Chapter

12

Radiant Barriers and Reflective Insulation

Images from B movies have propagated an unwarranted depiction of "radiation" and its effects on human health. In reality, radiation is the "stuff" of life. The sun emits electromagnetic waves, a form of radiation, that directly transport energy in a straight path at the speed of light across the vacuum of space. As postulated by Albert Einstein in 1905, electromagnetic radiation travels at 186,281.7 mi/s and is only slightly slowed when passing through the earth's atmosphere.

Radiation, or more specifically, electromagnetic radiation, is energy that can be detected only when it interacts with matter. This is best exemplified by the warmth that is felt on a person's face when stepping out into the sun after standing under a shade tree. Wood stoves work by this same principle by transferring heat primarily via long-wave radiation to solid objects such as furniture, walls, floors, and people that are in "their" line of sight.

The *electromagnetic spectrum* refers to the complete range of possible electromagnetic radiation energies. The six types of electromagnetic radiation (wavelengths or frequencies) in order of increasing energy level are

1. *Radio waves.* Radio waves (including television and radar communications) are the region of the electromagnetic spectrum with very long wavelengths.
2. *Infrared radiation.* Infrared radiation, or heat energy, is the region of the electromagnetic spectrum with wavelengths long

enough to cause molecules to vibrate, increasing the temperature of the molecules.

3. *Visible light.* Visible light is the region of the electromagnetic spectrum where photons have enough energy to interact with certain pigment molecules in the retina of the eye to allow sight. This corresponds to the region of greatest solar output. All the colors of the rainbow fall into this small region, ranging from violet through indigo, blue, green, yellow, orange, and red.
4. *Ultraviolet radiation.* Ultraviolet radiation is the region of the electromagnetic spectrum where photons are sufficiently energetic to change energy states within atoms and molecules, sometimes even breaking them apart. Ozone absorbs certain types of ultraviolet (UV) radiation from the sun, which protects biologic organisms from the effects of UV rays.
5. *X-rays.* Most commonly known are its medical applications, since x-rays can be used to investigate the structure of molecules. X-rays are energetic photons that are produced in nuclear reactions and solar storms.
6. *Gamma rays.* Gamma rays are the most energetic of photons in the electromagnetic spectrum and the most biologically damaging. Gamma rays are produced in nuclear fusion reactions and can strip electrons away from molecules and atoms.

Although *light* is the name given to the type of electromagnetic radiation that can be seen, the bulk of the earth's radiant emittance occurs in the infrared portion of the electromagnetic spectrum. A barrier to limit the transfer of infrared radiation is commonly referred to as a *radiant barrier.* In residential design applications, a radiant barrier is a single sheet of reflective material positioned so that it faces an open space, such as an attic or wall cavity. Generally more effective in hot climates than in cool climates, radiant barriers often are used in buildings to reduce summer heat gain and winter heat loss. The radiant barrier itself provides no significant thermal resistance and must be installed in conjunction with an airspace to be effective.

Reflective insulation is the use of radiant barriers in combination with other materials such as a system of reflective sheets and airspaces designed together to fill a cavity and act as insulation. Reflective insulation systems typically are fabricated from aluminum foils with a variety of backings such as kraft paper, plastic film, polyethylene bubbles, or cardboard.

The use of a reflective surface to intercept the flow of radiant energy is actually historical in origin. Metal foil, which is solid metal reduced to a leaflike thinness by beating or rolling, has been around for centuries. The first mass-produced and widely used foil was made from tin. Aluminum was discovered in 1825 and replaced tin as the base material of foil in 1910, when the first aluminum foil rolling plant was opened in Switzerland.

This process evolved into the production of Reynolds Wrap, an American kitchen staple since 1947 that has protected leftovers, candy bars, and even NASA's "space blankets." (Reappropriated for consumers, the "survival blanket" is a thin plastic sheet that has a thin layer of metallized aluminum powder that is electrostatically fused over the plastic sheet on either one or both sides and is available in most camping stores.)

Thermal Principles

As discussed in Chap. 3, there are three modes of heat transfer: convection, conduction, and radiation. *Convection* is the transfer of heat in a fluid or air that is caused by the physical movement of the molecules of the heated air or fluid. When warm air in a room rises and forces the cooler air down, convection is taking place. Convection also can be caused mechanically (forced convection), by a fan or by wind.

Conduction is the process by which heat transfer takes place in solid matter, resulting from physical contact. The transfer of heat by conduction is caused by molecular motion in which molecules transfer their energy to adjoining molecules and increase their temperature. A typical example of conduction is seen when heat is transferred from a stove burner to a tea kettle, causing its contents to boil.

The third method of heat transfer, *radiation,* can be "observed" by the way the sun warms the surface of the earth. Radiation is the only method by which solar energy can cross millions of miles of empty space and reach the earth. While conduction and convection can be transferred only through a medium, radiation can be transferred across a perfect vacuum by electromagnetic waves.

