REFLECTIVE TECHNOLOGIES IN THE THERMAL ENVELOPE

By David Yarbrough and Wesley Hall

There are three categories of reflective products that are used in the thermal envelope of residential and commercial buildings. These include radiant barriers, reflective insulations, and interior radiation control coating systems (IRCCSs). The common physical thermal characteristics that these building materials share are high reflectance and low emittance.

Emittance (or emissivity) refers to the ability of a surface to radiate energy. Materials have emittances ranging from 0 to 1. The lower the emittance of a material, the lower the rate at which heat (infrared radiant energy) is radiated. Aluminum foil and metalized films have thermal emittances in the range of 0.03 to 0.10, which is the basis for their use in reflective insulations and radiant barriers.

Reflectance (or reflectivity) refers to the fraction of incoming radiant energy that is not absorbed by a surface. Reflectivity and emissivity are related, and a low emittance is indicative of a highly reflective surface (for opaque materials). For example, aluminum foil, with an emittance of 0.03, has a reflectance of 0.97.[1]

In addition to these physical characteristics, reflective products are installed to form an assembly that includes one or more air spaces. When installed as part of the thermal envelope of a building, the low-emittance side of the insulating material must face an air space. For reflective insulations, the air space is enclosed, and for radiant barriers, the air space is ventilated. IRCCSs (*Figure 1*) can be used in ventilated or unventilated locations in a building. The performance of reflective products depends on proper installation, as is the case with all insulation products. If an installation is different from that specified by the manufacturers, then the thermal performance will likely be affected.

ASTM Committee C16 (Thermal Insulation) includes Subcommittee C16.21, which deals specifically with reflective products. C16.21 develops standards and practices for reflective building material products. The following seven documents dealing with reflective products are currently published in the ASTM *Book of Standards* and indicate the scope of reflective technologies currently being used in buildings:

- C727-12, *Standard Practice for*

Figure 1 – IRCC installation sprayed to the underside of the roof deck.

Installation and Use of Reflective Insulation in Building Constructions

- C1224-15, *Standard Specification for Reflective Insulation for Building Applications*
- C1313/C1313M-13, *Standard Specification for Sheet Radiant Barriers for Building Construction Applications*
- C1321-14, *Standard Practice for Installation and Use of Interior Radiation Control Coating Systems (IRCCS) in Building Construction*
- C1340/C1340M-10 (2015), *Standard Practice for Estimation of Heat Gain or Loss Through Ceilings Under Attics Containing Radiant Barriers by Use of a Computer Program*
- C1743-12, *Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction*
- C1744-12, *Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Commercial/Industrial Building Construction*

Reflective insulation is a material with a low-emittance surface, such as aluminum that is bonded to plastic film, Kraft, polyethylene bubble pack, or plastic foam. Products are available in a variety of widths and lengths—as wide as 10 feet and as long as 250 feet—and packaged in rolls. Reflective insulation assemblies have R-values that depend on the heat flow direction, size (depth) of the enclosed air space, and effective emittance of the air space.[2] These assemblies are used in roofs, walls, and floors to provide thermal resistance and, in some cases, resistance to water vapor transmission. Thermal performances for walls are reported as single R-values, while roof and floor assemblies may list two values (heat flow up and heat flow down). Stand-alone product assembly R-values can range from around R-3.0 to R-21, while combinations of reflective products and other insulation products to form hybrids include an even greater range of thermal resistance values. Assembly R-values can be measured using Test Method ASTM C1363 (Hot Box Test

Figure 3 – Radiant barrier installation attached to the underside of the rafter.

