

The mechanical portion of the tool indicates the minimum efficiencies for each category of equipment, as well as equipment size. COMcheck then identifies the HVAC size threshold for the economizer requirement. If the architect and/or engineer choose not to use an economizer, the program will indicate the increased equipment efficiency needed to be exempted from the requirement.



COMcheck software also automatically generates easy to read summary reports of the design and its compliance margin for lighting and envelope and the efficiency requirements for mechanical systems. It also contains the mandatory requirements for each of the building systems along with a check list of mandatory measures the architect and/or engineer is required to sign off. The simplicity and clarity of this tool explains why COMcheck is widely used in the United States.

Appendix A: Glossary

ANSI: American National Standards Institute is the national organization that coordinates development and maintenance of consensus standards and sets rules for fairness in their development. ANSI also represents the United States in developing international standards.

Assembly: A group of mutually dependent and compatible components or subassemblies of components.

Blanket (batt) insulation: A layer or sheet of flexible fiberglass thermal insulation.

British Thermal Unit (Btu): The standard measure of heat energy. One Btu can raise the temperature of one pound of water by one degree Fahrenheit at sea level. For example, it takes about 2,000 Btu to make a pot of coffee.

Builder: A party who, as a routine part of his business, buys the Metal Building System from a manufacturer for the purpose of resale.

Building Code: Regulations established by a recognized agency describing design loads, procedures and construction details for structures usually applying to a designated political jurisdiction (city, county, state, etc.).

Building Envelope Interior: The elements of a building that separate conditioned space from unconditioned space or that enclose semiheated spaces through which thermal energy may be transferred to or from the exterior, unconditioned spaces, or conditioned spaces.

Building Envelope: The elements of a building that enclose conditioned spaces through which thermal energy is capable of being transferred.

Building: A structure forming an open, partially enclosed, or enclosed space constructed by a planned process of combining materials, components, and subsystems to meet specific conditions of use.

Caulking: Filling the joints, seams or voids between adjacent units with a sealant in order to make them weather-tight.

Cavity Insulation: Insulation installed between structural members such as wood studs, metal framing, and Z-clips.

Ceiling: The ceiling requirements apply to portions of the roof and/or ceiling through which heat flows. Ceiling components include the interior surface of flat ceilings below attics, the interior surface of cathedral or vaulted ceilings, skylights, and sloped building assemblies less than 60 degrees from horizontal, but excluding skylight shafts.

CFM: Cubic feet per minute. A standard measurement of airflow.

Cladding: The exterior metal roof and wall paneling of a Metal Building System. See also "Components and Cladding."

CMRC: Cool Metal Roofing Coalition.

Conditioned Space: An enclosed space within a building that is cooled by a cooling system whose sensible output capacity is greater than or equal to 5 Btu/(hr × ft²) of floor area.

Semiheated space: an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/(hr × ft²) of floor area but is not a conditioned space.

Conductance: The quantity of heat, in Btu's, that will flow through one square foot of material in one hour, when there is a 1 °F temperature difference between both surfaces. Conductance values are given for a specific thickness of material, not per inch thickness.

Conduction: The passing of heat through a roof material into the layer in contact directly beneath the surface. The transfer of heat energy through a material (solid, liquid or gas) by the motion of adjacent atoms and molecules without gross displacement of the particles.

Conductivity (k): The quantity of heat that will flow through one square foot of homogeneous material, one inch thick, in one hour, when there is a temperature difference of one degree Fahrenheit between its surfaces.

Continuous Insulation (ci): Insulation that runs continuously over structural members and is free of significant thermal bridging; such as rigid foam insulation above the ceiling deck. The insulation is installed on the interior, exterior, or is integral to any opaque surface of the building envelope.

Contract Documents: The Documents that define the material and work to be provided by a Contractor or the General Contractor for a Construction Project.

Convection: The heating of the air that passes over a hot surface.

Cooling Load: The rate at which heat must be extracted from a space in order to maintain the desired temperature within the space.