The sun's transmission of electromagnetic waves to material surfaces, where they are absorbed and experienced in the form of heat, is analogous to a television signal. For example, a television transmitter emits an electromagnetic wave that travels through space. The wave is captured by the antenna and converted to a video image by the television. The radiant heat transfer between objects operates independently of air currents and is controlled by the character of the material's surface and the temperature difference between objects. Warm objects and cool objects will emit radiation, just at different rates. For example, radiant heat transfer takes place when a person feels cold while standing in front of a cold window, even if the inside air is warm. The human body radiates its stored heat toward the cold window surface. (The window is also emitting heat toward the warm body, just at a much slower rate.)

All matter emits radiation, provided that its temperature is above absolute zero. (Absolute zero is 459°F below zero.) Electromagnetic radiation does not contain any heat but only energy. The energy travels in a straight line at the speed of light until it is absorbed or reflected by another substance. Heat is generated when the energy in the different parts of the electromagnetic spectrum is transferred to the molecules in the substances that absorb the heat rays. The transfer of radiant energy from one object to another occurs without adding temperature to the airspace between them. For heat to move by radiation, there must be only a space between the objects. If the objects are touching, then the heat moves by conduction, not by radiation.

Incident energy striking an object can be absorbed by the object, reflected by the object, or transmitted through the object if it is not opaque. Since the building materials available for radiant barrier application are opaque, transmittance is not applicable to this discussion.

Absorptance is the quantitative measure of a material's ability to absorb radiant energy. Although an ideal blackbody is hypothetical, objects are often identified by comparison of their radiative properties with those of a blackbody at the same temperature. A blackbody radiator is referred to as *black* because an ideal blackbody is a hypothetical object that absorbs all radiation incident on its surface. Since it does not reflect any radiation (including visible light), it appears black. An approximate blackbody is lampblack, which reflects less than 2 percent of incoming radiation. Pot belly stoves, for example, are flat black so that they will freely emit radiant heat. In theory, a mirrored surface may reflect 98 percent of the energy, while absorbing 2 percent of the energy (although aluminum foil does not have to be shiny to reflect 95 to 97 percent). A good blackbody surface will reverse the ratio, absorbing 98 percent of the energy and reflecting only 2 percent.

Emittance refers to the ability of a material's surface to emit radiant energy. In layperson's terms, this means to "give off heat." Materials that radiate a large amount of heat and absorb a large percentage of the radiation that strikes them have high emittance values. The lower the emittance of a material, the lower the amount of heat that is radiated from its surface. Aluminum foil has a very low emittance value of 0.03 to 0.05 (Fig. 12.1).

Emittance value is often expressed as a material's emissivity. *Emissivity* is the ratio of the radiant energy emitted by a source to that emitted by a blackbody at the same temperature, expressed in a value ranging from 0 to 1. Most common building materials, including glass and paints of all colors, have high emissivities near 0.9. These materials are ineffective barriers to radiant energy transfer because they are capable of transferring 90 percent of their radiant energy potential.

Kirchoff's law states that for any object, absorptivity equals emissivity. This means that an object that is a strong absorber at a particular wavelength is also a strong emitter at that wavelength and an object that is a weak absorber at a particular wavelength is also a weak emitter at that wavelength. Emissivity of a blackbody is 1. Conversely, a perfect reflector has an emissivity of 0.

Material Surface	Emittance
Asphalt	0.90-0.98
*Aluminum foil	0.03-0.05
Brick	0.93
Concrete	0.85-0.95
Glass	0.95
Fiberglass / Cellulose	0.8-1.0
Iron (polished)	0.06
Iron (rusty)	0.85
Limestone	0.36-0.90
Marble	0.93
Paint: white lacquer	0.80
Paint: white enamel	0.91
Paint: black lacquer	0.80
Paint: black enamel	0.91
Paper	0.92
Plaster	0.91
Silver	0.02
Steel (mild)	0.12
Wood	0.90

Figure 12.1 Emittance values. (*RIMA*)

Reflectance (or *reflectivity*) refers to the measure of how much radiant heat is reflected by a material. Reflectivity and emissivity are inversely related. When the emissivity and reflectivity are added together, the sum is 1. Therefore, a material with a high reflectivity has a low emissivity, and a low emittance is indicative of a highly reflective surface. For example, since aluminum has an emissivity of 0.03, it has a reflectance of 0.97. Since it eliminates 97 percent of the radiant transfer potential, aluminum foil is very effective as an excellent radiant barrier and reflective insulation product.

Radiant Barriers

Product description

Mass-type insulations limit heat flow by possessing low thermal conductivity, allowing less heat to be transferred, or by trapping still air within the insulation, thereby limiting convection. A radiant barrier is a reflective surface on or near a building component that intercepts the flow of radiant energy to and from the building component. Typically a layer of reinforced foil, a radiant barrier reduces the amount of heat radiated across an airspace that is adjacent to the radiant barrier. The effectiveness of a radiant barrier is based on its ability to reflect the radiation that strikes it and at the same time not radiate energy. As discussed earlier, the lower the emissivity, the higher is the reflectance and the better is the radiant barrier.

