Effect of Radiant Barriers on Heating and Cooling Bills

Have heating and cooling effects been tested?

At present, there is no standardized method for testing the effectiveness of radiant barriers in reducing heating and cooling bills. But numerous field tests have been performed that show, depending on the amount of existing conventional insulation and other factors, radiant barriers are effective in reducing cooling bills, and also possibly heating bills.

Most of these field tests have been performed in warm climates where a large amount of air-conditioning is used. The Florida Solar Energy Center (FSEC) at Cape Canaveral has performed tests for a number of years using attic test sections, and has also performed tests with full-size houses. A test using a duplex house in Ocala, Florida has been performed by the Mineral Insulation Manufacturers Association. The Tennessee Valley Authority has performed a number of winter and summer tests using small test cells in Chattanooga, Tennessee. The Oak Ridge National Laboratory (ORNL) has performed a series of tests using three full-size houses near Knoxville, Tennessee. The ORNL tests included summer and winter observations. So far, very little testing has been done in climates colder than that of Knoxville. Also, little testing has been done in hot, arid climates such as the southwestern United States.

The tests to date have shown that in attics with R-19 insulation, radiant barriers can reduce summer ceiling heat gains by about 16 to 42 percent compared to an attic with the same insulation level and no radiant barrier. These figures are for the average reduction in heat flow through the insulation path. They do not include effects of heat flow through the framing members. See Tables A1 and A2 in the Appendix for a comparison of measured performance.

THIS DOES NOT MEAN THAT A 16 TO 42 PERCENT SAVINGS IN UTILITY BILLS CAN BE EXPECTED. Since the ceiling heat gains represent about 15 to 25 percent of the total cooling load on the house, a radiant barrier would be expected to reduce the space cooling portion of summer utility bills by less than 15 to 25 percent. Multiplying this percentage (15 to 25 percent) by the percentage reduction in ceiling heat flow (16 to 42 percent) would result in a 2 to 10 percent reduction in the cooling portion of summer utility bills. However, under some conditions, the percentage reduction of the cooling portion of summer utility bills may be larger, perhaps as large as 17 percent. The percentage reduction in total summer utility bills, which also include costs for operating appliances, water heaters, etc., would be smaller. Tests have shown that the percentage reductions for winter heat losses are lower than those for summer heat gains.

Experiments with various levels of conventional insulation show that the percentage reduction in ceiling heat flow due to the addition of a radiant barrier is larger with lower amounts of insulation. Since the fraction of the whole-house heating and cooling load that comes from the ceiling is larger when the amount of insulation is small, radiant barriers produce the most energy savings when used in combination with lower levels of insulation. Similarly, radiant barriers produce significantly less energy savings when used in combination with high levels of insulation.

Most of the field tests have been done with clean radiant barriers. Laboratory measurements have shown that dust on the surface of aluminum foil increases the emissivity and decreases the reflectivity. This means that dust or other particles on the exposed surface of a radiant barrier will reduce its effectiveness. Radiant barriers installed in locations that collect dust or other surface contaminants will have a decreasing benefit to the homeowner over time.

The attic floor application is most susceptible to accumulation of dust, while downward facing reflective surfaces used with many roof applications are not likely to become dusty. When radiant barriers are newly installed, some testing shows that the attic floor application will work better than the roof applications. As dust accumulates on the attic floor application, its effectiveness will gradually decrease. After a long enough period of time, a dusty attic floor application will lose much of its effectiveness. Predictive modeling results, based on testing, suggest that a dusty attic floor application will lose about half of its effectiveness after about one to ten years.

Testing of radiant barriers has been primarily concerned with the effect of radiant barriers on the heat gains or losses through the ceiling. Another aspect of radiant barriers may be important when air-conditioning ducts are installed in the attic space. The roof applications of radiant barriers can result in lowered air temperatures within the attic space, which in turn can reduce heat gains by the air flowing through the ducts, thus increasing the efficiency of the air-conditioning system. These changes in heat gains to attic ducts have not been tested; however, computer models have been used to make estimates of the impact on cooling bills.

