A worker retrofits a radiant barrier to the underside of rafters. The foil faces down to avoid dust accumulation.

Radiant Barriers– High Performance or Hype

"Just the facts, m'am," was a line immortalized by the TV series Dragnet. Trying to get just the facts about radiant barriers is like trying to solve a bunch of who-done-its. Even after a lot of digging, you still don't have all the answers. Where is Sgt. Joe Friday when we need him?

Researchers have long confirmed that radiant barriers can cut cooling bills in warm climates. But since the upsurge of interest in the 1980s, questions have arisen faster than scientists could provide answers. Here's an overview of what we know about radiant barriers today, and what remains murky.

It's a System

How radiant barriers work seems pretty simple in concept, but it is different enough from conventional insulation that it can fool you. For example, one Florida builder interviewed for this article mistakenly offered his buyers a "radiant barrier" in both his walls and ceiling. The shiny material stapled beneath his roof trusses was indeed saving energy as he promised. But the foil facing on his foam sheathing wasn't saving anything because it was covered directly with stucco.

To block radiant heat flow, a radiant barrier needs two things: a foil material with a low-emissivity (low-e) rating—preferably .06 or lower—and an air space next to it, preferably 3/4-inch or more (see "Foiling Radiant Heat Flows"). When the air space and foil are open to air circulation, as in an attic, you have what's called a radiant barrier system (see Figure 1). When the air space next to the foil is sealed or enclosed within a wall cavity, the feature is called reflective insulation. The focus here is radiant barrier systems in attics.

The R-Value Question

Radiant barriers have no R-value.

An R-value describes an element's resistance to heat flow by conduction—heat moving through solid building materials and "mass" insulation such as fiberglass batts. Being a very thin metallic material, radiant barriers have virtually no insulating capacity in that sense. So asking what's the R-value of a radiant barrier system is comparing apples to oranges.

There have been attempts to give radiant-barriers credit by granting them a so-called "effective R-value." In 1986, however, the Federal Trade Commission essentially eliminated that approach, and no accepted performance measure has replaced it.

The main problem is that an attic radiant barrier's performance depends on placement of the barrier, the amount of ceiling insulation and ventilation, and the climate (for example, hot-humid versus hot-arid). Tennessee Technical University researcher David Yarborough says a computer program developed at Oak Ridge National Laboratory (ORNL) is currently viewed as the best hope to sort out performance ratings.

Savings in Hot climates

Radiant barriers are most effective in hot, sunny climates (see "Mapping Out Barriers"). Research in Florida, Texas, Tennessee, and Mississippi indicates that a radiant barrier will typically reduce summer heat gains through a ceiling by about 40 percent. The key question here is "40 percent of what?"

Since ceiling heat gains account for only 15 to 30 percent of the cooling load in a typical Florida ranch, The Florida Solar Energy Center (FSEC) estimates that a radiant barrier should

By Steve Andrews

It's clear they can save energy in warm climates, but the rest remains murky

Figure 1. *The three essential elements of a radiant barrier system are shown: adequate insulation, good ventilation, and a foil barrier. Not shown, but also important for cooling, is a light-colored roofing shingle.*

cut annual cooling costs by 8 to 12 percent when used above R-19 ceiling insulation. If the annual cooling bill in a hot climate is projected at $500, savings should be roughly $50 per year. In a home with better energy performance, savings from adding a radiant barrier will be lower.

During the peak summer cooling season, southwestern desert climates like in Phoenix are sunny 72 percent of the time as opposed to 49 percent in Miami. When you factor in the lower humidity, a larger portion of a Tucson or Las Vegas home's cooling problem is caused by solar radiation. Thus you can make a good case for attic radiant barriers saving more in southern Arizona than in southeastern climates. Estimated savings run as high as 20 percent of the total cooling load but this has not been scientifically proven.

