

Thermal Performance of Insulated Metal Panels per ASHRAE 90.1-2010

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Abstract

Insulated Metal Panels, or IMPs, are a type of insulated structural cladding commonly used in Metal Buildings as well as many other architectural applications. They combine excellent structural capacity with superior insulation and air/water barrier performance, are custom engineered to project requirements and are produced in a factory-controlled environment. However, because IMPs are a specialized type of insulation, there are currently no standards in circulation that establish a "Rated R-value" for insulation as required in many energy codes. This paper presents the methodology used by NCI companies to determine the R-value and U-factor of the IMPs they supply and provides the technical basis by which they can be applied against ASHRAE 90.1 requirements.

Introduction

A minimum R-value determined by testing is the most common way to specify thermal performance of any insulating material, including Insulated Metal Panels, or IMPs. However, a minimum R-value alone does not guarantee a certain level of performance due to the fact that many things affect the tested R-value of insulation, including:

- Insulation temperature or mean temperature of hot and cold side of test apparatus
- Specimen orientation and heat flow direction of test (Roofs only)
- Allowance for air film effects
- Presence of joints, fasteners, and thermal bridges in the insulation that were not represented in the tested specimen
- Test method utilized

Therefore if this information is not specified in conjunction with the desired R-Value, the designer will likely not receive what he or she expects. This can lead to code compliance issues as well as poor performance of the finished building. Therefore a more thorough approach must be considered to ensure the specified assembly will be building energy efficiency code compliant.

Code Compliance

In North America, the most accepted energy efficiency standard for commercial construction is the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 90.1. The current edition is 2010. This standard provides both a prescriptive and a performance path to be chosen at the designer's discretion. The prescriptive path is most commonly used and also provides the baseline performance level that is used to determine compliance for the performance path as well, so understanding this set of requirements is critical. Within the prescriptive path, two possible methods of compliance are available to determine the minimum thermal performance of opaque areas on the building envelope. Section 5.5.3 is the pertinent passage and it reads:

5.5.3 Opaque Areas. For all opaque surfaces except doors, compliance shall be demonstrated by one of the following two methods:

1. Minimum *rated R-value of insulation* for the thermal resistance of the added insulation in framing cavities and *continuous insulation* only. Specifications listed in Normative Appendix A for each *class of construction* shall be used to determine compliance.
2. Maximum *U-factor*, *C-factor*, or *F-factor* for the entire assembly. The values for typical construction assemblies listed in Normative Appendix A shall be used to determine compliance.

Exceptions to Section 5.5.3:

- a. For assemblies significantly different from those in Appendix A, calculations shall be performed in accordance with the procedures required in Appendix A.
- b. For multiple assemblies within a single class of construction for a single space-conditioning category, compliance shall be shown for either (1) the most restrictive requirement or (2) an area-weighted average U-factor, C-factor, or F-factor.

The definitions pertinent to this passage italicized above are:

Continuous insulation (c.i.): insulation that is 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.

Rated R-value of insulation: the thermal resistance of the insulation alone as specified by the manufacturer in units of $h \cdot W \cdot ^\circ F / Btu$ at a 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.

U-factor (thermal transmittance): heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Units of U are $Btu/h \cdot W \cdot ^\circ F$.

So in effect, there are two possible ways to comply with the prescriptive requirements for a roof or wall assembly:

1. Provide insulation with a Rated R-value that meets or exceeds the minimum R-value requirement from the prescriptive tables 5.5-1 through 5.5-8, depending on climate zone
2. Provide an assembly with a U-factor that meets or falls below the maximum U-factor requirement from the prescriptive tables 5.5-1 through 5.5-8, depending on climate zone

Appendix A of 90.1 contains calculation and testing requirements for R-value and U-factor determination as well as a dataset of U-factors that have been predetermined in accordance with the appendix for some common assemblies. If the assembly being provided does not meet the descriptions of the common assemblies in the appendix, then a thermal test or calculation method is the only way to determine a U-factor. In fact, exception a. of 5.5.3 provides the user with a shortcut to that conclusion. Testing requirements are given in Section A9.3 and calculation requirements are given in A9.4 of Appendix A. Different levels of rigor are to be used when calculating U-factors depending on the type of assembly; however, Section A9.2 does state that two-dimensional finite element methods are always allowed.