Radiant barrier materials must have high reflectivity (usually 0.9, or 90 percent, or more) and low emissivity (usually 0.1 or less) and must face an open airspace to perform properly. A radiant barrier by itself provides no thermal resistance; it must be installed in conjunction with an airspace. For example, aluminum foil is a good thermal conductor but has an extremely low R-value. If it is placed between materials that are attempting to transfer thermal energy by radiation, it must be separated from these materials by an air layer. The foil effectively eliminates the normal radiant energy exchange across the airspace. If the airspace is not maintained, conduction is introduced. For example, where a radiant barrier surface comes in contact with another surface, such as mass insulation, direct conduction of heat will occur at all the points of contact.

The Department of Energy (DOE) reported that radiant barriers tend to offer a much lower potential for energy savings in colder climates. Radiant barriers are more effective in blocking summer heat gain and saving air-conditioning costs.[1] At present, there is no standardized method for testing the effectiveness of radiant barriers in reducing heating and cooling bills. Numerous field tests have been performed, however, that show that radiant barriers are effective in reducing cooling bills by limiting total heat gain. For example, solar energy is absorbed by the roof on a sunny day, which in turn heats the roof sheathing. This causes the underside of the sheathing and the roof framing to radiate heat downward toward the attic floor. If a radiant barrier is placed below the roof sheathing or on the attic floor, much of the heat radiated from the hot roof is reflected back toward the roof and not emitted to the attic airspace. This makes the top surface of the insulation cooler than it would have been without a radiant barrier and thus reduces the amount of heat that moves through the insulation into the rooms below the ceiling. The best results from this installation are achieved when there is ventilation between the radiant barriers and the roof. This prevents that space from overheating and reducing the effectiveness of the radiant barriers. Test results indicate that cooling bill savings are more dramatic in homes having lower amounts of conventional insulation. The DOE has established typical savings amounts based on attic insulation values[2] (Figs. 12.2 and 12.3).

The North American Insulation Manufacturers Association (NAIMA) performed a number of tests in 1988 that studied the effects of adding radiant barriers to existing homes. These tests showed that radiant barriers located on the top of the rafters and draped between the cavities resulted in a 20 to 26 percent reduction in summer ceiling heat flow for a home with R-19 ceiling insulation. Studies were not performed with R-30 insulation and radiant barriers.[3]

Installation standards and practices

Radiant barriers can be manufactured in a variety of ways. Commercial products include radiant barrier material that is preapplied to rigid insulation, applied to structural sheathing, and as reinforced sheet radiant barrier material. Sheet materials include single-sided and double-sided foils. Radiant barriers that are manufactured as multilayered foil systems with airspaces are discussed in the reflective insulation section of this chapter. The application of sheet material is discussed in this section.

The installation of multiple layers of radiant barrier materials is generally discouraged. One layer of a typical radiant barrier material will block 95 percent of radiant heat gain. A second layer for the purpose of blocking additional radiant gain will block less than 5 percent. The material and labor costs incurred when installing

Present Value Savings for Radiant Barrier Attached to Bottoms of Rafters
(Note: R-11, R-19, R-30, and R-38 refer to the existing level of conventional insulation.)

City	Present Value Savings, Dollars per Square Foot of Attic Floor			
	R-11	R-19	R-30	R-38
Albany, NY	0.17-0.19	0.08-0.09	0.04-0.05	0.03-0.04
Albuquerque, NM	0.24-0.27	0.12-0.15	0.08-0.10	0.06-0.08
Atlanta, GA	0.21-0.25	0.10-0.13	0.06-0.08	0.05-0.07
Bismarck, ND	0.18-0.20	0.09-0.10	0.05-0.06	0.04-0.05
Chicago, IL	0.17-0.19	0.08-0.10	0.05-0.06	0.04-0.05
Denver, CO	0.19-0.22	0.10-0.12	0.06-0.08	0.05-0.07
El Toro, CA	0.19-0.22	0.10-0.12	0.06-0.08	0.05-0.07
Houston, TX	0.23-0.28	0.12-0.15	0.07-0.10	0.05-0.08
Knoxville, TN	0.22-0.25	0.11-0.13	0.07-0.09	0.05-0.07
Las Vegas, NV	0.30-0.36	0.15-0.19	0.09-0.12	0.07-0.10
Los Angeles, CA	0.11-0.12	0.06-0.07	0.04-0.05	0.03-0.04
Memphis, TN	0.23-0.27	0.11-0.14	0.07-0.09	0.06-0.08
Miami, FL	0.28-0.36	0.15-0.20	0.09-0.13	0.07-0.10
Minneapolis, MN	0.18-0.19	0.08-0.10	0.05-0.06	0.03-0.04
Orlando, FL	0.26-0.32	0.13-0.17	0.08-0.12	0.07-0.10
Phoenix, AZ	0.36-0.43	0.17-0.23	0.10-0.14	0.08-0.12
Portland, ME	0.14-0.15	0.06-0.06	0.03-0.04	0.03-0.03
Portland, OR	0.14-0.16	0.07-0.08	0.04-0.05	0.03-0.04
Raleigh, NC	0.20-0.24	0.10-0.12	0.06-0.08	0.05-0.07
Riverside, CA	0.27-0.37	0.13-0.17	0.07-0.10	0.06-0.08
Sacramento, CA	0.23-0.26	0.12-0.14	0.07-0.10	0.06-0.08
Salt Lake City, UT	0.21-0.24	0.10-0.12	0.06-0.08	0.05-0.07
St. Louis, MO	0.21-0.24	0.10-0.13	0.06-0.08	0.05-0.07
Seattle, WA	0.11-0.12	0.05-0.05	0.03-0.03	0.02-0.02
Topeka, KS	0.22-0.26	0.11-0.13	0.07-0.09	0.05-0.07
Waco, TX	0.26-0.31	0.13-0.17	0.08-0.11	0.06-0.09
Washington, D.C.	0.20-0.23	0.09-0.12	0.06-0.07	0.05-0.06