Daylighting Control: A control system that varies the light output of an electric lighting system in response to variations in available daylight.

Daylighting: The use of sunlight to supplement or replace electric lighting.

Design Energy Cost: The annual energy cost calculated for a proposed design.

Design Loads: The loads expressly specified in the contract documents that the Metal Building System is designed to safely resist.

Design Professional: The Architect or Engineer responsible for the design of a Construction Project.

Door: Doors include all operable opaque assemblies (which are not fenestration) located in exterior walls of the building envelope. Doors with glass can be treated as a single door assembly, in which case an aggregate U-factor (a U-factor that includes both the glass and the opaque area) must be used, or the glass area of the door can be included with the other glazing, and an opaque door U-factor can be used to determine compliance of the door.

Double Glazing: Windows having two sheets of glass with airspace between.

Emissivity: The property of emitting radiation; possessed by all materials to a varying extent.

Emittance: The ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions. Emittance values range from 0.05 for brightly polished metals to 0.96 for flat black paint.

Enclosed Space: A volume substantially surrounded by solid surfaces such as walls, floors, roofs, and operable devices such as doors and operable windows. Spaces not meeting these criteria for enclosure are considered to be exterior to the building for purposes of determining envelope requirements.

Energy Budget: A requirement in the Building Energy Efficiency Standards that a proposed building be designed to consume no more than a specified number of British thermal units (Btus) per year per square foot of conditioned floor area.

Energy Cost: The total estimated annual cost for purchased energy for the building, including any demand charges, fuel adjustment factors and delivery charges applicable to the building.

Energy Efficiency: Using less energy/electricity to perform the same function. Programs designed to use electricity more efficiently. "Energy conservation" is a term which has also been used but it has the connotation of doing without in order to save energy rather than using less energy to do the something and so is not used as much today. Many people use these terms interchangeably.

Energy Efficient Ratio (EER): The ratio of net equipment cooling capacity in Btu/hr to total rate of electric input in watts under designated operating conditions. When consistent units are used, this ratio becomes equal to the coefficient of performance.

Energy Factor (EF): A measure of water heater overall efficiency.

Energy Performance Rating: The energy use of the proposed building under actual operating conditions. Projected energy use targets can be used for buildings in the design or construction process.

Energy: The capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Customary measurement units are British thermal units (Btu).

Envelope Components: The building assemblies that provide a retarder between conditioned space and unconditioned space, including the floors, walls, and ceiling/roof assemblies of the building.

Exterior Wall: An above-grade wall enclosing conditioned space. Includes between-floor spandrels, peripheral edges of floors, roof and basement knee walls, dormer walls, gable end walls, walls enclosing a mansard roof, and basement walls with an average below grade-wall area that is less than 50 percent of the total opaque and non-opaque area of that enclosing side.

Fahrenheit: A temperature scale in which the boiling point of water is 212 degrees and its freezing point is 32 degrees. To convert Fahrenheit to Celsius, subtract 32, multiply by 5, and divide the product by 9. For example: $100 \text{ degrees Fahrenheit} - 32 = 68$; $68 \times 5 = 340$; $340 / 9 = 37.77 \text{ degrees Celsius}$.

Fenestration Area: Total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area.

Fenestration: All areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than one-half glass, and glass block walls. A skylight is a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building is considered vertical fenestration.

F-Factor: The perimeter heat loss factor for slab-on-grade floors, expressed in Btu/hr × °F.

Galvalume®: A proprietary trade name for a coating, used over sheet steel, that is composed of an aluminum-zinc alloy for corrosion protection.

Girt: A horizontal structural member that is attached to sidewall or columns and supports paneling.

Glazing: Any translucent or transparent material in exterior openings of buildings, including windows, skylights, sliding doors, the glass area of opaque doors, and glass block. A covering of transparent or translucent material (typically glass or plastic) used for admitting light.

Heated space: An enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 5 Btu/(hr × ft²) of floor area.