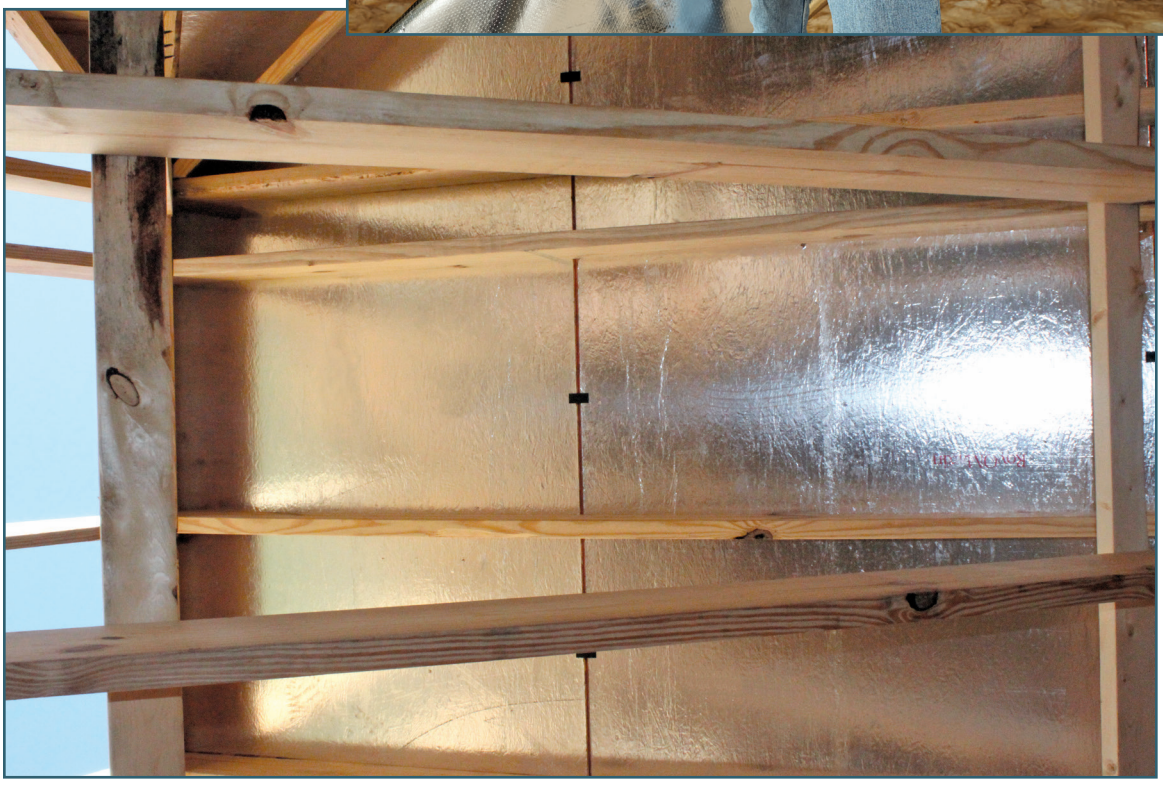

Figure 2 – Radiant barrier installation directly to the roof decking.

Average Temp (°F)	R-value (ft²·h·°F/Btu)		
	Heat Flow Up	Horizontal	Down
25	2.36	3.94	5.07
75	2.42	3.87	4.58
125	2.45	3.71	4.15

Table 1 – R-values for single, 1-in. enclosed reflective air spaces.[4]

Apparatus), estimated from data contained in the ASHRAE *Handbook of Fundamentals*,[3] or by using correlations published in ASTM Special Technical Publication 1116.[4] The standard specification for reflective insulation[5] contains a list of important physical properties for reflective insulation that includes water vapor permeance, humidity resistance, adhesive performance, pliability, surface burning characteristic, and fungi resistance, in addition to the previously discussed properties.

Table 1 contains values for R for a 1-in. enclosed reflective air space with emittance of 0.87 (wood) on one surface and 0.03 (aluminum foil/film) on the opposite surface. The temperature difference across the air space is 10°F for all of the calculations. The R-values in the table include heat transfer by conduction, convection, and radiation.

