**Building Science Education**

Solution Center

Methods of Heat Transfer: Radiation- Resource Guide

One of the least understood mechanisms of heat transfer is radiation. The easiest way to understand radiant energy is to think about radiation from the sun. About half of the sun's energy reaching earth comes as natural daylight; the other half comes in the infrared spectrum, which we cannot see but which carries a lot of heat. Roughly 250 to 320 BTUs per hour per square foot of heat energy from the sun strikes the surface of a home. So, for example, one sliding glass door at roughly 40 sq. ft. receives 10,000 BTUs of energy per hour, which is equivalent to one ton of air conditioning — not an insignificant amount of heat.



*Radiation* is the transfer of heat through space via long-wave electromagnetic heat energy (radiant energy) from a warmer body to a cooler body. A unique property of radiation is that it transmits across space without having to warm that space. The sun can warm you even if there is wind; it is not affected by air (or by the millions of miles of cold space between the sun and the earth).

Heat transfer by radiation always travels in a direct line of sight and it happens incredibly fast. That’s why when you go outside on a hot day, you immediately feel the sun strike you, and when you step in the shade, you instantly feel cooler.

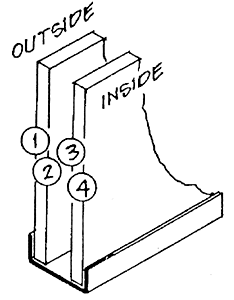
Like all heat-transfer mechanisms, radiant heat moves from a warmer to a cooler surface, and the greater the temperature difference, the greater the transfer of energy.

**Radiation and Reflectivity**

A piece of aluminum foil placed between you and a heat source tends to reflect heat back. This reflectivity suggests how we deal with radiant energy in cooling climates — by creating surfaces that reflect radiation. Low-e glass in a window is a prime example.

Low-e coatings on glass consist of thin metallic oxide coatings that reflect specific wavelengths of energy, thereby reducing heat flow from a warmer air space to a colder glazing surface. Low-e coatings allow short-wavelength solar radiation through windows, but reflect back longer wavelengths of heat. Since heat always migrates from warmer areas to cooler ones, the heat absorbed at the outside surface of the glass works its way inward and literally jumps off the other side of the glass into the home. In a double-pane window, the same process is repeated on the interior pane. Heat easily migrates into the home unless there is a low-e coating or film to stop it.

The "jumping" action characteristic of radiant heat is called emittance. Emissivity is a measure of the amount of electromagnetic radiation emitted by an object relative to the amount of radiation emitted by a "black body" — a theoretical body with a surface emissivity of 1. (A black body will absorb 100% of the thermal radiation striking it; most physical objects have surface emissivities less than 1, meaning they reflect some heat and cannot absorb it all.)

Low-e coatings prevent the transfer of heat if the coatings are applied to "surface 2" — the inside surface of the exterior pane of a double pane window (see illustration below). There, the low-e treatment reflects away the heat absorbed by the exterior glass before it has a chance to radiate across the air space toward the cooler inside pane of glass.

For those climates where there is a significant heating season, a low-e coating on "surface 3" (the outside surface of the interior pane) will render a reverse effect — heat will be kept in the house.

Low-e coatings aren't the only option to keep the heat out, however. If windows are shaded from direct sun, the majority of the heat flow will be blocked; sunshine reflected off water or the earth doesn't contain much heat. Shading windows is the best defense because it prevents the sun's heat from ever getting to the window, and shading reduces glare as well as heat transmission.

**Radiant Barriers**

In cooling climates, heat absorbed through roofs is another significant source of heat gain in homes. Field research by the Florida Solar Energy Center (FSEC), the Oak Ridge National Laboratory, and others has found several effective ways to limit rooftop heat gain. Using a highly reflective roofing material is the simplest and most effective method. A light-colored or reflective roof stops the sun’s energy before any heat can be absorbed by the roofing materials and re-radiated into the attic.

If the existing roof is dark-colored or the homeowner prefers a darker roof, heat can still be blocked by adding a radiant barrier — a reflective foil surface installed below the roof deck. The easiest and cheapest way to install a radiant barrier in new construction is to install roof sheathing with a radiant barrier. Several manufacturers now offer OSB or plywood roof sheathing with a laminated radiant barrier. A radiant barrier system can also be installed under the bottom of the top chord of a roof truss, or to the bottom edge of rafters. Installing a radiant barrier on an attic floor is not recommended, since such barriers easily get dirty, reducing the performance of the radiant barrier significantly. Radiant barriers are installed shiny side down.

Radiant barriers in attics make the most sense in locations where there are 2,000 cooling degree-days or more. Research has consistently shown that a radiant barrier in these regions can reduce the amount of heat entering a home through the ceiling by 25% to 40%. But the amount of energy saved by a radiant barrier depends on the level of insulation in the attic. For attics with a thick layer of ceiling insulation, a 40% reduction in the small amount of heat coming through the ceiling is correspondingly small. On the other hand, in an attic with minimal insulation, a 40% reduction in heat flow through the ceiling is a much larger amount. Generally, if an attic has R-30 or better attic insulation, the payback period for the installation of a radiant barrier will probably be quite long, although the radiant barrier will save energy.

**Radiant Heating Systems**

In heating climates, radiant energy is a principal heat source in hydronic systems. Both hot water and steam systems depend on "heat emitters." Though more commonly known as radiators in homes, most radiators do not transfer heat by radiation alone. Most of the heat generated by a finned-tube baseboard is actually convective. Cooler air enters the bottom of the baseboard enclosure, is warmed by the fins, and then rises from the top. By contrast, most of the heat produced by radiant floors and the heavy cast-iron Euro-style radiant baseboard is in the form of radiant heat waves, though some convection currents are also created as the air around them is heated and rises.