Note: First value applies to houses with no air-conditioning ducts in attics. Second value applies to houses with air-conditioning ducts in attics.

Figures in table are based on a radiant barrier with an emissivity of 0.05 or less, with the radiant barrier covering the insides of the gables. Savings are for a 25 year period.

Figure 12.2 Energy savings. (*Department of Energy*)

multiple layers will not be recouped by the additional energy use savings.

Likewise, a radiant barrier material with two foil sides is only modestly better than one with a single foil side. In an attic airspace, one foil side blocks up to 95 percent of the radiant heat transfer. A second foil surface can block only a portion of the remaining 5 percent. Therefore, a second foil surface usually is not cost-effective.

Attic locations

Radiant barriers are easiest to install during construction. Nevertheless, installing a radiant barrier system in an existing

Present Value Savings for Radiant Barrier Draped over Tops of Rafters or Attached to Roof Deck
(Note: R-11, R-19, R-30, and R-38 refer to the existing level of conventional insulation.)

City	Present Value Savings, Dollars per Square Foot of Attic Floor			
	R-11	R-19	R-30	R-38
Albany, NY	0.16-0.17	0.07-0.08	0.04-0.05	0.03-0.04
Albuquerque, NM	0.21-0.24	0.11-0.14	0.07-0.09	0.06-0.07
Atlanta, GA	0.19-0.22	0.09-0.12	0.06-0.07	0.04-0.06
Bismarck, ND	0.17-0.18	0.08-0.09	0.05-0.06	0.03-0.04
Chicago, IL	0.15-0.17	0.07-0.09	0.04-0.05	0.03-0.04
Denver, CO	0.17-0.19	0.09-0.10	0.05-0.07	0.05-0.06
El Toro, CA	0.17-0.20	0.09-0.10	0.05-0.07	0.05-0.06
Houston, TX	0.20-0.25	0.10-0.14	0.06-0.09	0.05-0.07
Knoxville, TN	0.19-0.22	0.10-0.12	0.06-0.08	0.05-0.07
Las Vegas, NV	0.27-0.32	0.14-0.17	0.08-0.11	0.06-0.09
Los Angeles, CA	0.10-0.11	0.06-0.06	0.03-0.04	0.03-0.04
Memphis, TN	0.20-0.24	0.10-0.13	0.06-0.08	0.05-0.07
Miami, FL	0.25-0.31	0.13-0.18	0.08-0.11	0.06-0.09
Minneapolis, MN	0.16-0.18	0.07-0.09	0.04-0.05	0.03-0.04
Orlando, FL	0.23-0.28	0.11-0.15	0.07-0.10	0.06-0.09
Phoenix, AZ	0.31-0.38	0.15-0.20	0.09-0.13	0.07-0.11
Portland, ME	0.13-0.13	0.06-0.06	0.03-0.03	0.02-0.03
Portland, OR	0.13-0.14	0.06-0.07	0.04-0.04	0.03-0.04
Raleigh, NC	0.18-0.21	0.09-0.11	0.06-0.07	0.04-0.06
Riverside, CA	0.24-0.33	0.11-0.15	0.07-0.09	0.05-0.07
Sacramento, CA	0.20-0.23	0.10-0.13	0.06-0.08	0.06-0.07
Salt Lake City, UT	0.19-0.21	0.09-0.11	0.05-0.07	0.04-0.06
St. Louis, MO	0.18-0.21	0.09-0.11	0.05-0.07	0.04-0.06
Seattle, WA	0.10-0.11	0.04-0.05	0.02-0.03	0.02-0.02
Topeka, KS	0.20-0.23	0.10-0.12	0.06-0.08	0.05-0.06
Waco, TX	0.23-0.28	0.11-0.15	0.07-0.09	0.05-0.08
Washington, D.C.	0.18-0.21	0.08-0.10	0.05-0.06	0.04-0.05

Note: First value applies to houses with no air-conditioning ducts in attics. Second value applies to houses with air-conditioning ducts in attics.

Figures in table are based on a radiant barrier with an emissivity of 0.05 or less, with the radiant barrier covering the insides of the gables. Savings are for a 25 year period.