In virtually all locations, radiant barriers appear to save the most energy when combined with upgraded attic ventilation. FSEC's lead researcher Philip Fairy says proper ventilation—at soffit and ridge—can nearly double radiant barrier performance. Fairy sums up hot-climate performance this way: "In cooling-dominated climates, attic radiant-barrier systems are the thermal upgrade of choice once reasonable levels of ceiling insulation have been achieved."

Savings in Moderate Climates

The jury is still out. In moderate climates, the prospects for saving energy with radiant barriers appear mixed.

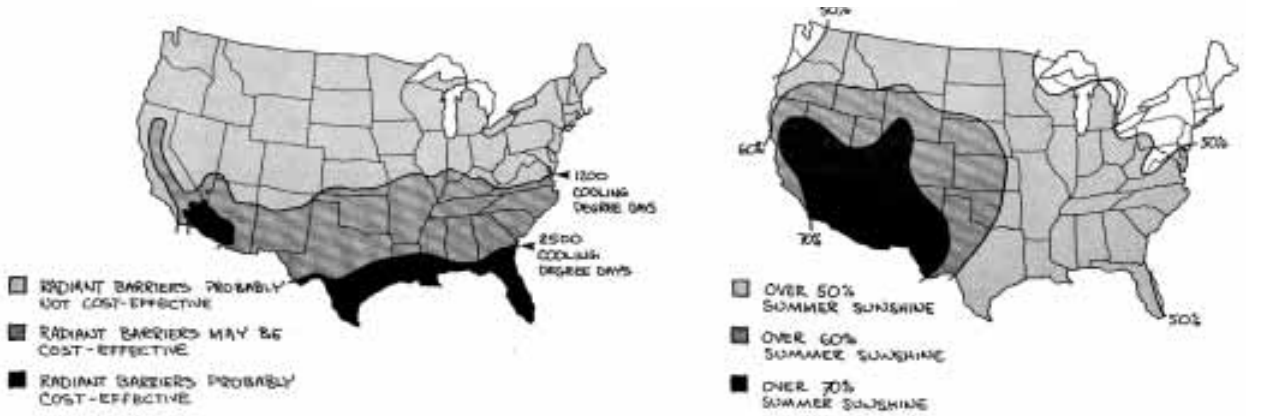
ORNL has conducted numerous field tests in three 1,200-square-foot unoccupied "laboratory homes" in Knoxville, Tenn. In Knoxville, heating needs outweigh cooling by more than two to one. The summer sun shines just over 50 percent of the time and humidity is high.

Researchers found that adding a radiant barrier to R-19 insulation saved between 12 and 21 percent of total cooling costs. But they found little effect when adding radiant barriers to R-30 attic insulation.

FSEC's computer analysis indicates that in Atlanta and Baltimore R-19 attic insulation and inexpensive radiant barriers (20¢/sq. ft. installed) were more cost-effective than R-30 insulation without radiant barriers.

In a computer study for Sacramento, Calif., the Davis Energy Group predicted that radiant barriers would save from 10 to 25 percent of cooling costs, depending on barrier location

MAPPING OUT BARRIERS



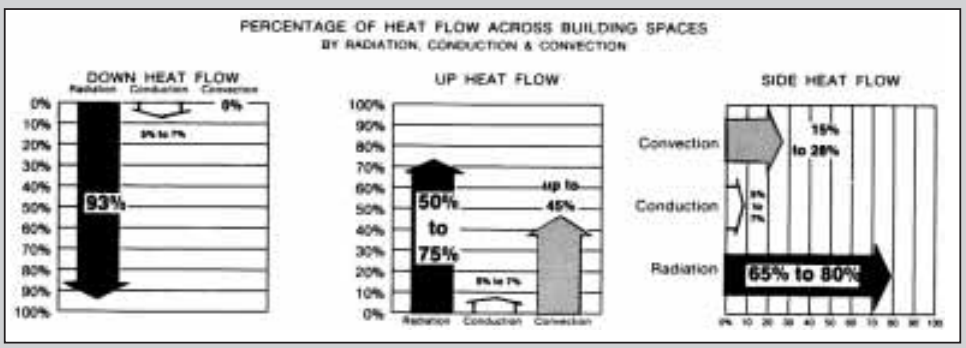
Radiant barriers make the most economic sense in the deep South, as shown on the map at left. The degree of sunshine, as shown on the map at right, also plays a role—the more sun, the more effective the barriers. Local utility costs play a big role. As a rule of thumb, if you can install a radiant barrier for the same price as one year's cooling bill, you'll get roughly a seven to 10 year payback, which justifies the investment.

