Reflective Technology-It's About Saving Energy

Reflective technology to reduce building and industrial energy demand has been used in the modern world by designers and engineers dating back to the early part of the 20th century: Am. Soc. Refrigerating. Engineers, Vol. 3, (1916) and Am. Soc. of Heating and Ventilating Engineers., Vol. 26, (1920). Since these early papers on reflective air spaces there have been perhaps 100 published reports and research papers on the subject of reflective insulations and radiant barriers many of which as listed in a 1989 review by Goss and Miller: ASHRAE Transactions, Vol. 95 (1989). The subject of reflective insulations is rich with technical documentation but remains an unknown to some potential users. In addition to current applications in buildings, reflective systems have been part of radiation technology as indicated by ASTM Standards originally published in the early 1970's: ASTM C 740 (1973) and ASTM C 667 (1971). In past decades, the Dewar flask and "vacuum bottles" for hot and cold fluids relied in part on the use of very-low emittance surfaces to virtually eliminate the transfer of heat by thermal radiation. The standards literature contains a practice for the use of reflective insulation in buildings originally published in 1972 (ASTM C 727). More recently, computer codes have been developed for evaluating radiant barriers in residential applications (ASTM C 1340). The comprehensive Handbook of Fundamentals published annually by ASHRAE contains thermal resistances (R-Values) for reflective air spaces based on data from the U.S. National Bureau of Standards (now N.I.S.T.) and the Federal Government had its own specification for reflective insulation: HH-I-1252 (1971): that was eventually superseded by ASTM Standard Specifications. These citations are far from exhaustive, providing just a glimpse of the published resources that are available.

The terms "reflective insulation" and "reflective insulation systems" are commonly used to identify one type of reflective technology. Reflective insulations consist of one or more low emittance surfaces attached to a supporting material such as kraft, plastic film, foam, or bubblepack. In some case the reflective insulation has thickness and R-value associated with the thickness. The major part of the thermal resistance obtained using a reflective insulation, however, is derived from reflective air spaces. Reflective air spaces are enclosed regions with low-emittance boundaries. The low-emittance boundaries are generally aluminum foils or deposited aluminum films laminated to a substrate for mechanical strength. The enclosed air, a material with low thermal conductivity, is the insulating material as it is in the case of mass-type insulations. The low-emittance surfaces facing the enclosed air space significantly reduce radiation transport across the space. The dimensions of many reflective insulation systems are selected to reduce the transfer of heat by convection (movement of the enclosed air). Since there is a convective component in most reflective insulation systems, the thermal resistance or R-value depends on the heat flow direction. This is sometimes a confusing factor that is the result of the fact that gases expand when the temperature increases. Mixing (convection) can occur in an air space containing air at different temperatures. If the warm air is at the top of the enclosed air space as it is in the case of heat-flow down, then the convective component will be small. If the warm air is near the bottom of the enclosed air space as it is in the case of heat flow up, then the convective component can be significant. The result is that most reflective insulation products are labeled with R-values for three principal directions of heat flow: up, down, and horizontal. The federal insulation labeling law clearly addresses this issue for residential insulations (16 CFR Part 460). There are many commercial building applications where the primary concern is heat flow down into a conditioned space. This is the type of application where reflective insulations perform best.

As in the case of porous mass-type insulations like fiberglass or cellulose, the low thermal conductivity of air is the controlling factor. Heat is transferred across reflective air spaces by conduction through the air just like it is in porous insulations. The proportion of heat flow by conduction is higher for porous insulations containing solid materials than across enclosed air spaces. This is because the thermal conductivity of solids like glass, paper, or plastic are quite large in comparison with the thermal conductivity of air or the gases used in some foam plastic insulations. A well-designed reflective system has a much smaller thermal radiation component than the radiation across low-density glass or foam insulations. The convective heat-flow component, however, is more a factor in reflective insulation systems than in mass insulation systems thus requiring careful design and evaluation on the part of reflective insulation manufacturers.

The performance of reflective insulations largely depends on low-emittance surfaces. The emittance controls the rate at which radiant energy moves from a warm surface to a cool surface. The emittance is a measurable property that is the ratio of the energy radiated by a surface to the maximum radiation possible from the surface. Emittance values range from 0 to 1 with aluminum films and foils generally being in the range 0.03 to 0.05. Most building materials and mass insulations tend to be at the opposite end of the emittance spectrum with values between 0.7 and 1. The complementary property "reflectance" which is often used to describe reflective insulation materials is one minus the emittance. As a result, a material such as aluminum foil with a very low thermal emittance (0.03) has a very high thermal reflectance (0.97). These complimentary properties mean that reflective insulations operate in two directions just like mass insulations. Reflective insulation systems are used to keep heat out of a conditioned space in hot weather or inside the conditioned space in cold weather. Relatively low emittance coatings are also available in the marketplace. Low-emittance coatings are part of the reflective technology that is available to builders and specifiers.

Reflective insulation systems like all insulation systems must be properly installed in order to deliver the desired thermal resistance. Published standards provide general guidelines for the use and installation of reflective systems: ASTM C 727 (reflective insulations), C 1158 (radiant barriers) and C 1321 (radiation control coatings). Individual manufacturers provide instructions for the proper installation of their products that must be followed to achieve the label R-values. The thermal performances of reflective systems have been verified by testing, engineering analysis, and field studies.

In many case, thermal insulation materials are used to control water vapor movement as well as heat movement. The foils and films used to produce reflective insulations do not allow passage of water vapor. The water vapor transmission resistance offered by an aluminum film or films is supplemented by the substrate material that in many cases is a plastic material having near zero water vapor transmission. The results in products with measured perm values near zero. This is especially important for reflective duct insulation and reflective insulations used in metal buildings where it is important that water-laden air not contact cold surfaces and form liquid water. Thermal designs to prevent condensation include low water vapor transmitting materials, sufficient thermal insulation to maintain surface temperatures above the dew point temperature of the interior air, humidity control for the conditioned space, and ventilation. Reflective insulations can provide the needed vapor resistance and thermal resistance in many cases. Satisfactory performance requires taping or closure of seams and irregularities in the insulation surface as is the case with all insulations used in buildings or around air-handling systems. Well-established laboratory procedures are used to verify both the water vapor transmission rates and thermal performance values of reflective insulation materials.

A degree of flexibility is achieved by reflective insulations in that perforations can be used to transform a water vapor retarder into a water vapor transmitter. The transformation of a near zero perm product to a greater than five-perm (or higher) product can be achieved by perforations that are barely visible. Perforations increase the emittance, but the change in thermal performance is very small because the perforations generally cover less than 1 % of the area of the material. This results in an increase in surface emittance from 0.03 to perhaps 0.04.

Since this article is about saving energy, the primary emphasis is thermal performance that can be provided by a well-designed and installed reflective insulation or radiant barrier system. There are a host of corollary benefits such as weight, light distribution, handling, and durability that are addressed by the marketing departments of the various reflective insulation manufacturers.

The science associated with reflective products is well established. Consensus methods for establishing performance have been developed. Reflective technology has an important place in reducing utility bills in residential and commercial buildings. This family of products is available to engineer and architects seeking to design and construct energy efficient buildings – It's about Saving Energy.

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