HVAC (Heating Ventilation And Air-Conditioning): A system that provides heating, ventilation and/or cooling within or associated with a building.

IECC: The International Energy Conservation Code. The IECC was published in 1998, 2000, and every three years thereafter.

Indirectly Conditioned Space: An enclosed space within a building that is not a heated or cooled space, whose area-weighted heat transfer coefficient to heated or cooled spaces exceeds that to the outdoors or to unconditioned spaces; or through which air from heated or cooled spaces is transferred at a rate exceeding three air changes per hour.

Infiltration: The uncontrolled inward leakage of air through cracks and gaps in the building envelope, especially around windows, doors and duct systems. The uncontrolled inward air leakage through cracks and interstices in any building element and around windows and doors of a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both.

Infrared Emittance: The ability of a material to radiate the heat that builds up in the material from absorbed or non-reflected radiation. The emitted energy is in the far infrared part of the spectrum. Solar radiation that is absorbed heats a roof surface. The absorbed energy is no longer solar energy – it is characterized by a surface material's temperature which is lower than the equivalent solar temperature. A roof surface continuously exchanges radiation in the infrared part of the spectrum with the sky at its equivalent temperature. On clear nights, the sky temperature is lower than the air temperature. The amount emitted is in direct proportion to a roof surface's infrared emittance.

Insulation R-Values: R-values are used to rate insulation and are a measurement of the insulation's resistance to heat flow. The higher the R-value, the better the insulation.

Insulation, Thermal: A material having a relatively high resistance of heat flow and used principally to retard heat flow.

Insulation: Any material used in building construction to reduce heat transfer.

Liner Panel: A metal panel attached to the inside flange of the girts or inside of a wall panel.

Manufacturer: A party who designs and fabricates a Metal Building System.

Manufacturer's Engineer: An engineer employed by a manufacturer who is in responsible charge of the structural design of a Metal Building System fabricated by the manufacturer. The manufacturer's engineer is typically not the Engineer of Record.

Masonry: Anything constructed of materials such as bricks, concrete blocks, ceramic blocks, and concrete.

Metal Building Roof: A roof that is constructed with (a) a metal, structural, and weathering surface, (b) has no ventilated cavity, and (c) has the insulation entirely below deck (i.e., includes neither a composite concrete and metal deck construction nor a roof framing system that is separated from the superstructure by a wood substrate), and whose structure consists of one or more of the following configurations: (1) Metal roofing in direct contact with the steel framing members, (2) Insulation between the metal roofing and the steel framing members, or (3) Insulated metal roofing panels installed as described in 1 or 2.

Metal Building System: A complete integrated set of mutually dependent components and assemblies that form a building including primary and secondary framing, covering and accessories, and are manufactured to permit inspection on site prior to assembly or erection.

Metal Building Wall: A wall whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain wall systems).

Net Wall Area: The net wall area includes the opaque wall area of all above-grade walls enclosing conditioned spaces, the opaque area of conditioned basement walls less than 50% below grade (including the below-grade portions), and peripheral edges of floors. The net wall area does not include windows, doors, or other such openings, as they are treated separately.

Opaque Areas: Opaque areas referenced in this guide include all areas of the building envelope except openings for windows, skylights, doors, and building service systems. For example, although solid wood and metal doors are opaque, they should not be included as part of the opaque wall area (also referred to as the net wall area).

Order Documents: The documents normally required by the Manufacturer in the ordinary course of entering and processing an order.

Performance Approach: A performance approach (also known as a systems performance approach) compares a proposed design with a baseline or reference design and demonstrates that the proposed design is at least as efficient as the baseline in terms of annual energy use. This approach allows the greatest flexibility but may require considerably more effort. A performance approach is often necessary to obtain credit for special features such as a passive solar design, photovoltaic cells, thermal energy storage, fuel cells, and other nontraditional building components. This approach requires an annual energy use value. There are several commercially available software tools that perform this analysis.