The definitions above in conjunction with the requirements of Appendix A then dictate that if Method 1 is used, the R-value of the insulation must be determined by either ASTM C 518 or ASTM C 1363 with a mean temperature of 75 degrees Fahrenheit and cannot include air film effects. Furthermore, the assembly in question must meet the one of the descriptions in the Appendix. Otherwise, Method 2 must be used and the U-factor of the assembly is to be determined by testing per ASTM C 1363 or finite element modeling using a representative sample section including panel edges, joints and thermal bridges such as fasteners and should include air film allowance. If a calculation method is applied, then air film R-values provided in Section A.9.4.1 are to be included in the calculation since they are measured directly in ASTM C 1363.

Insulated panels are not an assembly type but instead are insulated sheathing that can be utilized on various kinds of assemblies. Therefore, it is not entirely clear how they apply to ASHRAE requirements. IMPs have thermally broken side joints and since the presence of fasteners does not violate the requirements for continuous insulation, IMPs can be interpreted to meet that definition. However, many designers do not agree with that interpretation and instead want to treat it as an assembly and therefore require U-values from the manufacturer since Method 1 would not apply in that instance. Unfortunately, 'thermal bridge' is not defined in ASHRAE 90.1, so no guidance is provided by the standard itself. Because of this ambiguity, it is not clear which method from Section 5.5.3 is to be used for IMPs. Therefore, R-values determined by test and U-factors determined by calculation in accordance with ASHRAE are presented in Table 2 below and it is left to the designer's discretion which to use.

Insulated Metal Panel R-value and U-factors

The R-value of insulation provided herein is based on ASTM C 518 conducted at 75 degrees mean temperature. U-factors have been determined using the Lawrence Berkeley National Laboratories finite element software, Therm V7, using the geometry of the panel and given R-value as the thermal conductivity of the core. Typical results are shown in Figures 1 through 5. Painted surfaces have been modeled with a thermal emittance of 0.85 and Galvalume® surfaces with a thermal emittance of 0.15. Frame cavities have been accounted for using the ISO 15099 calculation method with surface emittances of 0.9 and air within the cavity. Wall assemblies have been modeled vertically and roof panels modeled horizontally assuming winter conditions (i.e. cold to the exterior and hot to interior side) using the temperatures and air films shown in Table 1 as boundary conditions, which are consistent with the U-factor tables in Appendix A.

Table 1: Air Film R-Values

Element	Location	Temperature (°F)	Air Film R-value (h·ft²·°F/BTU)
Roof	Interior	100	0.61
	Exterior	50	0.17
Wall	Interior	100	0.68
	Exterior	50	0.17

It should also be noted that although the mathematical relationship $R = 1/U$ holds true in the underlying heat transfer theory used to derive the presented data, that rule does not hold true for the table below since air films are included in the U-factors but not the R-values as required by ASHRAE 90.1.

