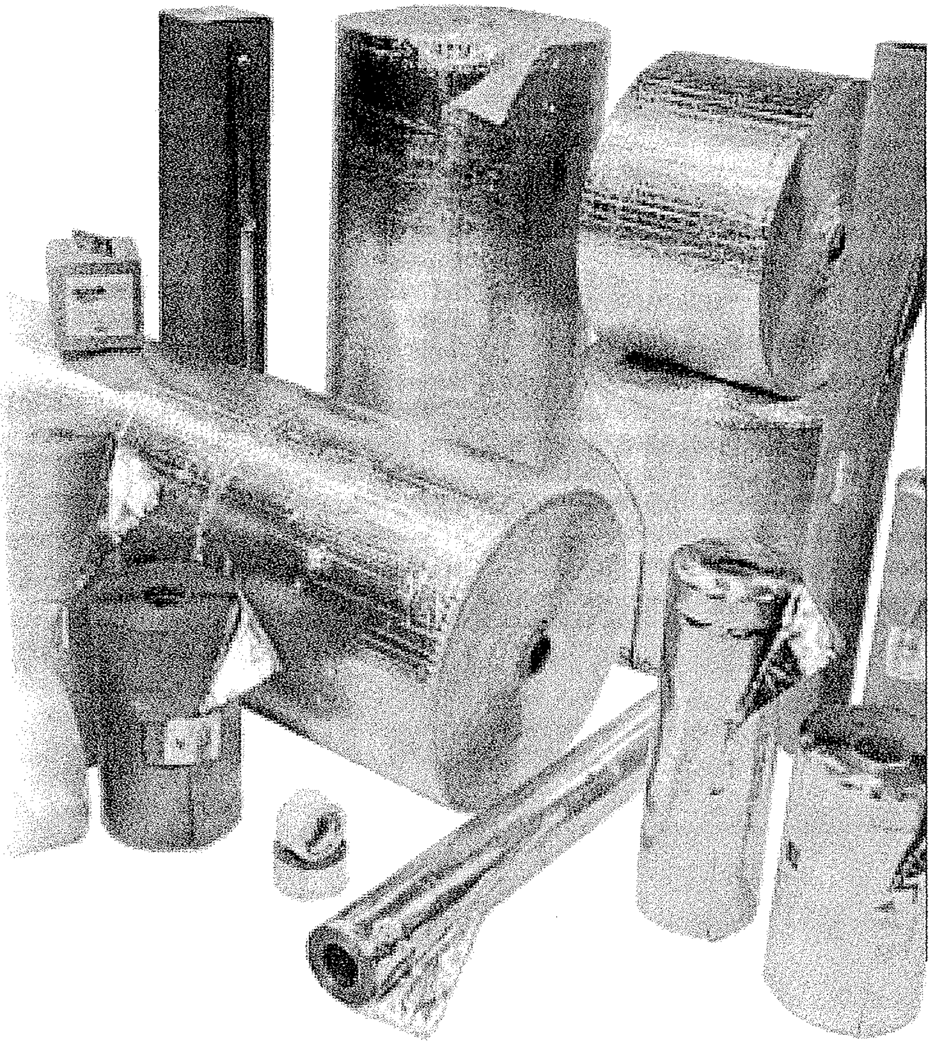
Radiant Barriers: Performance Revealed

In the summertime, radiant barriers give attic insulation a clear advantage in cutting the demand for cooling energy.



FI-FOIL

by Mario A. Medina

Radiant barriers—sheets of aluminum foil that are normally adhered to a fiberglass mesh or a Mylar bubble wrap—obstruct the transfer of heat from the attic into the conditioned space and can cut summertime cooling loads. But exactly how well do radiant barriers work in different attics with different levels of insulation? Surprisingly few field data exist to help answer this question. To sort out the situations in which radiant barriers would have the most impact, I chose to investigate how the level of attic insulation would affect the performance of radiant barriers during a hot summer. I conducted the experiment in College Station, Texas, where hot summers and mild winters are typical of a subtropical climate. I used two identical single-room test houses with identical insulation characteristics. One of the houses was used as a control, while the other was retrofitted with a radiant barrier.