Prescriptive Approach: A prescriptive approach lists the minimum R-value or maximum U-factor requirements for each building component such as windows, walls, and roofs. For lighting systems in commercial buildings, a prescriptive approach would simply list the allowable watts per square foot for various building types. For mechanical systems and equipment, a prescriptive approach would list the minimum required equipment efficiencies.

Projection Factor (PF): The exterior horizontal shading projection depth divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the external shading projection in units consistent with the projection depth.

Purlin: A horizontal structural member that supports roof covering.

Rated R-Value of Insulation: The thermal resistance of the insulation alone as specified by the manufacturer in units of $h \times ft^2 \times ^\circ F / Btu$ at the mean temperature of 75°F. Rated R-value refers to the thermal resistance of the added insulation in framing cavities or insulated sheathing only and does not include the thermal resistance of other building materials or air films. (see Thermal Resistance.)

Reflectance: The ratio of the light reflected by a surface to the light incident upon it.

Resistance: The measure of the resistance of a material to the passage of heat, expressed in units of $^\circ F \times ft^2 / (Btu/hr)$.

Rigid Board Insulation: Typically, a rigid polyisocyanurate or polystyrene foam insulation.

Roof Assembly: A roof assembly is considered to be all roof/ceiling components of the building envelope through which heat flows, thus creating a building transmission heat loss or gain, where such assembly is exposed to outdoor air and encloses conditioned space. The gross area of a roof assembly consists of the total interior surface of all roof/ceiling components, including opaque surfaces, dormer and bay window roofs, trayed ceilings, overhead portions of an interior stairway to an unconditioned attic, doors and hatches, glazing, and skylights exposed to conditioned space that are horizontal or sloped at an angle less than 60 °F from the horizontal.

Roof: The upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60 degrees from horizontal.

R-Value: A unit of thermal resistance used for comparing insulating values of different material. The R-Value is a measure of the effectiveness of insulation in stopping heat flow. The higher the R-value number, a material, the greater its insulating properties and the slower the heat flow through it. The specific value needed depends on climate, type of heating system and other factors. The R-value is the reciprocal of the U-factor.

Screwed Down Roof System: See "Through-Fastened Roof System."

Secondary Framing: Members that carry loads from the building surface to the main framing, such as the purlins and girts.

Semiheated space: An enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/(hr × ft²) of floor area but is not a conditioned space.

Shading Coefficient (SC): The ratio of solar heat gain through fenestration, with or without integral shading devices, to that occurring through unshaded 1/8 in. thick double strength glass.

Shading: The protection from heat gains due to direct solar radiation. Shading is provided by permanently attached exterior devices, glazing materials, adherent materials applied to the glazing, or an adjacent building for nonresidential buildings, hotels, motels and high-rise apartments.

Skylight: A fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration.

Solar Heat Gain Coefficient (SHGC): Solar heat gain coefficient (SHGC) is the glazing's effectiveness in rejecting solar heat gain. SHGC is part of a system for rating window performance used by the National Fenestration Rating Council (NFRC). SHGC is gradually replacing the older index, shading coefficient (SC), in product literature and design standards. When using glass whose performance is listed in terms of SC, the SHGC may be converted by multiplying the SC value by 0.87.

Solar Reflectance: Solar Reflectance is expressed as a ratio of the reflected solar flux to the incident solar flux. The solar radiation in the near ultraviolet to near infrared spectrum that is reflected away from a surface expressed as a percent or within the range of 0.00 to 1.00.

Standing Seam Roof System: A standing seam roof system is one in which the side laps between the roof panels are arranged in a vertical position above the roof line. The roof panel system is secured to the roof substructure by means of concealed hold down clips attached with screws to the substructure, except that through fasteners may be used at limited locations such as at ends of panels and at roof penetrations.

Thermal Block: A thermal insulating material that is placed between the metal building roof and the compressed insulation over the purlins. Also known as a "thermal spacer block."