Foiling Radiant Heat Flows

Heat transfer by radiation sounds simple enough: warm materials radiate heat (technically, far-infrared radiation) across open spaces to colder ones. The rate at which a warmer object radiates to a colder one is proportional to the temperature difference between them. For example, a 140°F roof deck on a July mid-afternoon will radiate heat to the 100°F ceiling insulation below. In winter, a 40°F single-glazed window radiates to a 5°F snowbank outside. But other factors—particularly surface emissivity—have a big impact and muddy the waters.

Emissivity (or emittance) is basically a material's ability to give off (radiate) thermal energy. Most building materials—like the underside of plywood decking—will emit heat at about 90 percent of the maximum possible rate (emittance of .90). Place a layer of shiny foil (emittance of .03 to .06) underneath the roof deck and the foil will emit very little heat—effectively blocking nearly all radiant heat energy from flowing across the attic air space. That's a major plus on a sunny June day in Dallas, but something of a negative on a sunny January day in Denver when you want the solar gains.

Don't confuse emissivity with reflectivity. White paint works well as a reflector of solar radiation; it reflects over 75 percent of the sunlight that strikes it. But white paint is a good emitter of far-infrared (heat) radiation. So white roof shingles will reflect back solar radiation, but painting the underside of your roof sheathing white will have no effect. Just because something is a good reflector of sunlight, doesn't mean it's an effective radiant barrier.



Charts like this, developed in the 1950s, are widely used in marketing literature to highlight the role of radiant barriers. They are deceptive, however, because they only describe heat flows across empty spaces, not across insulated walls or ceilings.

and a home's insulation levels. Bear in mind, however, that a 15-percent savings in Sacramento or Baltimore is smaller than a 15-percent savings in Florida, which has higher cooling bills.

Savings in Cold Climates

Yarborough sums up what we know about savings from using radiant barriers in cold climates: "We don't have the necessary data yet. What is available is not worth mentioning." Nearly all independent researchers agree on this point.

Lacking cold-climate data, Yarborough said logic tends to argue that a radiant barrier is not going to be as effective in cold climates as in hot ones. For one thing, foil reduces useful solar gains to the attic during the heating season.

FSEC's Phil Fairey believes that the single most effective place to put foil in cold climates may be in crawlspaces. The rationale: Most heat transfer in a downward direction is by radiation. Furthermore, foil in crawlspaces is not subject to moisture damage and can be easy to apply.

Product Placement: The Other Key Issue

As illustrated in Figure 2, there are four possible places you can put the foil

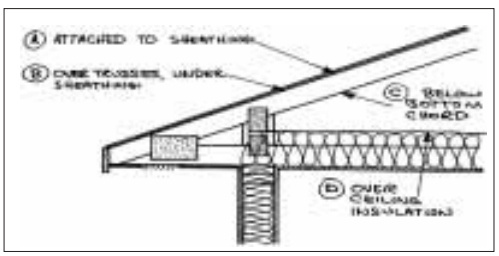


Figure 2. *There are four places to install an attic radiant barrier. In theory, sites A, B, and C will each perform satisfactorily. But site D, on the attic floor, remains controversial.*

material. With all four minor tears in the product during installation won't affect energy savings.

Attached to the decking. This approach should perform well, but has some practical problems. You'd either have to staple on foil at the job site, which could be time-consuming and could make a mess of the foil. Or you'd have to find a supplier who glues foil to plywood roof sheathing. Few have had experience with this approach.