Radiant barrier products include a surface with an emittance of 0.1 or less that is installed in roof assemblies or attics with the low-emittance surface facing an open or ventilated air space.[5] The low-emittance material can be bonded to plastic film, woven fabric, reinforced paper, OSB, or plywood. The thermal performance of radiant barriers depends on emittance and location in the attic, wall, or roof assembly. Radiant barriers are predominantly installed in attic spaces below the roof deck. The low-emittance surface characteristic of radiant barrier products dramatically reduces the heat gain by radiation into the structure and lowers attic air and surface temperatures. For this reason, radiant barriers are especially effective in warm, sunny climates where they provide reduced use of air conditioning.

Available radiant barrier products include single-sheet material, multilayer assemblies, and wood sheathing with attached aluminum film or foil. The single-sheet material is installed in roof assemblies by attaching directly to the roof deck, in between the rafters or trusses, or to the underside of the rafters or trusses. The foil-faced sheathing is installed with the low-emittance side of the sheathing or panel facing toward the attic space to create a radiant barrier. The additional characteristics for radiant barriers similar to those of reflective insulation are described in the ASTM standard specification.[6]

IRCCs having installed surface emittances in the range of 0.14 to 0.25 are generally sprayed, rolled, or brushed on surfaces to reduce radiant heat transfer to the interior of the building. IRCC is quite often applied to metal or concrete surfaces where application can readily be achieved.

Reflective products are installed in a wide variety of building designs and across all climate zones. The application with the most widespread use and highest square footage of installation is low-emittance aluminum foil or film bonded or attached to the underside of roof decking to form a radiant barrier system. Three companies are the primary manufacturers of this type of product. The radiant barrier system is formed by aluminum foil or film attached to 4- by 8-ft. sheets of roofing decking that is subsequently installed with the low-emittance side facing the attic or interior side of the home. The radiant barrier side of the product is generally perforated to provide for water vapor transmission.

These radiant barrier products enjoy considerable market share, being widely used in new home construction in Climate Zones 1, 2, and 3. The manufacturers of these products report annual installation of over 800 million square feet a year. A key advantage to utilizing this product is that the benefit of a radiant barrier can be included in the building enclosure without additional labor cost. *Figures 2* and *3* show two commonly used attic radiant barrier assemblies.

Enclosed reflective air spaces (reflective insulations) are being combined with other insulations such as cellular plastic or mineral fiber insulation to form hybrid assemblies. This can be done whenever an unventilated air space is present. Both single-sheet reflective insulations (such as foil-faced gypsum) and multilayer reflective insulations (*Figure 4*) are being specified

Figure 4 – Reflective insulation installation of a double-layer R-21 to a floor joist in crawl space.

and installed to provide added thermal resistance to building enclosures in all climate zones. This application turns empty air spaces into regions with thermal resistance at modest additional cost.

Reflective insulation, radiant barriers, and IRCCs are installed in residential and industrial/commercial buildings and agricultural structures. The products have a presence throughout North and South America, Australia, Europe, and Asia. Worldwide, reflective building material technologies have been in the marketplace for over 70 years. As our society becomes more and more focused on energy consumption and the reduction of the byproducts to produce that energy, insulation technologies such as reflectives will continue to be in the forefront of development. Product configurations, applications, and material compositions will continue to expand and evolve.

REFERENCES

1. Reflective Insulation Manufacturers Association International, "Understanding and Using Reflective Insulation, Radiant Barriers and Radiation Control Coatings," (2014) pp 4-5, www.rimainternational.org.
2. *2009 ASHRAE Handbook-Fundamentals*, Chapter 26, "Heat, Air, and Moisture Control in Building Assemblies – Material Properties," Table 3 footnote e.
3. loc cit. 2, Table 3
4. *ASTM STP 1116*, Ronald S. Graves and Donald C. Wysocki, editors, "Prediction of the Thermal Performance of Single and Multi-Airspace Reflective Insulation Materials," (1991), pp 24-43.
5. ASTM C1224, *2014 Annual Book of ASTM Standards*, Vol 04.06 (2014), pp 710-714.
6. ASTM C1313, *2014 Annual Book of ASTM Standards*, Vol 04.06 (2014), pp 758-761.

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