Reflective Insulations Internationally

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Reflective technology that is used to reduce energy use in buildings is represented by three commercially available product types. In all three cases the performance of the reflective product depends on reduction in radiative transport across air spaces due to low thermal emittance surfaces.

Products identified in North America as 'radiant barriers' typically have a low-emittance surface adjacent to a relatively large air space that may be ventilated or unventilated. The performance of radiant barriers is related to reduction in thermal radiation from the low-emittance surface, which is directly proportional to the emittance at a specified surface temperature.

Surfaces with low-emittance coatings perform much like radiant barriers. The coating for the surface, known as interior radiation control coating (IRCC), reduces radiative transport in the same manner as radiant barriers. Radiant barriers and IRCCs are not typically assigned thermal resistance values (R-values).

Reflective insulations and assemblies

A reflective insulation is a material that has a low-emittance facer or surface material that is attached to a core to facilitate handling and installation. The material of choice for reflective insulation is aluminum used either as a foil or a metalized film. The foils and films generally have emittances in the range 0.03 to 0.10.[1]

The core can be a single-sheet material, a cellular plastic or layers of a fibrous insulation. In many cases, the core material has a small material R-value due to its thickness. A reflective insulation assembly is an enclosed (unvented) air space that includes the reflective insulation bound on at least one surface in the direction of heat flow by a low-emittance surface. As is the case with much conventional insulation, the thermal performance is related to the low thermal conductivity of air. A low-emittance surface reduces heat flow by radiation that adds to the heat flow by conduction. In some cases there is a reduction in convective heat transport due to the limited space for air movement in a reflective insulation assembly.

Reflective insulations are labeled and marketed with thermal resistance values that can be measured using standard test methods. The thermal resistance of a reflective insulation assembly depends on the emittance of its surfaces, the dimensions of the air space, the average temperature of the air space, the temperature difference across the air space and the heat-flow direction. The temperature difference and heat-flow direction are factors because in many cases there is a convective contribution to the total heat flow. The convective contribution is due to natural convection in the enclosed air space that is the result of air-density variations that result from temperature differences and the relative orientation of the hot and cold surfaces.

Evaluation of performance

The thermal resistance of reflective insulation assemblies is measured in many parts of the world by means of a hot-box facility. This type of apparatus provides a steady-state measurement of heat flow across a building assembly (a reflective insulation assembly, for example) from a warm region to a cold region.

The R-value (R) is calculated from measured heat flux (Q/A) and temperature difference (ΔT) using Equation 1, which follows from the one-dimensional steady-state form of Fourier's Law...

$R = \Delta T \cdot A/Q$ (Equation 1)

...where A is the assembly area (m^2) perpendicular to the heat-flow direction, Q is the rate of energy transfer (W), ΔT is the temperature difference (K), giving R with units of $m^2 \cdot K/W$.

Figure 1 shows a guarded hot-box facility operated in accordance with ASTM C 1363.[2] This apparatus can be rotated to obtain R for any heat-flow direction. Measurements of reflective insulation performance are also made with small buildings that provide for in-situ evaluation of an insulation product. Figure 2 shows a facility of this type maintained by the Actis Company in the south of France. Both large-scale laboratory and field tests are designed to measure heat flow and temperature differences across building elements in order to arrive at high thermal performance.

R-values are commonly obtained by calculations that are generally tied to experimentally-derived correlations for the convective component.[3-5] ASTM STP 1116 contains correlations for the convective component based on hot-box measurements that are used in North America, Australia, New Zealand and South Korea.[3] ISO 6946 provides a method for calculating reflective insulation performance that is used in Europe[4] and ANS/NZ 4859 provides requirements for calculations in Australia and New Zealand.[5] Table 1 contains the basic equations and sample results obtained with computational programmes.

The major difference between the three methods for calculating reflective air space resistance is the determination of the convective contribution characterized by the Nusselt Number (Nu). Nu = 1 when convection is absent and increases as convection increases. Nu includes energy transport by conduction (λ). The results in Table 1 show the variation in RSI with heat-flow direction, air-gap size and temperature difference. Nu is generally obtained from tabular data, graphs or complex equations that include temperature, air properties and spacing. E is the effective emittance[6] while ε_i is the thermal emittance of surface 'i'. The radiative term hr follows from the Boltzmann equation.[3-5]

R or RSI = $1/(E \bullet h_r + h_c)$

$E = 1/(1/\varepsilon_1 + 1/\varepsilon_2 - 1)$

$h_c = Nu \bullet \lambda/l$

l(mm) ΔT (°C) RSI ($m^2 \bullet K/W$)

(l is thickness)

E = 0.03

		Up	Horizontal	Down
12	10	0.33	0.41	0.42
24	10	0.36	0.6	0.76
36	10	0.38	0.57	1.03
12	15	0.3	0.4	0.42

Above - Table 1: Summary of R-value calculation.

Reflective insulation performance values calculated in different parts of the world tend to agree. Figure 3 compares RSI values calculated using the three standards mentioned above. The curves of RSI as a function of air gap dimension are for horizontal heat flow at a temperature difference of 6K, an average temperature of 33°C and an effective emittance of 0.03. The vertical error bars form a +/-5% interval around the DY (USA) curve. The different methods result in R-values enclosed by the error bars. All of the computational approaches are steady-state and one-dimensional.

Applications

The common denominator among reflective insulation applications is the formation of an enclosed (non-ventilated) air space. There are a number of wall designs that include a reflective air space as one element in the wall. In many cases the temperature difference across the air space is a small fraction of the total temperature difference across the wall, resulting in a small convective contribution, which results in good thermal performance. Figure 4 shows a popular reflective system used in the US for insulating masonry walls. Wood framing (furring) is used to provide an air space adjacent to the masonry wall that is enclosed with the reflective insulation product having two or three low-emittance surfaces.

A common application in South Korea involves the use of an enclosed air space as part of masonry construction. Figure 5 is an example of a Korean application that adds thermal resistance to the relatively low resistance offered by the concrete-slab construction. This type of application typically includes two reflective air spaces placed in the wall structure with brackets to prevent contact between the aluminum and concrete.

Roof applications are attractive for reflective insulations, especially in cooling-dominated climates, because RSI values are greatest for heat flow down. Reflective insulation below roof tiles in Japan shown in Figure 6 provides significant 'heat-flow down' thermal resistance.

A convenient application of low-emittance material to reduce heat flow between the roof of a structure and the interior is shown in Figure 7 where foil-faced oriented strand board (OSB) is being installed as roof sheathing, also known as roof deck. This aluminum foil faced product results in an emittance of 0.03 facing a large air space.

Applications for reflective insulation occur in large commercial buildings of the type shown in Figure 8 that shows reflective insulation being installed in a commercial building in Costa Rica to form a hybrid system with fibreglass insulation. In this case, the reflective insulation is being applied to both walls and ceiling.

Remote industrial applications are represented by the small buildings in a Canadian oil field. They contain reflective insulation that can be installed rapidly. In these cases a modest but compact thermal resistance can have a major impact on heat loss.

Summary

The evaluation of reflective insulations for residential, commercial and industrial applications has been discussed. Mature laboratory and field evaluation procedures in use around the world provide consistent RSI values. The introduction of enclosed air spaces varies internationally because of differences in building design and local customs.

An understanding of applications where low-emittance surfaces provide thermal resistance in the building envelope exists in Europe, North America, Central America, Asia, Australia and New Zealand. There is general agreement about the magnitude of thermal resistance that can be obtained using reflective technology.

References

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