Not all field tests have been able to demonstrate that radiant barriers or even attic insulation are effective in reducing cooling bills. In a field test performed by ORNL in Tulsa, Oklahoma, using 19 full-sized, occupied houses, neither radiant barriers nor attic insulation produced air-conditioning electricity savings that could be measured. As in all field tests, these results are applicable only to houses with similar characteristics as those tested. Unique characteristics of the houses used in this field test included the facts that the houses were cooled by only one or two window air-conditioning units, that the units were able to cool only a portion of the house, and that the occupants chose to limit their use of the units (initial air-conditioning electricity consumption averaged 1664 kilowatt-hours per year or about $119 per year).

How much will I save on my heating and cooling bills?

Your savings on heating and cooling bills will vary, depending on many factors. Savings will depend on the type of radiant barrier application, the size of your house, whether it is a ranch style or a two story house, the amount of insulation in the attic, effectiveness of attic ventilation, the color of the roof, the thermostat settings, the tightness of the building envelope, the actual weather conditions, the efficiency of the heating and cooling equipment, and fuel prices.

Research on radiant barriers is not complete. Estimates of expected savings, however, have been made using a computer program that has been checked against some of the field test data that have been collected. These calculations used weather data from a number of locations to estimate the reductions in heating and cooling loads for a typical house. These load reductions were then converted to savings on fuel bills using average gas furnace and central air-conditioner efficiencies and national average prices for natural gas and electricity.

ASSUMPTIONS. For these calculations, the house thermostat settings were taken to be 78F in the summer and 70F in the winter. In the summer, it was assumed that windows would be opened when the outdoor temperature and humidity were low enough to take advantage of free cooling. Also, it was assumed that the roof shingles were dark, and that the roof was not shaded. The furnace efficiency used was 65 percent, and the air-conditioner coefficient of performance (COP) was 2.34. Fuel prices used were 52.7 cents per therm (hundred cubic feet) for natural gas and 7.86 cents per kilowatt-hour for electricity.

Factors that could make your savings larger than the ones calculated would be: a summer thermostat setting lower than 78F, a winter thermostat setting higher than 70F, keeping the windows closed at all times, lower efficiency furnace or air-conditioner, or higher fuel prices. Factors that could make your savings less than the ones calculated would be: a summer thermostat setting higher than 78F, a winter thermostat setting lower than 70F, light colored roof shingles, shading of the roof by trees or nearby structures, higher efficiency furnace or air-conditioner, and lower fuel prices.

A standard economic calculation was then performed that converts the dollar savings from periods in the future to a "present value". The dollar savings were also adjusted to account for estimates of how prices for natural gas and electricity are predicted to rise in future years. This calculation gives a "present value savings" in terms of dollars per square foot of ceiling area. When this value is multiplied by the total ceiling area, the result is a number that can be compared with the cost of installing a radiant barrier. If the present value savings for the whole ceiling is greater than the cost of a radiant barrier, then the radiant barrier will be "cost effective." A real discount rate of 7 percent, above and beyond inflation, and a life of 25 years were used in the calculations.

Tables 3, 4, and 5 give present value savings for radiant barriers based on average prices and equipment efficiencies. Table 3 applies to the attic floor application, where the effects of dust accumulation have been taken into account. Since dust will accumulate at different rates in different houses, and since the effect of dust on performance is not well known, ranges of values are given for this application. Table 4 applies to radiant barriers attached to the bottoms of the rafters, while Table 5 applies to radiant barriers either draped over the tops of the rafters or attached directly to the underside of the roof deck. For comparison purposes, the same computer program has also been used to estimate present value savings for putting additional insulation in the attic; these values are listed in Table 6. By examining several options, the consumer can compare the relative savings that may be obtained versus the cost of installing the option. Generally, the option with the largest net savings (that is, the present value savings minus the cost) would be the most desirable. However, personal preferences will also enter into a final decision.

If you want a better estimate based on your local fuel prices or other equipment efficiencies, you may use the worksheet in the Appendix. Local fuel prices may be obtained from your local utilities.

