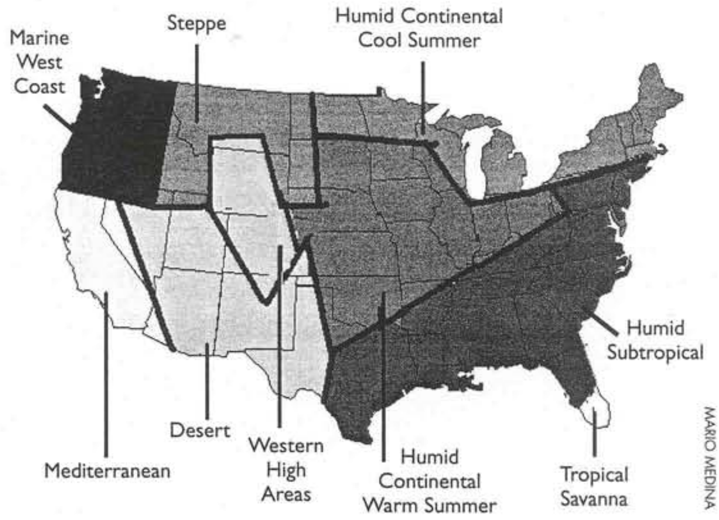
Radiant Barriers: Depends on Where You Live

Houses gain a lot of energy through their roofs. Studies have shown that, in the summer, 70%–90% of ceiling heat gain normally occurs through radiation from solar-heated roof surfaces. Radiant barriers—usually thin aluminum sheets at least one surface of which has an emissivity value of less than 0.05—are used to decrease this infrared radiation from the attic deck to the top of the insulation on the attic floor (see "Radiant Barriers: Performance Revealed," *HE* Sept/Oct '00, p. 30). Aluminum is normally used because it is inexpensive and because, once exposed to the elements, its surface becomes covered with a layer of transparent oxide that helps to maintain its emissivity value long-term. But while radiant barriers are very useful in some areas of the United States, their performance has been less cost-effective in other areas. Now a new study examines in which climatic regions radiant barriers work best.

New or retrofit radiant barriers are installed in three configurations: horizontally over the ceiling frame (Horizontal Radiant Barrier, or HRB), stapled against the trusses (rafters) of the attic (Truss Radiant Barrier, or TRB), or attached directly to the plywood deck (Draped Radiant Barrier, or DRB). The performance of the barrier is similar in all three cases. (With the HRB configuration, performance can deteriorate because of dust buildup that increases the value of the emissivity. Reductions in ceiling heat transfer drop at a rate of about 3.5 percentage points for each 0.05 units increase in emissivity.)



Modeling Heat Fluxes

A good measure of the performance of an attic radiant barrier is the percentage reduction in ceiling heat transfer that it produces. We used a computer model to estimate the ceiling heat fluxes for an attic composed of two pitched roof sections of equal length, two vertical gable end sections, and one horizontal ceiling frame. The model is based on an energy accounting approach; it allowed instantaneous sensible and latent cooling and heating loads to be calculated based on energy balance equations written for each enclosing surface and for attic air layers.

The analysis was done based on the hourly data during the three-month period from June 1 through August 31, using synthesized typical meteorological year (TMY2) weather files. Along with the known attic parameters, the input data included hourly outdoor air temperature, global horizontal solar radiation, wind speed, relative humidity, dew point, and cloud cover for each climate studied. We modeled the performance of attic radiant barriers, in the HRB configuration, in selected cities representing the nine climatic regions of the continental United States (see above).

Results by Region

Sample profiles of ceiling heat fluxes for selected stations in the climatic regions describe the performance of

It Also Depends on Where Your Ducts Are

Besides the climate and the presence of attic moisture, there are two other big factors that affect the energy-saving potential of radiant barriers:

• A radiant barrier and a duct system located in an attic can produce twice as much savings in cooling energy as a radiant barrier without ducts.