Thermal Break: An element of low heat conductivity placed in such a way as to reduce or prevent the flow of heat. Some metal framed windows are designed with thermal breaks to improve their overall thermal performance.

Thermal Bridge: A component, or assembly of components, in a building envelope through which heat is transferred at a substantially higher rate than through the surrounding envelope area.

Thermal Conductance: Time rate of heat flow through a body (frequently per unit area) from one of its bounding surfaces to the other for a unit temperature difference between the two surfaces, under steady conditions (Btu/h x ft² x °F).

Thermal Emittance: The ratio of the radiant heat flux emitted by a sample to that emitted by a blackbody radiator at the same temperature. Values are expressed from 0 to 1.0, with 1.0 being the maximum emittance possible.

Thermal Resistance (R): The reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions.

Thermal Transmittance: The coefficient of heat transmission (air to air). Thermal transmittance is the time rate of heat flow per unit area and unit temperature difference between the warm-side and cold-side air films (Btu/h x ft² x °F). The U-factor applies to combinations of different materials used in series along the heat flow path, single materials that comprise a building section, cavity airspaces and surface air films on both sides of a building element.

Through-Fastened Roof System: A through-fastened roof system is one in which the roof panels are attached directly to the roof substructure with fasteners that penetrate through the roof sheets and into the substructure.

Through-Fastened Wall System: A wall assembly in which the corrugated metal siding is fastened directly to the zee girts with self tapping screws.

Trade-Off Approach: A trade-off approach involves trading enhanced energy efficiency in one component against decreased energy efficiency in another component. These trade-offs typically occur within major building systems (e.g. envelope, mechanical) or in commercial lighting.

Translucent Light Panels: Panels used to admit light.

U-Factor: A measure of how well heat is transferred by the building component. The overall rate of heat flow. The time rate of steady-state heat flow, through combinations of different materials along the heat flow path including: single materials, cavity air spaces, and surface air films on both sides of a building element. This value is a function of temperature, and is expressed in Btu per square foot per hour per degree-Fahrenheit (Btu/ft² x hr x °F). The lower the U-Factor, the better the insulation. The U-Factor or U-factor is the reciprocal of R-Value (U-factor = 1/R-Value).

Unconditioned Space: A space that is neither directly nor indirectly conditioned space, which can be isolated from conditioned space by partitions and/or closeable doors.

Vapor Retarder: A component that retards water vapor diffusion but does not totally prevent its transmission. Vapor retarder material is usually a thin sheet or coating. However, a construction of several materials, some perhaps of substantial thickness, could also constitute a vapor retarder system.

Vertical Fenestration: All fenestration other than skylights.

Visible Light Transmittance (VLT) : The fraction of solar radiation in the visible light spectrum that passes through the fenestration. The ratio of visible light transmitted through a substance to the total visible light incident on its surface.

Wall: Opaque portion of the building envelope.

Window Projection Factor: A measure of the portion of glazing that is shaded by an eave or overhang.

Window: The terms "fenestration", "window", and "glazing" are often used interchangeably. However, window actually describes a system of several components. Window is the term given to an entire assembly comprised of the sash, glazing, and frame.

Window-Wall Ratio: The window-wall ratio is the percentage that results from dividing the total glazed area of the building by the total wall area.



Energy Code Compliance

A Guide for Metal Building Contractors

The MBMA *Energy Code Compliance: A Guide for Metal Building Contractors* is a synthesis of all of the pertinent information on how to design, construct, and maintain metal buildings to be energy efficient. Most municipalities in the United States have adopted an energy code. This guide is a resource for informing building owners, architects, specifiers, contractors, builders, and metal building manufacturers about the compliance options for satisfying the building envelope provisions of these energy codes.

Topics covered in the guide:

- Metal Building Systems and Applications
- Energy Code Fundamentals
- IECC and ASHRAE Standard 90.1 Provisions
- Compliance Paths and Tools
- Insulating Metal Building Systems



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