Table 2: R-Values and U-factors for Insulated Metal Panels per ASHRAE 90.1

Application	Panel	Nominal Thickness	R-Value ¹ (h·ft ² ·°F/BTU)	Modeled U-factor ² (BTU/h·ft ² ·°F)
Roof	CFR	2"	14.3	0.0600
		2 1/2"	17.9	0.0490
		3"	21.4	0.0414
		4"	28.6	0.0318
		5"	35.7	0.0257
		6"	42.9	0.0217
	LS-36™	1 1/2"	10.7	0.1006
		2"	14.3	0.0737
		2 1/2"	17.9	0.0583
		3"	21.4	0.0484
		4"	28.6	0.0369
		5"	35.7	0.0296
Wall	CF Mesa, Santa Fe [®] , Striated, CF Architectural	2"	14.3	0.0889
		2 1/2"	17.9	0.0642
		3"	21.4	0.0518
		4"	28.6	0.0382
		5"	35.7	0.0304
		6"	42.9	0.0253
	LS-36™	1 1/2"	10.7	0.0996
		2"	14.3	0.0734
		2 1/2"	17.9	0.0582
		3"	21.4	0.0482
		4"	28.6	0.0368
		5"	35.7	0.0296
	CF Fluted	6"	42.9	0.0248
		2"	14.3	0.0908
		2 1/2"	17.9	0.0656
		3"	21.4	0.0527
		4"	28.6	0.0386
		5"	35.7	0.0307
	CF Architectural (No reveals)	6"	42.9	0.0256
		2"	14.3	0.0915
		2 1/2"	17.9	0.0654
	7.2 Insul-Rib™	3"	21.4	0.0527
		2 1/2"	7.95	0.1018
		3"	11.3	0.0746
4"		17.6	0.0494	
5"		24.3	0.0372	
6"	30.9	0.0299		

Notes:

1. R-Values based on ASTM C 518 at 75°F times nominal panel thickness except for Insulated 7.2, which is based on ASTM C 1363 at 73°F mean temperature. Air films effects are not included.
2. U-factors based on finite element modeling per the procedures described in this paper. Air film effects included.



Figure 1: Finite Element Mesh, 3" Royal

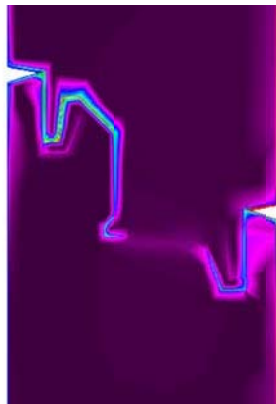


Figure 2: Heat Flux, 3" Royal



Figure 3: Color Infrared, 3" Royal

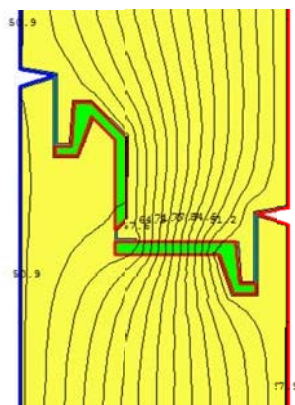


Figure 4: Isotherms, 3" Royal

Figure 5: Therm output, 3" Royal:

Therm Version 7.1.8.0
 Date: Tue Jun 04 15:43:30 2013

Created by:
 Created for:

Therm Filename: D:\My Documents\Therm\IMP U-factor Runs\Wall-Royal-3in x 42.THM
 Cross Section Type: Jamb
 Underlay Name: D:\My Documents\Therm\Underlays\CF wall panel master.dxf

U-factors

Name	Length in.	Basis	U-factor Btu/h-ft ² -F
Inside Face	42.00	Projected Y	0.0518

Solid Materials

Name	Conductivity Btu/h-ft-F	Emissivity
IMP - Painted Skin	30.00	0.85
IMP - Polyurethane Core,75 deg	0.01	0.90

Cavities

Name: IMP - Joint Cavity
 Gas Fill: Air
 Convection Model: ISO 15099
 Radiation Model: Standard

Poly ID	Heat Flow Dir	Side 1		Side 2		Dimension		Nu #	Keff Btu/h-ft-F	Cavity Height in.
		Temp F	Emis	Temp F	Emis	Horz. in.	Vert. in.			
19	Jamb: bottom to top	52.75	0.85	52.84	0.87	0.38	0.68	1.00	0.0417	240.0
20	Jamb: left to right	96.86	0.85	86.66	0.86	0.83	0.30	1.03	0.0548	39.4

Glazing Systems

None

Standard Boundary Conditions

Name	Temperature F	Film Coefficient Btu/h-ft ² -F
ASHRAE - Interior, Wall	100.00	1.471
ASHRAE - Exterior, Wall	50.00	5.880

Calculation Specifications

 Mesh Parameter : 8
 Estimated Error: 6.1%
 Calculations done in Version 7.1.8.0