Examples of Use of Present Value Tables

Example 1

I live in Orlando, Florida in an 1800 square foot ranch style house. I have R-11 insulation in my attic, and the air-conditioning ducts are in the attic. A contractor has quoted a price for a radiant barrier installed on the bottoms of my rafters and on the gable ends for $400. Would this be a good investment?

For this type of radiant barrier, the appropriate table is Table 4. For Orlando with R-11 insulation, the present value savings is listed as $0.32 when the air-conditioning ducts are in the attic. Multiplying this value by 1800 square feet gives a total of $576. This value exceeds the quoted cost of the radiant barrier of $400, and thus this would be a good investment.

Example 2

I live in Minneapolis, Minnesota in a 2400 square foot two-story house. I have R-19 insulation in my attic, and have no air-conditioning ducts in the attic. A contractor has quoted a price for a radiant barrier installed on the bottoms of my rafters and on the gable ends for $250. Would this be a good investment? Would investment in another layer of R-19 insulation be a better investment? A contractor has quoted a price of $564 for adding this insulation.

For this type of radiant barrier, the appropriate table is Table 4. For Minneapolis with R-19 insulation, the present value savings is listed as $0.08 when there are no air-conditioning ducts in the attic. Since the house is two-story, the ceiling area is 1200 square feet. Multiplying $0.08 by 1200 gives a total of $96. This value is less than the quoted cost of the radiant barrier of $250 and thus this would not be a good investment.

For adding another layer of insulation, the appropriate table is Table 6. For Minneapolis, this table gives a present value savings of $0.57 for adding a layer of R-19 insulation to an existing layer of R-19 insulation. Multiplying this value by 1200 square feet gives a total of $684. This value exceeds the quoted cost of the insulation, and thus this would be a good investment.

Important Non-Energy Considerations

Potential for moisture condensation

Condensation of moisture can be a concern when a radiant barrier is installed on the attic floor directly on top of conventional insulation. During cold weather, water vapor from the interior of a house may move into the attic. In most cases, this water vapor will not cause any problem because attic ventilation will carry excess vapor away. During cold weather, a radiant barrier on top of the insulation could cause water vapor to condense on the barrier's underside.

Condensation of large amounts of water could lead to the following problems: 1) the existing insulation could become wet and lose some of its insulating value, 2) water spots could appear on the ceiling, and 3) under severe conditions, the ceiling framing could rot.

Some testing has been performed to determine the potential for moisture condensation with perforated radiant barriers laid on top of the insulation. A test was conducted during the winter near Knoxville, Tennessee, using houses that were operated at much higher-than-normal indoor relative humidities. Since this testing did not reveal any significant moisture condensation problems, it is expected that moisture condensation will not be a problem in climates warmer than that of Knoxville. Further testing of radiant barriers is needed to determine if moisture condensation is a problem in climates colder than that of Knoxville.

One precaution for preventing potential moisture problems is the use of perforated or naturally permeable radiant barriers. The higher the perm rating, the less potential for problems. Avoiding high indoor relative humidities, sealing cracks and air leaks in the ceiling, using a vapor retarder below the attic insulation, and providing for adequate attic ventilation are additional precautions.

Attic ventilation

Attic ventilation is an important consideration. With adequate ventilation, radiant barriers will perform better in summer and excess water vapor will be removed in winter. Unfortunately, specific recommendations for the best type and amount of attic ventilation for use with radiant barriers are not available. Model building codes have established guidelines for the amount of attic ventilation area per square foot of attic floor area to minimize the occurrence of condensation. These guidelines specify one square foot of net free ventilation area for each 150 square feet of attic floor area. This ratio may be reduced to 1 to 300 if a ceiling vapor retarder is present or if high (for example, ridge or gable vents) **and** low (soffit vents) attic ventilation is used. Since part of the vent area is blocked by meshes or louvers, the net free area of a vent is smaller than its overall dimensions.

Effect of radiant barriers on roof temperatures

Field tests have shown that radiant barriers can cause a small increase in roof temperatures. Roof mounted radiant barriers may increase shingle temperatures by 2 to 10^{o}F, while radiant barriers on the attic floor may cause smaller increases of 2F or less. The effects of these increased temperatures on roof life, if any, are not known.