Draping the foil across trusses. Based on builder experience, FSEC favors this approach for new construction (see Figure 3). It reports that two men can install between 500 and 1,000 square feet per hour with this technique. Wind can be a problem, however. Another potential hassle is scheduling—the need to mesh barrier installation with framing. Builders who have their insulation contractors install the barrier usually pick another installation method.

Figure 3. *Draping the barrier over roof trusses before installing the roof sheathing is the favored approach of the Florida Solar Energy Center. Potential problems are scheduling hassles and wind during installation.*

Nailing the foil beneath rafters/trusses, after the decking goes on. Using 2-foot instead of the usual 4-foot-wide rolls, installers precut lengths of foil to staple beneath rafters or underneath the top chords of trusses. This reduces problems with wind and scheduling, but it usually takes longer.

With any of these applications, the shiny side of the foil should face down to prevent dust buildup. Also, in all cases, gable ends should be covered with foil to gain the full protection from radiant gains.

Rolled out on top of insulation. This cuts down on material use by roughly 20 percent, making it both the fastest and least expensive method. In a study by the Tennessee Valley Authority (TVA), it took 4.5 hours to roll out radiant barriers versus 12.5 hours to attach them to the top chords of trusses.

Despite its speed advantage, this application is controversial. Supporters rely on ORNL testing which shows a 17-percent reduction in cooling load, when laid over R-19 insulation, compared to 9 percent for truss-mounted barriers. In wintertime, heating bills went down 10 percent with the horizontal barrier, but actually increased about 3 percent with the truss barrier. (There is speculation that a barrier laid directly over insulation slows down infiltration from the house up into the attic or suppresses heat-robbing air movement within the insulation itself.)

Detractors cite three concerns. The first is a practical matter. Any repeated visits to the attic—such as to install an additional electrical circuit—could well demolish large parts of a horizontal barrier. The other two issues were cited in a 1988 position paper written by the industry's trade association, Reflective Insulation Manufacturers Association (RIMA), in which they advised against horizontal placement. The paper states: "The possibility exists that a moisture problem could occur if the material is installed in this manner. In addition, it is believed that dust accumulation on the surface of the radiant barrier will retard performance." FSEC also recommends against placing radiant barriers on top of insulation (see Figure 4).

Dust Can Reduce Effectiveness

Over time, a certain amount of dust will collection top of a horizontal radiant barrier. How much does that dust raise the emissivity of foils, how fast does it collect, and how will that effect energy savings?

Figure 4. *The findings are inconsistent, but current research indicates that dust will impair the performance of attic-floor installations. Attic access could also be a problem.*

A joint study by ORNL and TVA suggested that horizontal applications performed well despite the dust. A more recent study from Tennessee Technological University (Cooksville, Tenn.), however, based on five-year-old samples of radiant barriers removed from Chicago attics, found that the dust reduces the shininess enough to cut the radiant effect by 50 percent.

Here we have another case where the experts don't yet know enough to recommend what's best for the builder. But the recent data dealt a serious blow to horizontal applications.

Moisture Warnings

Researchers at Oak Ridge found that moisture formed on the underside of a horizontal radiant barrier (with perforations) in 35°F weather. They also observed that the moisture would typically evaporate into the attic air during the daytime, when the attic warmed a bit. But during long periods of subfreezing weather some condensation remained.

In theory, excessive condensation could soak insulation, stain ceilings, or decay wood. Oak Ridge researchers concluded that no such problems were likely in Tennessee's climate. They caution, however, that their data might not apply in colder climates.

There are numerous nit-picking little points that cold be considered, such as the size of perforations, shading of the attic by trees, etc. But the bottom line is that there are enough doubts about horizontal applications to warrant staying away from them, until there is more ironclad evidence to the contrary.

Shingle Meltdown?