Figure 12.3 Energy savings. (*Department of Energy*)

home can be relatively easy provided there is sufficient working room in the attic.

According to the DOE, there are five possible locations for the installation of an attic radiant barrier system to be effective[2] (Fig. 12.4):

1. Before the roof sheathing is applied, the radiant barrier is draped over the rafters or trusses. The radiant barrier should droop $1^1/_2$ to 3" between each rafter. An airspace is necessary between the radiant barrier and the roof sheathing. This is suitable for new construction only.

2. The radiant barrier is attached to the faces of the rafters or top chords of the roof trusses. If the barrier is single-sided, the reflective face should face downward, toward the attic, to minimize any dust accumulation. An airspace ($^3/_4$" minimum) is necessary between the radiant barrier and the roof sheathing.
3. The radiant barrier is attached to the bottom of the rafters or top chords of the roof trusses. An airspace ($^3/_4$" minimum) is necessary between the radiant barrier and the roof sheathing.
4. The radiant barrier can be laid out on the attic floor over the top of existing attic insulation, provided the insulation does not fill the cavity. As with all radiant barrier installations, an airspace must be maintained to avoid any conductive heat transfer. If the barrier is single-sided, the reflective face should face downward, toward the attic insulation (and above the airspace), to minimize any dust accumulation. This application always should be done with a perforated radiant barrier and one that has foil on both sides for maximum performance.
5. The radiant barrier material is preattached directly to the underside of the roof deck. Plywood and oriented strandboard products laminated with foil on one side are available.

There are some basic safety considerations that an installer, either a professional or a homeowner, should consider during radiant barrier installation:

1. Although American Society for Testing and Materials (ASTM) installation standards do not require special protection when handling radiant barrier materials, handling conventional insulation may cause skin, eye, and respiratory system irritation. If in doubt about the effects of the insulation, protective clothing, gloves, eye protection, and breathing protection should be worn.
2. Be especially careful with electrical wiring, particularly around junction boxes and old wiring. Never staple through, near, or over electrical wiring. Repair any obviously frayed or defective wiring in advance of radiant barrier installation.
3. Work in the attic only when temperatures are reasonable.
4. Working with a partner not only will expedite the process, but assistance will be immediately available should a problem occur.
5. Unfinished attics can be especially dangerous. Step and stand only on the attic joists or trusses, or use dimensional lumber for a working platform.

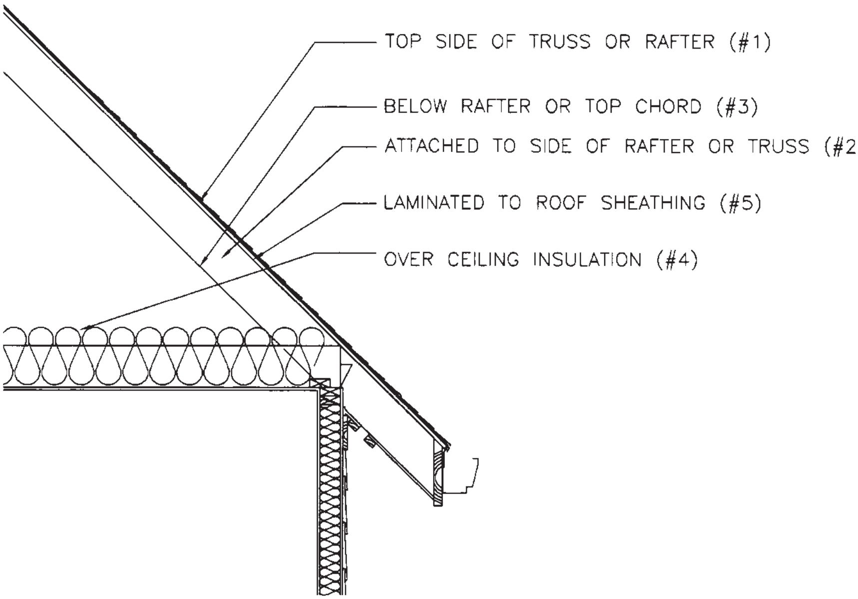

Figure 12.4 Radiant barrier locations. (*Bynum*)

6. In most attics, roofing nails penetrate through the underside of the roof.
7. Make sure that the attic space is well ventilated and lighted.
8. Do not cover any recessed lights or kitchen and bathroom vents with radiant barrier material during an attic floor application.

Radiant barriers can be used above unheated basements and crawl spaces and in wall and floor applications. These assemblies require specific design conditions, airspace clearances, and vapor retarder placement to be effective. (Unless perforated, radiant barrier materials will qualify as a vapor retarder. Perforated foils typically are used only when laying on top of existing attic insulation.) Foil-faced fiberglass batts with a fire-retardant binder, stapled to the sides of the wall studs, require an airspace between the foil facing and interior sheathing to be effective. A larger wall cavity, and subsequently deeper wall stud framing members, will be required. Another less common technique is to use foil-faced gypsum wallboard over furring strips on the interior stud faces. The furring strips create an airspace between the foil facing and cavity insulation.

