

Turning Empty Air Space into Thermal Resistance

Post-frame structures have many opportunities for creating enclosed reflective air spaces that have demonstrated thermal resistance (R-value). Enclosed reflective air spaces (reflective insulation assemblies) are regions with a low-emittance material on at least one side. The low-emittance surface that is part of a reflective insulation is installed in the walls, ceiling, or floor of a building so that it is perpendicular to the direction of heat flow. Insulation is installed to provide thermal resistance between warm regions and cool regions to reduce heating and cooling loads.

Reflective insulation reduces heat flow across the region it occupies by blocking thermal radiation from the warm side to the cool side. A low-emittance surface such as metalized film or aluminum foil gives off radiant energy at a much lower rate than high-emittance surfaces like wood or masonry. A low-emittance surface is also a highly-reflective surface. This means that a large fraction of the thermal radiation striking a low-emittance surface will be reflected away from the surface. As a result, a low-emittance (high reflectance) material on either side of an enclosed air space is effective in reducing heat transfer by radiation in both cold and warm weather.

Many commonly used building insulations rely on the low thermal conductivity of air to provide thermal resistance. This is true of fibrous or mass insulations like fiberglass, rock wool, cellulose, or open-cell foams. The same is true for reflective insulation systems. From a thermal insulation point of view, the purpose of the insulations listed above is to reduce heat transfer by convection (air movement) and thermal radiation. If convection and radiation are eliminated, then a thermal resistivity (R per inch of thickness) at 75°F near 5.6 ft²·h·°F/Btu·in. will result. Actual air-based insulations, however, have R-per-inch values much less than 5.6 because they do not completely eliminate radiation and convection. The fibrous insulations are very effective in suppressing convection and reducing radiation while reflective insulations are very effective in suppressing radiation and reduce convection. Natural convection is the movement of air inside a cavity due to temperature differences that affect the density of air (buoyant forces). Air moving through a region (forced convection, infiltration) has an adverse affect on most insulations.

Affect of Insulation on Heat Flow

	<u>Conduction</u>	<u>Convection</u>	<u>Radiation</u>
Mass insulation	Increase	Large Decrease	Decrease
Reflective insulation	Small increase	Decrease	Large Decrease

Reflective insulations in an enclosure reduce radiation to near zero as illustrated below for a warm-side temperature of 100 °F and a cold-side temperature of 70 °F. The results for “net thermal radiation in Btu per hour” are shown for 100 square feet of wall cavity. Heat also moves across the region by conduction and convection and this must be taken into account. Radiation does not change if the heat-flow direction changes. Natural convection depends on the heat flow direction with minimum convection occurring when the warm surface is on the top and maximum convection occurring when the warm surface is on the bottom. Heat flow by conduction does not depend on orientation or heat-flow direction.

Affect of Low-Emittance on Net Radiation Between Large Parallel Surfaces

Side 1	Side 2	Effective Emittance	Net Radiation	% Reduction
Wood	Wood	0.77	2560	-
Wood	Foil or film	0.04	133	95
Foil or film	Foil or film	0.02	66	97

The thermal resistance of an enclosed reflective air space depends on several factors, the most important of which are the effective emittance (a combination of individual emittances), the heat-flow direction, the distance across the air space, and the temperature difference across the air space. The effective emittance depends on the facing materials used by the reflective insulation manufacturer, the air space dimensions depend on the design of the wall, and the temperatures depend on the outdoor and indoor conditions.

Consider, for example, a building element with reflective insulation installed in a wood-frame cavity as illustrated in Figure 1. The reflective insulation material is attached to the framing member to form two air spaces of equal size in a cavity that is enclosed on all six sides.

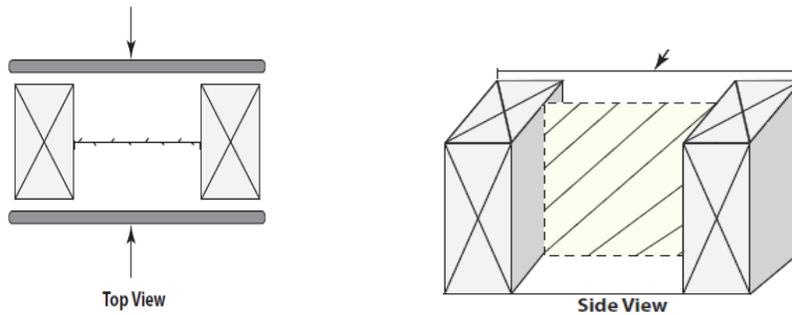


Figure 1. Reflective Insulation in Wood-Frame Cavity

R-values for the reflective insulation assembly can be determined for a warm-side temperature of 100 °F, a cool-side temperature of 70 °F, and sheathing to form two enclosed reflective airspaces. The subdivision of the region between nominal six-inch framing results in reduced temperature differences across the air spaces as shown in the following table along with calculated R-values for different heat-flow directions. The temperature differences across the air spaces are 10-12 °F

although the overall temperature difference is 30 °F. The reduced temperature difference and air gap width result in less natural convection than would be present in the empty cavity.

Details of a Reflective Insulation Assembly

	Heat Flow Up	Horizontal	Down
Location			
Outside exterior sheathing	100 °F	100 °F	100 °F
Inside exterior sheathing	97.3	97.5	98.6
Warm side of reflective	87.0	86.8	86.3
Cool side of reflective	83.0	83.2	84.2
Inside interior sheathing	72.7	72.5	71.4
Outside interior sheathing	70	70	70
R-value of cavity region	6.3	6.9	12.9

The results shown are based on an assembly with 1/2-inch thick OSB used as interior and exterior sheathing. The reflective insulation material is 1/4-inch thick with R-value 1 ft²·h·°F/Btu. Two-dimensional factors included.

The process of installing reflective insulations varies with the type of product. Attaching reflective insulation below floor joists or rafters to enclose a region can be accomplished with stapling and taping. Positioning reflective insulation to subdivide a cavity into two enclosed reflective air spaces also involves stapling and taping. Figure 2 shows a reflective insulation below floor and wall before closure.



Figure 2. Reflective Insulation Installed in Floor and Wall Applications

Reflective insulations can be combined, for example, with spray foam to form a hybrid insulations assembly as shown in Figure 3. Combinations of insulation technologies greatly increase the possibilities for effective and economical insulation packages.



Figure 3. A Hybrid Assembly that Combines Technologies

In summary: The family of insulations available to the builder includes easily installed reflective insulations that deliver R-values by blocking radiation. The performance of a reflective insulation assembly comes primarily from the enclosed air space next to the reflective insulation. An available air space can provide thermal resistance with one reflective surface with greater thermal resistance provided by dividing the air space into two or more enclosed reflective air spaces. The thermal resistance for a reflective assembly is valid in winter or summer provided that heat flow direction is taken into account. R-values for an assembly can be measured, estimated from handbook data, or calculated from well-established correlations. Reflective insulations can be combined with other types of insulation to form hybrid insulation systems.

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on behalf of the Reflective Insulation Manufacturers Association International (RIMA International). RIMA-I is a non-profit industry trade association that works to educate on the benefits and uses of reflective insulation, radiant barriers and interior radiation control coatings (IRCCs). For more information visit www.rimainternational.org