Fears of shingle degradation due to attic radiant barriers appear to be unfounded. On sunny summer days, asphalt shingles will often reach 160 to 190°F. ORNL found that a radiant barrier stapled to trusses increased shingle temperatures by 5°F. FSEC found that foil raised shingle temperatures only 2 to 5 degrees. The variation between different colors of shingles can have a much larger impact (15 to 30°F) on shingle temperatures.

Your only concern with shingles might be to check with your shingle manufacturer to ensure their warranty isn't affected by use of a radiant barrier.

Material Costs, Builder Experiences

FSEC says that, if you shop, you should be able to locate a radiant barrier material for 10¢/sq. ft. For this article, six manufacturers were asked for price sheets. Two complied. Their prices back up FSEC's estimate. Innovative Energy Inc. listed prices at 7¢, 10¢ and 13¢ per square foot depending on level of reinforcement (the 7¢ version tears easily, the 13¢ was very difficult to tear); large purchasers get a 10-percent discount. Fi-Foil charges 7¢/sq. ft. for its single-sided Kraft-backed foil, and 12¢ for its double-sided version (both reinforced, with moderate resistance to tearing). As a general rule, you'll want to avoid paying more than 15¢/sq. ft. for material.

According to FSEC, the installed cost of an attic radiant barrier, including labor and materials, should be approximately 20¢/sq. ft. That estimate involved talking with builders, installers, and manufacturers. Builders contacted for this article indicated their costs were somewhat higher.

Just outside of Orlando, custom builder Gary Carpaneto reported his installed cost of R-Bar at roughly 26¢/sq. ft. for his custom homes (usually 2,000 square foot and up). Stapling the barrier to the top chord of trusses after the roof decking goes on eliminates problems with wind. It takes one of his insulation contractors a full day. Said Carpaneto, "People aren't asking for it, but we're hard-core when it comes to energy efficiency, so we can sell the idea."

In Phoenix, insulation contractor Gary Banker charges 30¢ to 40¢ per square foot to install Insul-Foil (by R-Fax Technologies), usually above R-30 to R-38 insulation. But he doesn't see much demand for the product in his area.

In Merritt Island, Fla., builder Rich Weidig paid roughly $600 for R-Bar reinforced foil to line the trusses and end-walls of a 2,200 square foot home (27¢/sq. ft., material only). It took two workers two to three hours to install the product. Said Weidig, "Things can get a little hectic if the wind comes up. We install one 4-foot row of the barrier, sheet it with plywood, and then roll out another row of the foil. This product is pretty tough stuff, hard to tear. I've seen some others that tore in the wind."

Sacramento builder Ron McKin pays at least 40¢/sq. ft. for a radiant barrier installed. He has it stapled under the rafters or top truss chords once the roof is on, a step he acknowledges costs him more. He offers the radiant barrier as an option on the 100 homes he builds each year. Not many of his buyers pick the option.

FSEC researchers calculate that if a homeowner can purchase the installed product for less than 30¢/sq. ft., a radiant barrier will have a simple

payback of less than ten years in Florida. Keep in mind that the payback for your buyers will vary with their cooling load, utility costs, and other features in your building shell.

Picking a Product

You'll find a wide variety of radiant barrier products available today. Besides price, there are a number of other features to consider:

Emissivity should be low, preferably between .03 and .06. A proposed ASTM standard sets the normal cutoff point at .10. Adding holes in a radiant barrier will raise its emissivity somewhat (lowering its effectiveness).

One-sided versus two-sided materials: The additional energy savings from use of a two-sided product are insignificant. However, a two-sided product might help offset the gradual loss of the radiant-barrier effect due to dust in horizontal applications.

Strength is a practical concern. In windy conditions, installing a flimsy foil product is a headache. Some of the perforated barriers have little more resistance to tearing than a roll of Reynolds Wrap. Before picking a product, get samples and compare their resistance to tearing by hand. Typically, you'll find that products with a mesh of reinforcing thread offer more strength; a plastic backing or core seems to resist rough handling better than a Kraft-paper core.