"Vent skin" construction is commonly used in Florida. In this assembly, a radiant barrier is applied to the exterior of the wall, followed by furring strips and sheathing. The airspace created by the furring strips typically is vented top and bottom so that outdoor air can circulate into and through the space (Fig. 12.5).

Since radiant energy travels in a straight line through the air and is not affected by air currents, airtight seals are not necessary for a radiant barrier to perform effectively. Since radiant barriers are both barriers to heat transfer and vapor retarders, proper radiant barrier selection must be coordinated with vapor retarder placement to avoid trapping condensation in certain climates. Perforated radiant barriers are also used if moisture vapor condensation could present a problem, as in placement of the radiant barrier on top of mass insulation on an attic floor.

Limitations

Since radiant barriers redirect radiant heat back through the roof, tests have demonstrated that radiant barriers can cause a small increase in roofing material temperatures. Roof-mounted radiant

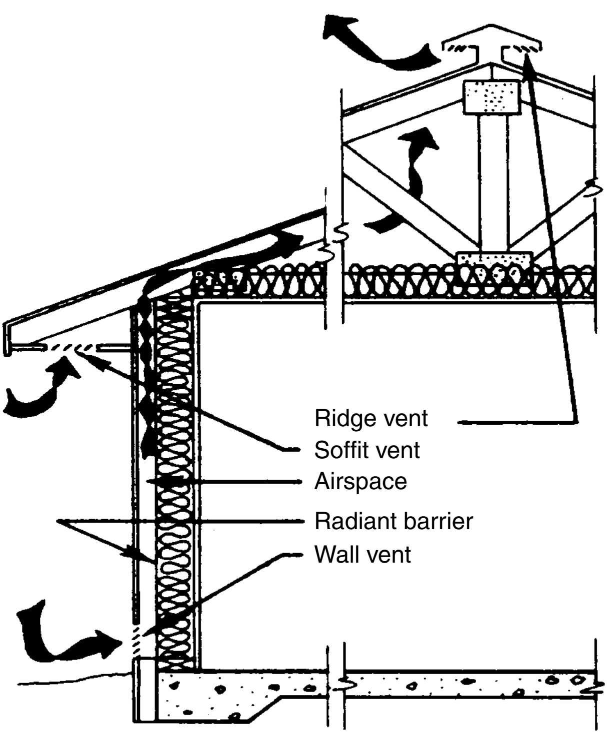

Figure 12.5 Vented radiant barrier wall section. (*Bynum*)

barriers may increase shingle temperatures by 2 to 10°F, whereas radiant barriers on the attic floor may cause smaller increases of 2°F or less. The effects of these sustained higher temperatures on the roof shingles or substrate have not been shown to degrade the life of shingles.

If the radiant barrier is installed directly on top of attic floor insulation, condensation of moisture vapor can become a problem. For example, moisture vapor from the interior of a house may move into the attic during the winter months. A radiant barrier on top of the insulation could cause the vapor to condense on the radiant barrier's underside. As is the case when a vapor retarder is placed on the wrong side of insulation, radiant barrier materials function as an additional vapor retarder on the opposite side of the wall cavity. For this reason, this application would call for a perforated radiant barrier. This can be especially critical in cold climates.

Installing a radiant barrier directly on top of attic floor insulation also can compromise its effectiveness due to dust accumulation. This location is also not appropriate when a large part of the attic is used for storage, since the radiant barrier surface must be exposed to the attic space. It also can be punctured or torn during any service work that may need to be done in the attic.

Durability during installation is an important consideration when comparing products. Thicker foil layers and the use of a reinforcing material are superior to the lower-cost foils that have minimal tear resistance.

Fire ratings

A radiant barrier must receive a Class A/Class 1 fire rating. A flame spread index of 25 or less and a smoke development index of 450 or less must be achieved according to ASTM E84. These ratings should be printed on the product or listed on the manufacturer's material safety data sheets (MSDS) or other technical data literature.

Cost

Installing an attic radiant barrier is obviously easier and less expensive during new construction. If a retrofit project is undertaken, the amount of room the contractor has to maneuver in in the attic will affect cost. Radiant barrier material costs vary, ranging from $0.10 to $0.45 per square foot. Although most materials can be installed by a homeowner, a contractor may charge an additional amount for installation costs.

The energy savings payback period will vary extensively, contingent on the cost of the radiant barrier installation, heating and cooling periods, amount of existing insulation, etc. Data are not available for specific calculations, but regional research in Florida suggests that a payback period of 10 years can be expected in hot southern climates.[4]

Reflective Insulation

Product description

Unlike single-sheet radiant barrier materials, reflective insulation is a multilayer radiant barrier product with an intrinsic R-value. Comprised of layers of aluminum foil, paper, and/or polyethylene, the insulation creates reflective airspaces within the cavity, thereby reducing radiant heat transfer and heat flow by convection. The use of aluminum foil as a reflective insulation ensures a minimum 95 to 97 percent reflectance of long-wave radiant heat.

