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RADIANT BARRIERS

Straight Talk about Radiant Barriers

by Cliff Henke

Radiant barriers do save energy, but many advocates worry that the overstated claims of some manufacturers will spoil the market before it gets established. This is the first of a two-part series investigating radiant barriers. The first article discusses the research done to date—and its limitations. The second will focus on the exaggerated claims made by some radiant barrier companies and the resulting confusion over their cost-effectiveness.

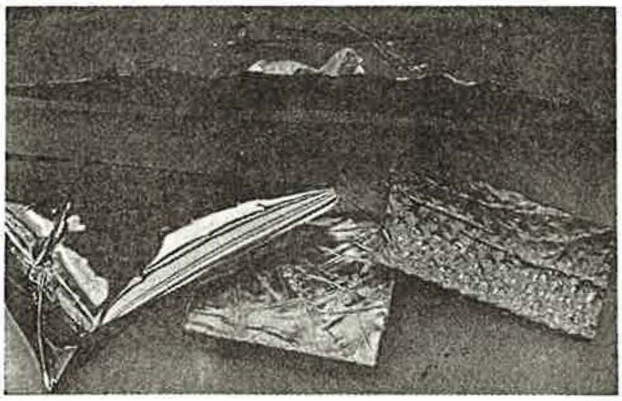
Radiant barrier technology has been around for at least a century, but widespread production for installation in attics as an energy-saving measure began only a few years ago, in the wake of the oil price hikes of the 1970s. Unfortunately, only a handful of studies have been conducted to demonstrate the technology's effectiveness, while others remain in the planning stages. Meanwhile, homeowners and builders are bombarding energy auditors with questions that even the experts don't have answers to. Some of the curious become early adopters without really understanding how the barrier works to reduce heat transfer. And they risk disappointment when energy bills don't fall as much as expected.

In basic terms, engineers explain that radiant barriers are reflective materials designed to counter one of the three primary modes of heat influx, that of radiant heat transfer. The other two modes of heat transfer are conduction (heat transfer from molecule to molecule) and convection (heat transfer due to bulk movements of a fluid, like air). Radiant barriers have little effect on conduction and convection.

Radiant barriers are usually made of a sheet of paper or polymer film, with a thin coating of aluminum on one or both sides. Retrofitters or builders can install them in attics in either of two locations: 1) laid directly on top of the conventional insulation, or 2) attached beneath the roof decking. During the summer, the sun heats the roof to temperatures of 150°F and higher. Without a radiant barrier, the hot roof emits radiation that travels across the attic space and is absorbed by the top of the insulation. Because its top surface is warm, the insulation transfers heat in through the ceiling by conduction.

If a radiant barrier is laid on top of the insulation (with the reflective side up), the radiant heat emitted by the roof is not absorbed, but is reflected back toward the roof. The result is that the top of the insulation is cooler, and heat transfer through the ceiling is reduced.

On the other hand, if a radiant barrier is installed near the roof, with the reflective side facing down, the radiant barrier will become heated by the roof via convection. Since a highly reflective surface is also a poor emitter, the radiant barrier emits less radiation than the roof surface would. With less radiation coming from the roof, the top of the insulation is cooler and the heat inflow through the ceiling is also reduced.



Companies are marketing radiant barriers in various forms: perforated, to avoid moisture problems; bubble pack, with a layer of plastic bubbles to add dead air space; reflective insulation, with several layers of aluminum; etc. Plain sheets come single and double sided.

During the summer, the air inside the attic becomes stratified. That is, the air at the top of the attic is warmer than the air at the bottom. Under these conditions, the air is said to be stable, and convective heat transfer across the air space is low.

In contrast, during the winter, the top of the insulation is often warmer than the roof. This means that the air at

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the bottom of the attic is warmer than the air near the roof. Under these conditions, the air is said to be unstable, since the warm, less dense air is at the bottom and has a tendency to fall. Because of this, convective heat transfer across the attic space is relatively more important in the winter than in the summer (see box).

Since the heat transferred across the attic space by convection and by radiation has a net effect, radiant barriers are relatively more effective in the summer when convection is smaller.

Confusion and Misinterpretation

"The mechanism by which radiant barriers work is something that the average person doesn't understand," says Ned Nisson, editor of *Energy Design Update*, a New York-based newsletter reporting on the conservation industry. Thus it is easy for advocates of the product to extrapolate conclusions beyond what the scientific studies actually report, he adds. And even the completed studies fuel almost as much confusion as they do information, because the studies themselves have been extremely limited in scope.