Fire ratings

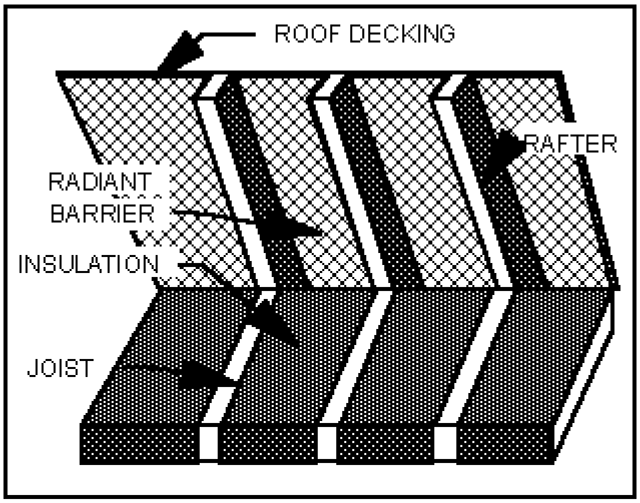
The fire ratings of radiant barriers are important because flame and smoke characteristics of materials exposed to ambient air are critical.

TO MEET CODE, A RADIANT BARRIER MUST BE RATED EITHER CLASS A BY THE NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) OR CLASS I BY THE UNIFORM BUILDING CODE (UBC).

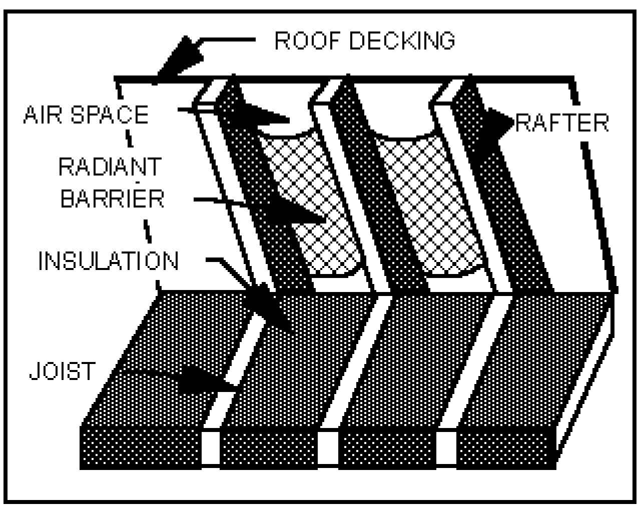
To obtain these ratings, a material must have an ASTM E-84 Flame Spread Index of 25 or less and a Smoke Developed Index of 450 or less. Look for these ratings either printed on the product, or listed on material data sheets provided by the manufacturer.

Installation Procedures

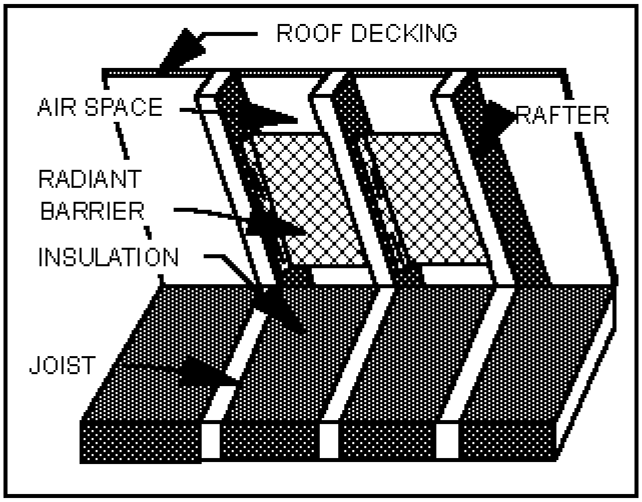
Most residential roofs provide some type of attic or airspace that can accommodate an effective radiant barrier system. In new residential construction, it is fairly easy to install a radiant barrier system. The following images show five possible locations for the installation of an attic radiant barrier system.