Reflective insulation installation applications are similar to those of radiant barriers. Since most foil-faced reflective insulation products also retard vapor transmission, special attention must be paid to vapor retarder placement in the wall, floor, or ceiling assembly. Trapping moisture between two vapor retarders can lead to condensation-related decay and damage. This can be problematic in attic floor insulation applications. If, for example, a vapor retarder is located on the interior ceiling side of the insulation, reflective insulation cannot be laid on top of the existing insulation.

Foil-faced polyethylene insulation

The most common reflective insulation products are foil-faced polyethylene sheets, which consist of layers of aluminum foil separated by polyethylene bubbles (Fig. 12.6). The polyethylene air cushioning can be from one to five layers depending on the manufacturer. Many products incorporate stapling flanges at the edge for easy installation. These products are noncarcinogenic, water-resistant, and fungus-resistant. With few exceptions, foil-faced polyethylene insulation is not restricted by code from being left exposed, provided the product is classified with a Class 1, Class A fire rating.

Foil-faced polyethylene insulation is lightweight, easy to install with a staple gun, and can be cut using a utility knife. Tears or excess cuts usually can be repaired with 2 or 3"-wide pressure-sen-

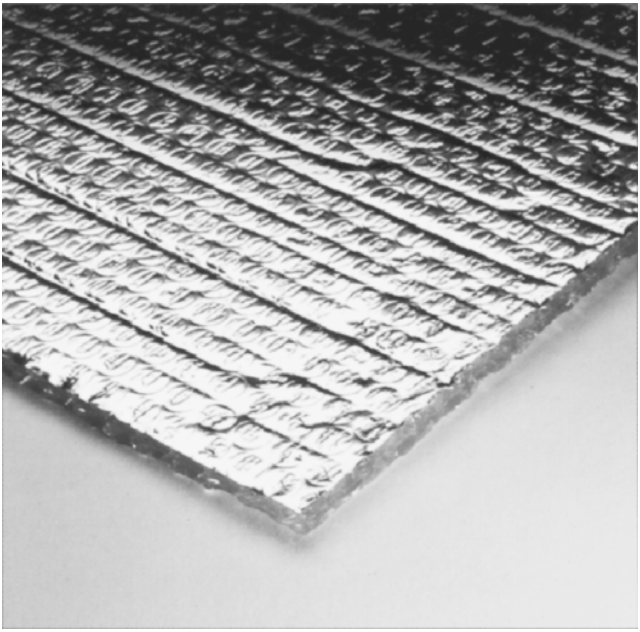

Figure 12.6 Astro-foil reflective insulation. (*Astro-Foil*)

sitive aluminum tape. (Do not use duct tape.) A $^3/_4$" minimum air-space must be maintained on each side of the insulation. The sizes available vary based on specific products. Rolls are usually available in widths of up to 6 ft and lengths of up to 125 ft. Typical thickness are $^1/_4$, $^3/_{16}$, or $^5/_{16}$".

Locations where reflective insulation can be installed include

1. Over roof trusses/rafters
2. Interior sides of wall studs/furring, exposed or encapsulated
3. Undersides of floor joists/trusses, exposed or encapsulated
4. Undersides of first floor joist/trusses at crawl spaces, exposed or encapsulated
5. Below interior ceiling joists/trusses/rafters, exposed or encapsulated
6. As a wrap for HVAC supply ducts
7. As a wrap for water heaters
8. As a wrap for water supply piping
9. As primary insulation for in-floor hydronic staple-up heating systems

R-values

R-values of reflective insulations depend on the direction of the heat flow. This can be confusing when one is accustomed to comparing singular R-values for conventional mass insulations. For example, one manufacturer of $^{5}/_{16}$" foil-faced polyethylene insulation reports R-values to be 15.0 down, 5.4 up, and 7.31 horizontal.

Sideways (horizontal) heat flow through a wall will result in nominal convection loss. Upward heat flow, as through the ceiling in the winter, is in the same primary direction as convection, so the R-value is significantly reduced. In downward heat flow applications, such as through the floor to a crawl space in the winter or through the roof in the summer, convection is not a factor, resulting in maximum R-values. Reflective insulations must be installed with an airspace in order for the radiant heat to be reflected. Therefore, the R-values are reported as an installed system that includes the R-value of the surrounding airspaces.[5] If the airspace dimension is changed, then the R-value of the system is changed.

Board and paper products

Foil-faced kraft paper is produced as a folded or rolled product and is available with two to five layers in a wide range of effective resistances. The airspaces are formed only when the product is stretched to its full width. Care must be taken in installation to ensure that the paper is sufficiently stretched and that foil layers are not touching, or the material will not be fully effective. Prices vary accordingly, from around 14 to 70 cents per square foot.[6]

There are a number of laminated structural sheathing materials, such as foil-faced paperboard, that have reflective surfaces but are not installed as radiant barriers. Production homebuilders ("national builders") commonly use these materials as the substrate for houses with vinyl siding. Installed in this manner, these products lack only an airspace in order to be used as a radiant barrier. Costs for these products range from 13 to 25 cents per square foot.[6]

A new name on the market is *TechShield,* and is produced by Louisiana Pacific. TechShield is highly polished, kraft paper–backed, perforated aluminum. Formerly labeled *Kool-Ply,* TechShield is a patented radiant barrier overlay that is laminated directly to either oriented strandboard (OSB) or plywood structural panels, and mainly used as roof decking. TechShield radiant barrier decking is installed in the same manner as standard APA-rated sheathing. A $^{1}/_{2}$

to $^3/_4$" airspace must be maintained between the foil and the insulation blanket between the roof rafters or ceiling joists (Fig. 12.7).