One case of misinterpretation of scientific research is an apt illustration. A study done by William P. Levins and Michael A. Karnitz, of Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tenn., tested radiant barriers in one climate, over a short period of time, under laboratory conditions (see *HE* Nov/Dec '87, pp. 22). Yet manufacturers continually cite the study, then extrapolate from the results to support bogus claims about other climates, long-term payback periods, and the like. For example, one manufacturer claimed the ORNL tests "conclusively prov(e) reflective barrier saves you money."

What the tests actually "proved" must be stated with a bit more caution. Levins and Karnitz measured differences in cooling and heating loads in four experiments involving three unoccupied houses. Beginning in the summer of 1985 and ending in the winter of 1986-87, the scientists compared the energy loads for three levels of fiber-glass batt insulation (R-11, R-19, and R-30) with the two types of radiant barrier installation, horizontal and truss. In all installations, they used double-sided radiant barriers. They installed the horizontal barriers on the floor of the test houses' attics, covering the insulation. They attached the truss barriers to the rafters (in new

Usefulness in Cold Climates Debatable

Research to date generally confirms that radiant barriers protect best against heat influx from the sun via the roof and attic during the summer, and save considerably less energy by stopping heat radiated from the living space to outdoors during the winter. Part of the explanation involves the unique nature of radiated heat.

The amount of thermal radiation given off by any object is a product of its emissivity times the fourth power of its absolute temperature (the number of degrees above absolute zero, which, in the Kelvin scale, is 273 degrees more than its temperature on the Celsius scale). That is, objects emit exponentially more energy at higher temperatures. By contrast, conducted and convected heat transfer varies in a linear fashion. Of course, the net heat transfer depends on the difference in T^4 between the two objects (in this case, the roof deck and the attic floor). Still, radiant heat remains a much more considerable factor in hot weather than conducted and convected heat transfer, and under cooler climate conditions, radiant heat transfer is much less of a consideration than conduction or convection.

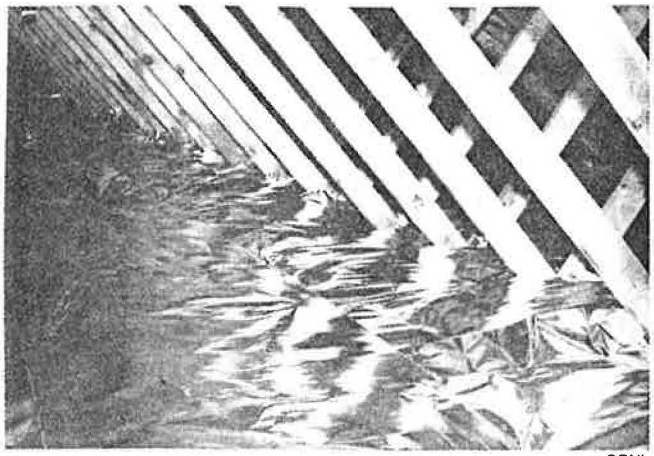
Another possible problem with using radiant barriers in cold climates is that they may counteract winter solar heat gain. The loss of solar gain may actually increase annual HVAC energy use in some climates, as some studies have found.

Another limit to radiant barrier effectiveness, even for cooling, is placement. The materials are only measurably effective for cooling when installed in the attic space, not in the walls. This is because the source of radiant heat—the sun—warms the roof much more than the walls, and, because of the exponential relationship to temperature, the warm roof radiates heat through the attic much more than walls—especially if the walls are even partially shaded. In the hottest summer months, this effect is exaggerated by the high angle of the sun, which makes the roof more important per square foot. In the winter, depending on the latitute, the reverse may be true.