• A radiant barrier, a duct system, and an air handler in the attic can produce even more savings.

A simulation for a house in Miami with an R-30 ceiling showed a 13% savings in cooling energy with a radiant barrier, a duct system, and an air handler in the attic; a 9% savings with a radiant barrier and a duct system in the attic; and a 5% savings with just the radiant barrier in the attic.

Our own empirical work for the Florida Power Corporation backs up those simulation numbers. We measured the cooling energy before and after the installation of a radiant barrier. The average measured cooling energy reduction postretrofit was 9%. We also saw that savings were greatest for those sites where the air handler was in the attic. (The full report on the Florida study is available from the Florida Solar Energy Center by going to www.fsec.ucf.edu/bldg/pubs/rbs/.)

—Danny Parker

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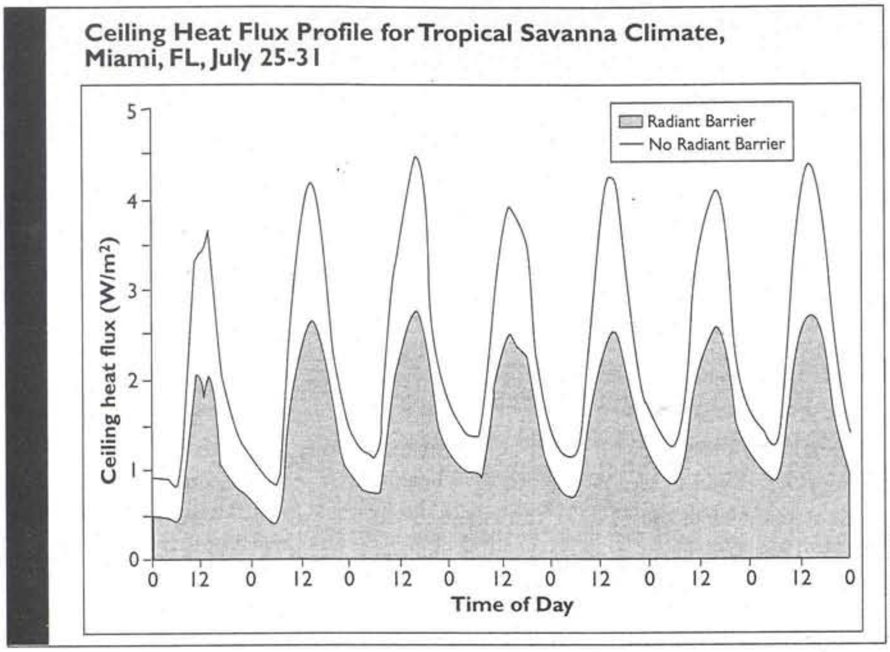