Standards

The following are the ASTM standards associated with reflective insulation materials and radiant barrier products.

C236-89, "Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box"

C727-90, "Standard Practice for Use and Installation of Reflective Insulation in Building Constructions"

C976-90, "Standard Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box"

C1158-90, "Standard Practice for Use and Installation of Radiant Barrier Systems (RBS) in Building Construction"

Figure 12.7 Radiant barrier laminate. (*Louisiana-Pacific Corp., Tech-Shield*)

C1224-93, "Standard Specification for Reflective Insulation for Building Applications"

C1313-95, "Standard Specification for Sheet Radiant Barriers for Building Construction Applications"

C1340-96, "Standard Practice for Estimation of Heat Gain or Loss Through Ceilings Under Attics Containing Radiant Barriers by Use of a Computer Program"

C1371-96, "Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers"

E84-95b, "Standard Test Method for Surface Burning Characteristics of Building Materials"

E96-95, "Standard Test Method for Water Vapor Transmission of Materials"

Paints

Coatings can be applied to the interior of a home that will work as radiant barriers. Interior radiation control coating (IRCC) is a non-thickness-dependent silver-colored low-emittance coating. When applied to nonporous building materials such as plywood, OSB, metal siding, or plasterboard, it lowers the normal surface emittance of these materials to 0.24 or lower. It is somewhat less efficient because of its higher emissivity when compared with a foil or film product.[7]

One manufacturer reports that about 40 percent of the radiant energy generated within a room in the winter is reflected back into the room after this paint is applied. Similar results are claimed in the summer: A room coated with a low-E (low-E is an abbreviation for low emissivity) wall paint on the interior of a building's walls will not allow about 40 percent of the radiant energy to be emitted into the room.[8]

A water-based IRCC can be rolled or spray applied (either air atomization or airless is the most effective method of installation) in existing structures where the cost of installing foil or film products may be prohibitive. Brush painting is usually impractical because these coatings have a very low viscosity and are not formulated for brush application. It is imperative that after installation the surface painted with the IRCC face a minimum of a 2" airspace.

Technical data and field testing research are limited with these new products. *Low-E coatings,* as these products are commonly called, have a lower emissivity than the higher-build ceramic coatings. See Chap. 14 for a discussion of ceramic pigmented solar radiation control coatings for exterior application.

Low-E glass

In order to minimize the transfer of radiant heat through glass, a revolutionary product was invented in the early 1980s called *low-E glass*. Low-E glass allows natural light to enter, while reflecting indoor heat energy back into the home in winter. Likewise, it reflects outdoor heat energy back to the outside in summer.[9] There are two types of low-E coatings, softcoat and hardcoat. Softcoat low-E coatings are vacuum deposited on the glass after it comes off the float glass manufacturing line. These coatings are created as the room-temperature glass passes through a series of vacuum chambers where metallic particles are deposited onto the glass surface.

Hardcoat low-E coatings are applied in a pyrolytic process on the float glass manufacturing line before the glass has cooled. This means the coating is sprayed on the molten glass and is fused to the glass as it cools, creating a permanent bond. Although this product is not as thermally effective as softcoat glass, the process produces a coating that is as durable as the glass itself.[10]

While ordinary clear glass allows more solar energy into your home than low-E glass does, clear glass has such a low R-value that it allows not only the solar energy gain but any furnace-generated heat (during the winter) to escape. Low-E windows can achieve R-values as high as R-5, a marked improvement over R-1 single-pane or even R-2 double-pane windows. Low-E windows cost a little more than standard windows and allow slightly less light to enter but are often cost-effective in extremely hot or cold climates.[11]

Miscellaneous

As an interesting sidenote, reflective insulation is also available for windows. Proprietarily known as *Sailshades,* this product is a seven-layered roll product. When raised during winter days, Sailshades allow the benefits of the sun's passive heating to reach the interior of the home. When lowered during winter evenings, the product serves as a wall of insulation for the structure. Similar to foil-faced polyethylene insulation, two outer layers of aluminum foil are bonded to a layer of polyethylene for strength. Two inner layers of bubblepack resist heat flow, whereas a center layer of polyethylene gives the insulation additional strength. The product features an

R-value as high as 8.83. The shades are custom made for each window but are not cheap. A typical 24 × 48" window covering will cost about $176.[12]

Appendix

Radiant Barrier Fact Sheet
DOE/CE-0335P
June 1991
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Assistant Secretary for Energy Efficiency and Renewable Energy

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