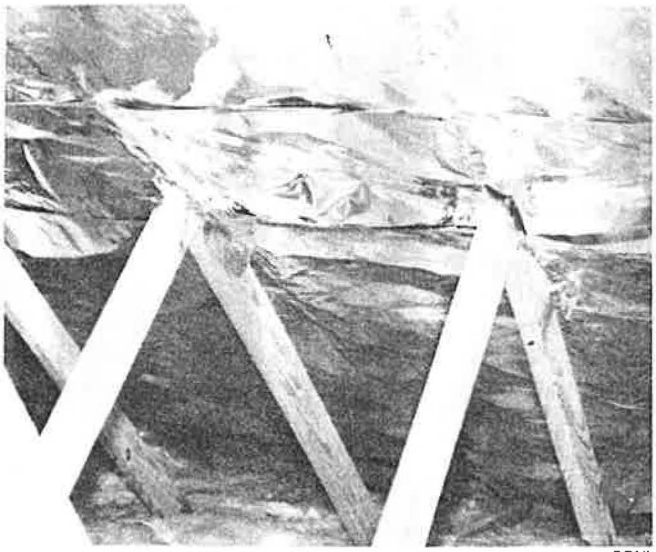
There is one application, however, in which radiant barriers may significantly reduce *heating* load. The basement or crawl space under a house receives more radiant heat than any other kind, and clearly collects no direct sunlight. Roofs and attics lose a great deal of heat via convection, since warm air can rise through the roof. In contrast, warm air rises *away* from a crawl space, since it is under the house. Conduction accounts for very little of the heat loss through either the roof or the floor, as the air in the sky and the crawl space is an excellent insulator. About 15% of a residential building's heat loss is through the floor,[1] and the radiant component of this is about 150 times the conductive component.[2] Robert Farrington of the Solar Energy Research Institute (SERI)[3] modeled crawl-space heat loss and concluded that a radiant barrier at the top of a crawl space could cut *total* heat loss through the floor by almost 95%. Of course, Farrington still forsees problems with dust or moisture accumulation reducing the reflectivity of the radiant barrier. In any case, his results should be tested experimentally. But retrofitters might well profit from this one application of radiant barriers in cold climates.

Given the dearth of hard data about cold climates, the best guess, then, is that the most appropriate application of radiant barriers above the floors is to reduce the portion of the cooling load caused by radiant heat entering through the roof and attic. If only applied to this purpose, radiant barriers' savings to consumers will vary by the cooling load as a share of the energy bill, as well as climate, the local cost of electricity, the amount of conventional insulation already in the attic, and whether the barrier is installed on the trusses or joists. In areas where the heating load is greater than the cooling load, the proper place for a barrier may be under the house.

1 U.S. Department of Energy, 1986. *Housing Characteristics 1984.* Washington, DC: U.S. Government Printing Office.
2 Incropera, F.P., and D.P. DeWitt, 1985. *Fundamentals of Heat and Mass Transfer.* New York: John Wiley & Sons.
3 Farrington, R.B., "Reducing Crawl Space Heat Loss," To be published in ASHRAE Transactions 1989.



One of the ORNL study test houses, with radiant barrier installed on the attic floor—the horizontal method.



Another test house attic, with the radiant barriers installed on the underside of the roof—the truss method.

construction, truss barriers are often tacked right onto the roof decking).

The ORNL study found that horizontally installed radiant barriers were more effective than truss barriers in reducing HVAC loads. The cooling load reductions ranged from 4–22% when compared to the same attic insulation R-value with no radiant barrier. Meanwhile, heating load differences between barriers and comparable R-value insulation ranged from a net savings of 4% to a net increased use of 10% for the highest R-value insulation in the experiment (R-30).

Radiant barrier advocates sometimes claim the Oak Ridge studies corroborated others by the Florida Solar Energy Center at the University of Central Florida in Cape Canaveral. In a series of tests conducted throughout the 1980s, Florida Solar measured heat flux and temperature in cases with several levels of batt insulation, insulation and radiant barrier, and no insulation. These studies were conducted in test attics of Florida Solar's passive cooling laboratory by Phillip Fairey and others.

The center's studies are most frequently cited by manufacturers in their marketing literature. The research found savings of 8–12% of annual cooling costs for the Southeastern homes studied. Using Florida Solar's data, the National Energy Specialist Association—an industry group representing predominantly radiant barrier manufacturers—figures these savings produce a payback time of six to seven years. (We will discuss these hotly debated calculations in part two of this article.) What the industry often ignores is that the high level of savings were not corroborated by the ORNL study, nor were its conclusions about the relative merits of truss and horizontal barriers.

There is concern, too, that Florida Solar's research may be tainted by its manufacturer sponsorship. Although the center is part of a state university, its radiant-barrier studies were funded in large part by center "customers" who are radiant barrier manufacturers, said a staff member of the center who wished to remain anonymous.

Another study, conducted by the Tennessee Valley Authority (TVA) in Chattanooga, tested radiant barriers for heat flux in three configurations—barrier atop insulation, barrier attached to the underside of rafters, and barrier underneath the roof decking—against an insulated control cell. To minimize variances for construction and climate, TVA employed a "Latin Square" methodology, whereby the test is rotated so that each configuration is tested twice for both winter and summer tests in each cell. Testing began in June 1985 and was completed in March 1986.