Both the radiant barrier and the fiberglass insulation were new at the time of installation. Over the summer, I sequentially fitted both houses with three different levels of fiberglass insulation: R-11, R-19, and R-30. Each level was measured for seven to ten days, with air and surface temperatures taken in the attics and living spaces.

To produce reliable experimental results, it is critical to control air movement in the attic. For this reason, I chose to use forced attic ventilation instead of natural ventilation. Since attic ventilation flow rates greater than 0.25 CFM/ft^2 do not affect the reduction in ceiling heat flow caused by a radiant barrier, and since higher air flow rates are more accurately measured than lower rates, I ventilated the attics at a rate of 1 CFM/ft^2. Finally, as the results were strongly influenced by the indoor temperature of the houses, I was careful to keep the temperature inside each house as constant as possible. The average difference in indoor temperature between the two houses never surpassed 0.3°F.

Keeping Cooler

My experiments confirmed that radiant barriers cut summertime heat gain through the attic floor, when the sun is shining. The average reduction in ceiling heat flow when radiant barriers were used in combination with R-11 insulation was 42% (see Figure 1). When R-19 was used, the average reduction was 34%. When the insulation level was R-30, the average reduction was approximately 25%. This reduction in ceiling heat flow contributed to maintaining the indoor temperature at a constant value without placing much demand on the air conditioner.

Two notable conclusions may be drawn from these data. First, radiant barriers cut air conditioning demand. Second, the less insulation there is, the larger the effect produced by the radiant barrier. In attics where insulation levels are low, and installing more insulation is difficult, radiant barriers should be used, since they clearly reduce the heat gain and increase comfort levels during the summer. (See Table 1 for cost-effectiveness of materials.)

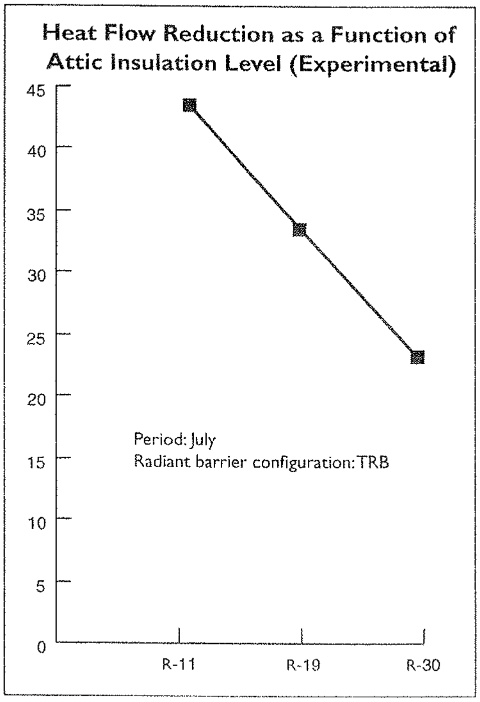


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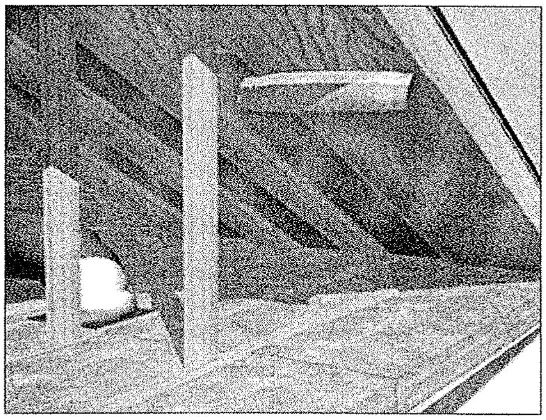
Figure 1. The reduction in ceiling heat flow contributes to maintaining the indoor temperature at a constant value without placing much demand on an air conditioner.



R-FOIL

Radiant barriers obstruct the transfer of heat from the attic into the conditioned space of a house.