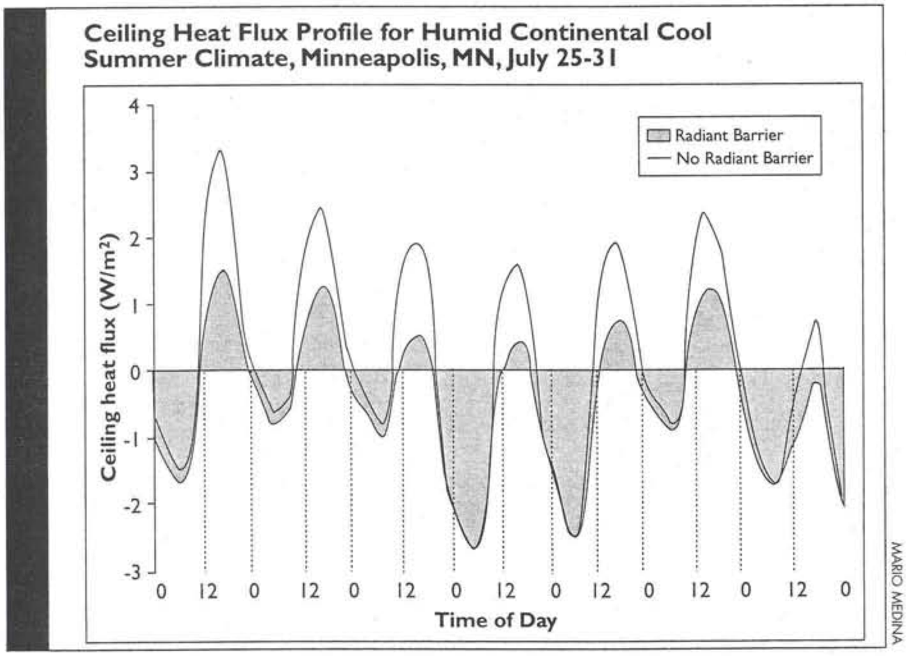

Figure 1. *(top)* Computer analysis shows that radiant barriers work best in humid, tropical, and dessert climates in the United States. **Figure 2.** *(bottom)* In climate regions that experience cool summer evenings, radiant barriers reduce heat flux during the day but have little effect at night.

the radiant barriers (see Figures 1-3). The profiles provide an analytical tool that can be used to determine how radiant barriers work in the various climates. Although the performance of the attic radiant barriers was evaluated continuously during the entire three-month period, the profile time frame spans seven typical summer days (July 25 to July 31).

Tropical Savanna, Humid Subtropical, and Desert climates. The radiant barriers performed similarly in all three of these climates. The key similarity is that, in these climates, heat transfer is almost always into the conditioned space. That is, attic temperatures are generally higher than the temperatures in the conditioned space. The performance profiles prove that radiant barriers are useful in these climates because they help to reduce ceiling heat gains, which increase during periods of high solar activity. In the afternoons the interior surfaces of the attic deck reach 129°F–140°F. Ventilation air also helps to reduce attic air temperatures by enhancing the convective component from the roof deck or radiant barrier surface, and the attic floor, to the attic air.

The profiles show that in the Tropical Savanna climate, radiant barriers are useful throughout the entire 24 hours of the day. In the Humid Subtropical and Desert climates, radiant barriers are useful mainly from 10 am through 6 pm, though they still help somewhat to decrease the heat transfer rate during the night and early morning hours. The best possible performance is achieved during the periods of high solar radiation. These results are not obvious, because mean air temperatures are almost identical in the three climates, and mean hourly global horizontal solar radiation and cloud cover fraction are lowest and highest, respectively, in the Tropical Savanna climate. The reason for these results is that the relative humidity of the Tropical Savanna climate is higher than in the Subtropical and Desert climates. This means that higher solar loads alone do not determine the performance of radiant barriers. Rather, it is a combination of solar load, which drives the ambient air temperatures, and relative humidity that determines how well radiant barriers perform.

In humid climates an evaporation of deposited moisture takes place on the attic surfaces. The evaporation produces a cooling effect, which seems to be greater in the attic fitted with radiant barriers (we have relative humidity and attic temperature data that seem to support this claim), thus producing the largest difference in ceiling heat fluxes between control and retrofit cases. In the Tropical Savanna climate this process continues until the late hours of the day, as the wood surfaces release stored moisture. This translates to the largest observed ceiling heat transfer reductions in this climate. (There is another effect that might explain it, that is sky temperature—the effective radiant temperature of the sky. In high humidity areas, the sky temperature is warmer for the same air temperature.)