The study's author, James Hall, concluded as Levins and Karnitz did: that the barrier-atop-insulation method of installation afforded the best cooling-load savings. The study even demonstrated savings at nighttime and cooler daytime temperatures when the other configurations had experienced cooling load increases. All barrier configurations yielded 16-40% savings in the test cells' ceiling cooling load. Here again, the figures must be interpreted carefully; the ceiling cooling load is *not* the total cooling load.

Dust and Moisture

Critics, even proponents of radiant barriers like Southface Institute Director Dennis Creech, are quick to dispute extrapolations of the results of ORNL's and other studies to a longer period of time than one or two years. This is tempting to do, especially when trying to calculate payback time.

Two factors affecting radiant barriers' long-term performance are of the greatest concern: dust accumulation and moisture condensation. "There has been a lot of confusion about the effects of dust," notes Nisson. "It is hard to tell if dust accumulates quickly; in some cases it might accumulate in two years, in other cases it might be 10 years."

This becomes important because many experts believe that dust can dramatically undermine the effectiveness of barriers by making their surface less reflective. Explains Creech, "We have found that dust can decrease performance even within one or two years. The problem is that the dust is not necessarily visible to the naked eye."

"Long-term effects of dust on the performance of radiant barriers as well as the effects of moisture condensing on the surface of a radiant barrier during cold winter temperatures remain unanswered," wrote Levins and Karnitz in a paper they presented at the American Council for an Energy-Efficient Economy's summer study at Asilomar, Calif., last August.

Because of this important qualification, Creech believes that their data favoring the horizontal-type barriers does not mean horizontal barriers are always best. "Horizontal-type installation is a big mistake for two reasons that they mention," says Creech. "Moisture is a bigger problem in colder climates due to greater condensation. There needs to be more research in northern climates."

"The second problem is dust, and it is an even more serious issue. Anyone who's been up in an attic lately knows it can be a pretty dusty place. According to a study done in Chicago,[1] reflectivity of radiant barriers can decline by a factor of ten within two years because of dust."

Frank Vigil of the North Carolina Alternative Energy Corp., who moderated a panel on radiant barriers at the recent Affordable Comfort Conference in Pittsburgh, agrees that there is a need for a more complete, real-world test. "All of the studies have one thing in common," he begins, "They are not field tests, with real houses and people living in them. Karnitz (at ORNL) comes closest with real test houses, but they were not real-world situations" with residents stirring up dust, affecting moisture patterns, and varying levels of conditioning.

On the other hand, Vigil acknowledges the value of the laboratory studies. When studying real homes, he points out, it is often difficult to distinguish the effects of radiant barriers on energy bills from the effects of occupant lifestyles.

As an illustration, he cites a study of flue-damper technology performed several years ago. Three styles of flue dampers were studied, the last of which was a control without the damping mechanism. That the control performed significantly better is an almost legendary warning to energy scientists: sometimes the mere extra awareness of energy savings and resultant change in lifestyle can have an even greater effect than the measure itself. To further confuse the effects of radiant barriers, some salespeople throw in a free setback thermostat with their radiant barrier systems.

There is yet another problem with the body of research conducted to date: most of it has been performed in one region of the country—the hot and humid Southeast—and the conclusions therefore may not transfer accurately to other regions. To address this, many utilities are conducting studies of radiant barriers for their service areas. One such utility is the Sacramento (Calif.) Municipal Utility District (SMUD). According to Richard Kallett, principal demand-side planner for SMUD, "Our studies show that attic insulation helps to cut energy costs more in the winter than radiant barriers, but radiant barriers cut cooling costs in the summer more. Overall, attic insulation is slightly more cost-effective, but it depends, for example, on how much insulation a customer has in the attic."

In addition, Kallett notes that the two technologies can complement one another, so that when both radiant barrier and insulation are installed, even further energy savings can result. Yet he warns, "If a customer has R-30 value insulation in the attic, radiant barriers will not help that much. On the other hand, if the customer has little insulation—R-11 or less—then installing radiant barriers as well might be more cost-effective."