Why do radiant barriers reduce heat flow less as insulation levels increase? One possible explanation is that, as insulation level increases, so does the surface temperature of the radiant barrier (as well as other parts of the attic). This causes the radiation exchange to occur at higher temperatures, making the relative heat flow reduction smaller. Every heat transfer process is driven by a temperature difference between the bodies (or surfaces) that exchange heat. Therefore, if the temperature difference between the "hot" body and the "cold" body is significant, the heat transfer will be significant. On the other hand, if the temperature difference between "hot" and "cold" bodies is relatively small, the heat transfer is low. In the case of the attics with R-30, what happens is that the top of the fiberglass (assuming that the fiberglass is installed on the attic floor) develops a relatively high temperature. This happens because the insulation prevents the heat from traveling to the conditioned space. So now we have a "hot" deck and a not-so-"cold" top of the fiberglass (or top of the radiant barrier). As a result, the temperature difference that drives the heat transfer process is small, and thus the heat transfer is lower than it is with lower levels of insulation.

How Radiant Barriers Work

Heat transfer across the ceiling from the attic space, or across roofing directly into the living space when a home has cathedral ceilings, contributes significantly to the cooling load in residential buildings. Ceiling heat flows originate with the incident solar radiation that is absorbed by the roof. The amount of heat that is not reradiated or convected from the roof is conducted across the attic decking material. Of the heat that arrives at the opposite surface of the deck, part is convected to the attic air and the rest is radiated to the ceiling frame, the lateral endgables, and other roof sections. The net heat that is absorbed by the ceiling frame during the radiation exchange is both convected to the attic air and transported in the direction of decreasing temperature into the conditioned space, where it becomes part of the cooling load. In general, except for the solar energy that is absorbed by the roofing materials, heat transfer processes in the heating season are similar to those described above, but in the reverse direction.

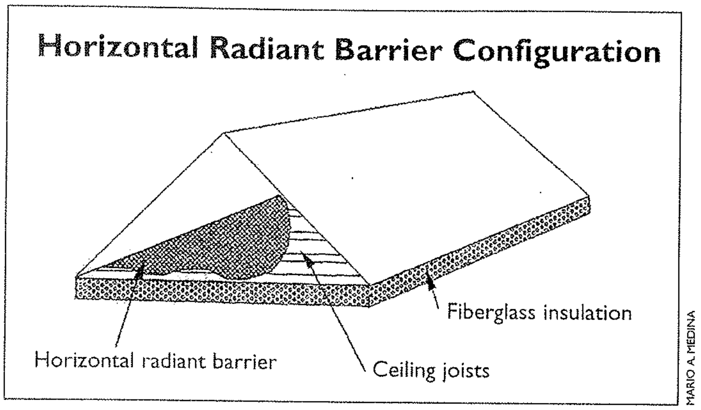


Figure 2. The barrier is installed horizontally over the attic frame.

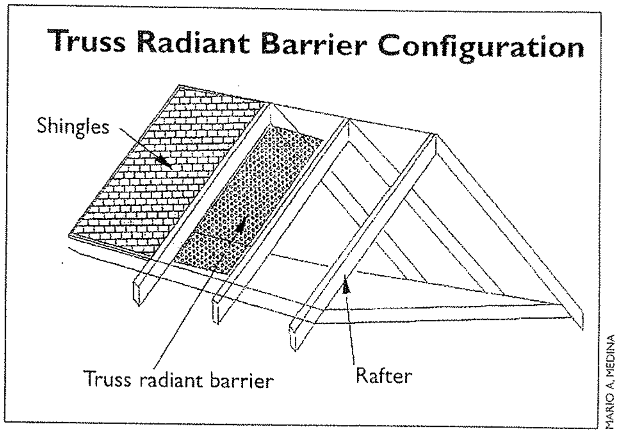


Figure 3. The barrier is attached to the rafters that support the deck.