Fire rating is another feature you'll have to check for on a manufacturer's spec sheet. Florida requires a Class-A flammability rating for a product exposed in the attic, as will virtually any code body. Ned Nisson, editor of the newsletter Energy Design Update, recently caught a lot of flak for questioning whether or not some radiant barrier products are actually as fire-resistant as their fire ratings would indicate; he recommends a small-scale test burn before you buy. RIMA counters that ASTM tests are the only valid way to test the surface burning characteristics of most building materials, and that you should simply be sure the product you buy has the proper ASTM-verified fire rating.

Dubious Marketing

Have you ever noticed photos of astronauts in promotional literature put out by some radiant barrier manufacturers? Did you ever wonder, why astronauts? The answer may be that many of these companies' performance claims seem like they came from outer space.

For example, Denny Products, one of the more established marketers of radiant barriers, claims in one of its sales flyers that "about two-thirds of the winter heat loss and summer heat gain are through the ceiling and attic." Along the same lines, Eagle Shield's president claims, in a training video, that "we guarantee that this product will pay for itself in the first three years."

Then there's the flyer from Innovative Energy Inc., that states, "No matter how much regular insulation you already have, R + [their 7¢/sq. ft. radiant barrier] is so cost-effective that the payback is usually one to three years, depending on climate." Where is Sgt. Friday when we need him?

Irresponsible marketing claims for an otherwise good product have tarnished the image of the radiant barrier industry. In one case last summer, the Texas attorney general sued Eagle Shield for violations of the Trade Deceptive Trade Practices Act. The attorney general blasted sales associates of Eagle Shield who claimed that 93 percent of summer heat gain came through the attic. Eagle Shield had to agree to reasonable performance claims—like 3 to 8 percent savings on the annual utility bill—until they could accurately document higher performance.

RIMA claims to have made some headway in cleaning up misleading or false advertising. RIMA president Roy Akers says the group reviews the advertising material of its members and occasionally asks them to tone it down. They even helped force two firms making fraudulent claims out of business. Unfortunately, not all manufacturers are members, and not all members are as responsible with their claims as others.

Breaking Barriers to Barriers

Working with both industry and researchers, the Department of Energy (DOE) is preparing a technical fact sheet on radiant barriers. Project leader Ernie Freeman says the sheet, due out in November, will provide the best information available on the cost-effectiveness of radiant barriers in both new and existing homes.

ASTM is preparing a more technical guide to the installation of radiant barriers. The paper—a product of over two years of work—should be in print by the end of the year and it should bolster the acceptability of radiant barriers. A second ASTM effort, addressing the issue of thermal performance, will probably need another two years of work before it is finalized.

RIMA and the National Association of Homebuilders are at work on monitoring programs for moderate and cold climates. RIMA has installed foil in 30 low-income homes in Tulsa and should have information about energy savings within a year. NAHB has a multi-staged program—funded by Eagle Shield—that will start with 50 homes in Sterling, Va. over the summer and monitor 50 homes in Bismarck, N.D. this winter.

For more information:

Contact the following organizations for more information on radiant barriers.

- Florida Solar Energy center, 300 State Road 401, Cape Canaveral, FL 32920; 407/783-0300. Has published a number of very informative handouts on radiant barriers for builders and consumers, including Radiant Energy Transfer and Radiant Barrier Systems in Buildings (1986), and Radiant Barriers: A Question and Answer Primer (1987).
- Radiant Barrier Systems: Principles and Practice plus Product Directory, written by Ned Nisson, is published by the Cutter Information Corporation, 1100 Massachusetts Ave., Arlington, MA 02174; 617/648-8700. Due out this summer.
- Reflective Insulation Manufacturers Association (Roy Akers, president), c/o F-Fax Technologies, 661 E. Monterey Ave., Pomona, CA 91767; 714/622-0662.
- For a copy of DOE's upcoming fact sheet on radiant barriers—to be published in November—contact Office of Scientific and Technical Information, Department of Energy, P.O. Box 62, Oak Ridge, TN 37831. ■

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