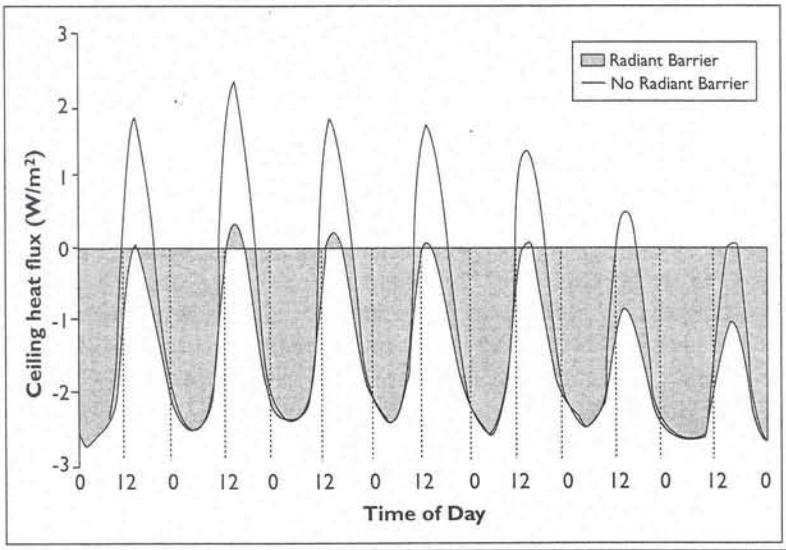

Figure 3. Over the course of a summer, radiant barriers are much less effective in Mediterranean climates compared to other U.S. climates. Peak hour heat flux reductions, however, can be near 100%.

Table 1. Performance of Attic Radiant Barriers by Climate

Climate	Sample Station	Summer Integrated Percent Reduction (%)	Peak-Hour Heat Flux Reduction in Represented Climate (%)
Humid Subtropical	San Antonio, Texas	34.3	31
	New York, New York	32.5	
	Atlanta, Georgia	38.5	
Humid Continental Warm Summer	Topeka, Kansas	30.0	46
	Indianapolis, Indiana	30.1	
Desert	Las Vegas, Nevada	19.2	23
	Tucson, Arizona	23.0	
Humid Continental Cool Summer	Minneapolis, Minnesota	25.7	54
	Detroit, Michigan	24.3	
Steppe	Pocatello, Idaho	16.0	36
	Helena, Montana	13.7	
Marine West Coast	Astoria, Oregon	9.6	~100
Mediterranean	San Francisco, California	2.3	97
Western High Areas	Boulder, Colorado	19.7	44
Tropical Savanna	Miami, Florida	36.8	42

Humid Continental Warm Summer, Humid Continental Cool Summer, Western High Areas, and Steppe climates. In these climates, heat transfer across the ceiling travels in both directions—to and from the conditioned space—as a result of ambient air temperature, which often drops below the indoor air temperature at night and in the early morning hours.

The performance profiles show that radiant barriers are effective in reducing heat transfer across the ceiling during the daytime hours, when the solar loads are high, but are not effective during the night and early morning hours. The profiles further indicate that in these climatic regions, outdoor temperatures fall below the simulated indoor temperature of 75°F for approximately half of the day. Cool nights and mornings are characteristic of these climates. This is probably due to enhanced sky radiation, which is further enhanced by atmospheric dryness and altitude.

Marine West Coast and Mediterranean climates. On a typical summer afternoon, the peak hour percentage reduction in ceiling heat flux is about 100% for the Marine West Coast climate and about 97% for the Mediterranean climate. The radiant barriers block nearly all heat transfer into the conditioned space. The heat loss from the conditioned space across the ceilings is practically the same in both the retrofit and the control cases in both the Marine West Coast and the Mediterranean climates. This means that if space heating were required during the night and early morning in these climates, having radiant barriers installed would not increase the costs attributable to space heating. (However, the reduction in heat transfer during the day means any thermal mass has less charge to carry the space through the heating hours. This deserves further exploration.)

It's the Climate

It is evident from the values generated by the model that the performance of attic radiant barriers depends on the climate in which the building is located (see "It Also Depends on Where Your Ducts Are," p. 14). For the climates considered, the summer integrated percent reduction in ceiling heat flux varied from 2.3% in the Mediterranean climate to 36.8% in the Tropical Savanna climate (see Table 1). The peak hour heat flux reductions varied from 23% in the Desert climate to about 100% in the Marine West climate. The results reveal that attic radiant barriers will prove to be at least somewhat useful in all climates during the cooling season.

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