Installation Configurations

In retrofit applications, radiant barriers are usually installed in one of two configurations. In the horizontal radiant barrier (HRB) configuration, the barrier is installed horizontally over the attic frame (see Figure 2). In the truss radiant barrier (TRB) configuration, the barrier is attached to the rafters that support the deck (see Figure 3). The HRB configuration is often not recommended for residential use because dust and other particulates accumulate on the barrier, which can reduce the barrier's performance. In addition, this type of installation eliminates attic space that might otherwise be used for storage purposes. However, the first problem can be minimized by using a radiant barrier with low emissivity on both sides. Most of the heat transfer from the bottom side of the radiant barrier to the insulation occurs via radiation. This radiation heat transfer is affected by surface emissivity. The surface emissivity of the bottom side of the radiant barrier is relatively low because this side faces down. Therefore, very little or no dust and other particulates accumulate on it.

In comparing the performance of the TRB and HRB configurations in attics equipped with R-19 insulation, I found that they showed similar profiles and almost identical heat flux reductions. However, the TRB showed a significantly greater reduction in attic air temperature than the HRB, because of the location of the radiant barrier. In the TRB configuration, the radiant barrier is above the attic space; in the HRB, the attic space is above the radiant barrier. In the TRB, there is therefore less heat transfer from the deck to the rest of the attic. This is because the HRB reflects a significant amount of the heat from the deck that arrives at the barrier, thus making the attic hotter. The temperatures of the shingles were nearly identical in both cases. The temperature probe was located where the shingles overlap, where the temperature is greatly influenced by the solar flux and convection from the shingles to the ambient air rather than by what is beneath the roof layers.

Table. 1. Costs of Insulation and Radiant Barrier Materials, Cents Per Square Foot.

INSULATION	
Batts — unfaced	**Cents per Ft^2**
R-11	30–35
R-19	36–42
R-30	54–63
Blown	
R-11	16
R-19	28
R-30	44
RADIANT BARRIER	
Residential — Polyethylene Scrim Reinforced	
500–5,000 ft^2	14.9
5,000–10,000 ft^2	13.9
10,000–25,000 ft^2	11.9
25,000–100,000 ft^2	10.5
>100,000 ft^2	9.5
Commerical — Polyethylene Mesh Reinforced	
500–5,000 ft^2	15.9
5,000–10,000 ft^2	14.9
10,000–25,000 ft^2	13.9
25,000–100,000 ft^2	12.9
>100,000 ft^2	11.5

Sources: 2000 National Repair and Remodeling Estimate and Innovative Insulation Inc.

Seasonal Savings

I used my measurements to calibrate an attic heat flow model. The model accurately predicted the reductions in ceiling heat flows in preretrofit as well as in retrofit cases for both HRB and TRB configurations. The weather data used to drive the simulations were from typical meteorological year (TMY) tapes for the city of Austin, Texas.

The modeling agreed with the experimental findings that reductions in heat flow differed depending on the level of insulation (see Figures 4 and 5). That is, there were more relative savings in the low-insulation case than in the high-insulation case. The modeling results for yearly aggregates—excluding the swing season months of March, April, October, and November—revealed that the radiant barrier produced the greatest reduction in heat flows (44%) in attics insulated with R-11. I excluded the swing season months because, in subtropical climates, little cooling or heating is done during these months. Reductions in ceiling heat flows, in the range of 28% and 23%, were realized by the use of radiant barriers in combination with insulation levels of R-19 and R-30, respectively. These results are aggregated over the year.

My experimental results differed slightly from the simulation results. In the field, I had obtained summertime reductions in ceiling heat flow of 42%, 34%, 25% for insulation levels of R-11, R-19, and R-30, respectively. One possible reason for the discrepancies in savings between the experiments and the simulations could be the number of days used in the two cases. During the experiments, the data were produced in seven- to ten-day increments, while yearly simulations using a TMY took into account every day in an eight-month period.