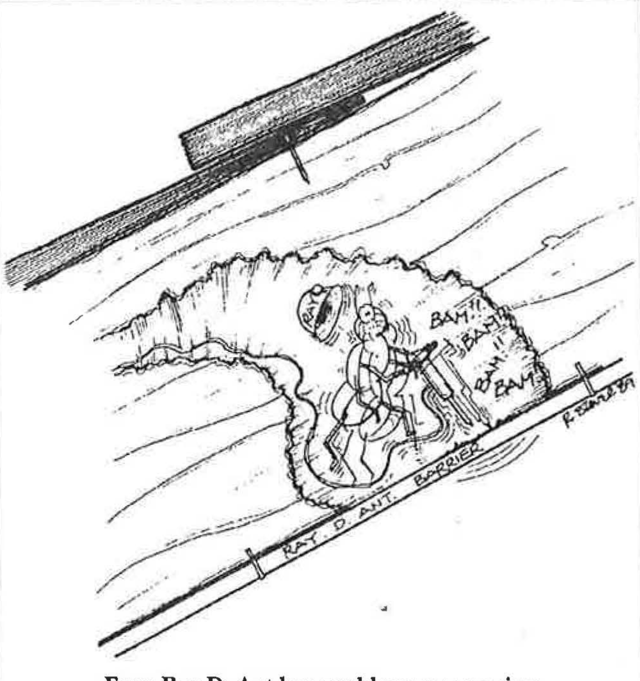
The Ongoing Saga of NAHB and Eagle Shield

Last fall, the National Research Center of the National Association of Home Builders (NAHB) planned the first major study to test the effectiveness of radiant barriers in northern climates. The NAHB intended to observe heating and cooling loads in 500 homes in a variety of climates and to measure the effects of dust accumulation.

The research was to be funded by a group of manufacturers led by Eagle Shield, the Dallas-based manufacturer recently sued by the Texas State Attorney General for alleged overstatements in its marketing campaigns there. In response to a challenge by NAHB to back up its claims, Eagle Shield made a verbal agreement to underwrite the research, the cost of which NAHB estimated would exceed $1 million.

Eagle Shield fronted the NAHB researchers funds for the study design, which the researchers completed and submitted to Eagle Shield in November 1988, along with a projected budget. To allay concerns about the objectivity of research funded by a manufacturer, NAHB also sent the study out for independent scientific review.

Bion Howard, the NAHB staff scientist in charge of the study, says an Eagle Shield representative telephoned him in December and "said they wanted to go ahead with the study." Since the projected costs were so high, however, the research center wanted more than a verbal agreement. When we spoke with Howard on February 16, he



Even Ray D. Ant has problems uncovering the facts behind radiant barriers. Rick Stover said he had received nothing in writing from Eagle Shield—no money, no contract, not even a letter.

"We've sent a number of letters, time extensions, and so on, and Eagle Shield hasn't responded. Basically we've bent over backwards for them...and until we resolve it we're on hold." He said the people assigned to the project had been gradually dispersing to other NAHB research groups. "If another few weeks go by we'll have to send out a press release [saying the study is off]...We've been getting quite a number of calls about it and...we can't go on with our reputation on the line."

The day after this conversation, we spoke with Sam Castor, one of the two owners of Eagle Shield. He said they fully intended to go ahead with the study. They had been "trying to decide whether to include the results" of the cold-climate study by Charles Shabica,[2] and therefore delayed contacting NAHB. They had just recently decided not to involve it. We informed him that Howard suspected that Eagle Shield had decided not to pursue the study, and that Castor would do well to contact NAHB as soon as possible. Castor said, "Yes, I will do that. Thank you for telling me."

Two weeks later, on March 1, we spoke with Howard again. He said Castor had not called or written to him, and that as far as he is concerned, the study is called off. "We've been waiting around for 9 weeks already. I'm really disappointed that Eagle Shield hasn't elected to go forward with it. We feel this research would be really valuable to the building industry.

We have had some problems. A radiant barrier salesman went into the office of a building firm and said our study would verify his claims."

"Quite frankly, a lot of people advised us not to get involved with Eagle Shield. But it's not our business to make a value judgement. Some companies would go to the point of taking legal action, since there was a verbal agreement, but that's not our style."

Howard says the research center would still like to pursue the project and has been investigating other sources of funding—other companies that make radiant barriers or similar products. "Just because we had a problem with one client doesn't mean radiant barriers don't work...It's time to get out of the lab and into the field. We're pushing for more federally-funded research."

As Howard says, there is plenty of research to be done. ORNL published a "Radiant Barrier Research Plan" last June, which outlines a plan to research issues of concern to the industry, utilities, and the government. Proposed topics include dust, moisture, placement, and climate. Authors K.E. Wilkes and D.W. Yarbrough recommend a variety of research, including some they state "would more properly be performed by private industry, utilities, or regulatory agencies" than national labs.

The report, which contains a comprehensive overview of the scientific research to date and a bibliography, is available from Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831. ■

Endnotes

1. Study by Charles Shabica, Northeastern Illinois University, 5500 N. St. Louis Ave., Chicago, IL 60625.
2. Apparently the same study as note 1.