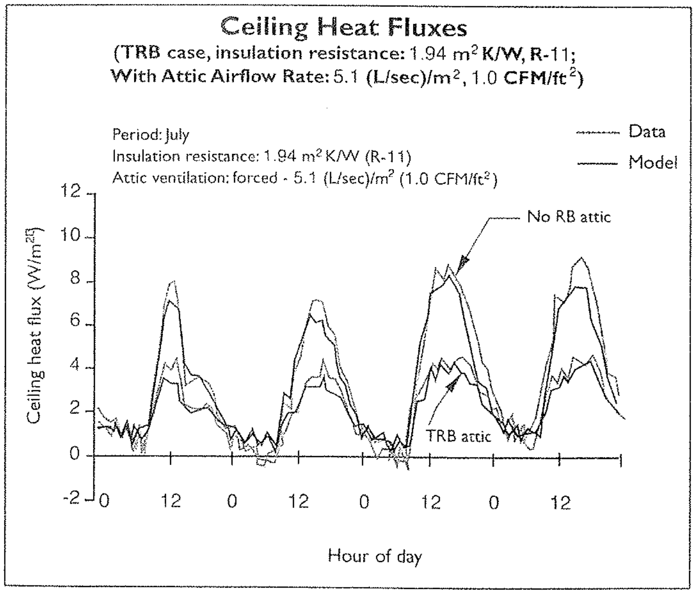


Figure 5. Reduction in heat flow for R-11.

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The model predicted negative savings of less than 10% in the heating season for an attic with a radiant barrier and either of two levels of insulation (R-11 or R-30) compared to an attic with no radiant barrier. It is not known why the middle level of insulation did not follow the same pattern as the other two in this regard. One of the reasons for these losses is weather related. In Austin, winters are mild with significant sunshine. In monthly simulations in subtropical regions, the heating energy savings would either be low—next to insignificant—or negative. Sunshine is desirable during the heating season because it reduces the load on heating equipment. Radiant barriers, on the other hand, limit the amount of solar radiation, which is carried to the conditioned space through the attic. This blockage of solar radiation from the attic deck is undesirable during the winter season, and helps to explain the negative savings produced. In warmer regions, wintertime savings could be realized. In subtropical (hot and humid) climates, more energy is used for cooling than for heating. Therefore, even with this detrimental effect, the net annual savings in subtropical climates are still positive, because of the energy reductions that are realized in the summer.

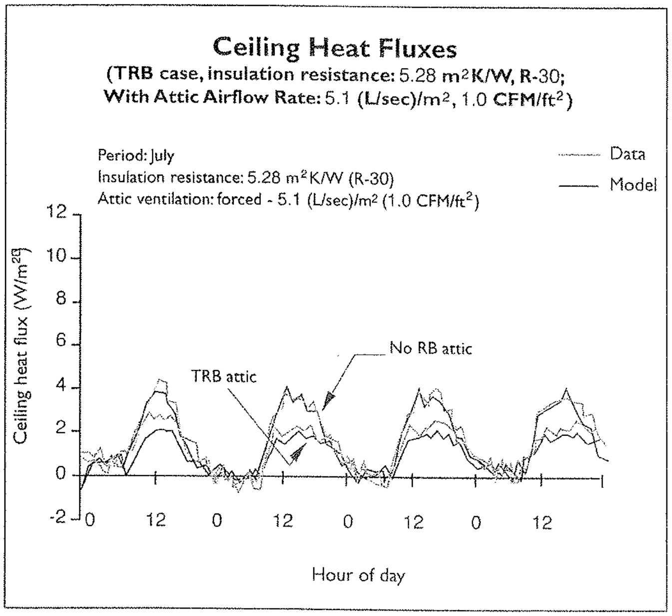

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Figure 4. Reductions in heat flow for R-30.

Radiant barriers cut cooling energy demand in every situation that I tested. Installing more insulation cuts both cooling and heating energy costs, and so would be preferable to relying on radiant barriers in most situations. However, in the summertime, radiant barriers give insulation a clear advantage.

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For more information:

Medina, M.A. "On the Performance of Radiant Barriers in Combination with Different Attic Insulation Levels." In *Energy and Buildings*, Elsevier Science, New York, in press.