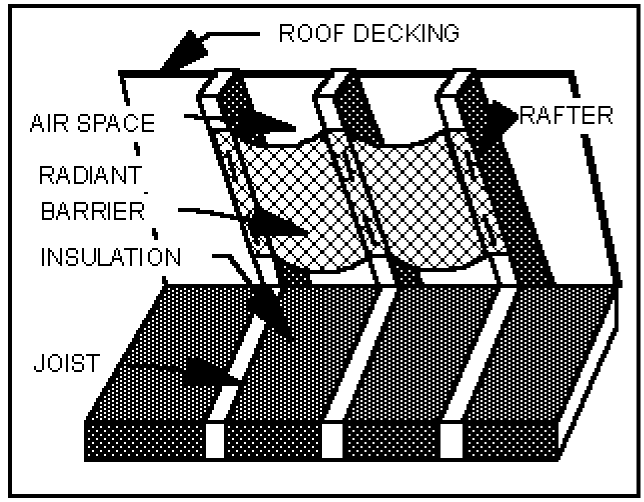


Location 1 is a relatively new application, where the radiant barrier material is attached directly to the underside of the roof deck.

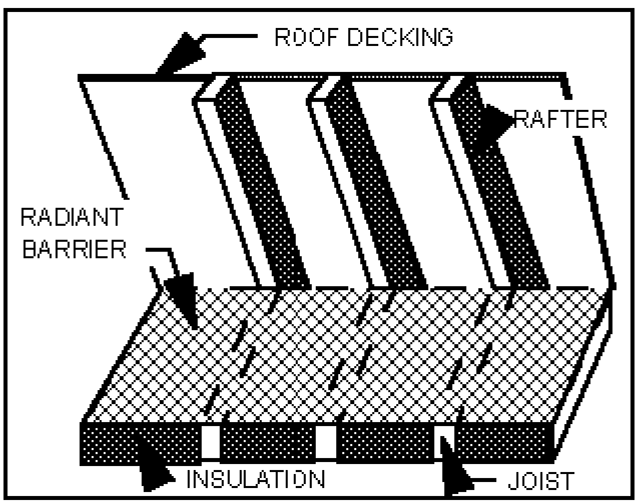


Location 2 may offer advantages to the builder during construction of a new house. Before the roof sheathing is applied, the radiant barrier is draped over the rafters or trusses in a way that allows the product to droop 1-1/2 to 3 inches between each rafter.





In Locations 3 and 4, the radiant barrier is attached to either the faces or bottoms of the rafters or top chords of the roof trusses. Locations 3 and 4 may be used with either new construction, or with retrofit of an existing house. With either Location 2, 3 or 4, the space between the roof sheathing and the radiant barrier provides a channel through which warm air can move freely, as shown in Figure 2.



In Location 5, the radiant barrier is laid out on the attic floor over the top of existing attic insulation. As discussed previously, this location is susceptible to the effects of dust accumulation. This location is 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. Also, kitchen and bathroom vents and recessed lights should not be covered with the radiant barrier.

To obtain the best performance with radiant barriers installed in Locations 1 through 4, radiant barrier material should also be installed over the gable ends. For attics that are open to the space over garages or carports, the radiant barrier should extend eight feet or more into the garage or carport to achieve the same effect as installing a radiant barrier on the gable ends. It is not necessary to cover the gable ends with Location 5.

Radiant barriers that are reflective on one or both sides may be used with any of these locations. However, if the radiant barrier is reflective on only one side, the reflective side must face toward the main attic space for Locations 1 and 5. Since a surface facing downwards is less likely to have dust settle on it, it is also recommended that the reflective side face downwards toward the main attic space for Locations 2, 3, and 4.

Since proper attic venting is important to obtain the best performance of the radiant barrier, some modification in the attic vents may be required to achieve expected performance. Where no ridge or gable vents exist, it is recommended that one or the other be installed. Always check existing ridge vent systems to ensure that roofing paper is not blocking the vent opening, and check the soffit vents to ensure that they have not been covered with insulation.

When installing a radiant barrier, care should be taken not to compress existing insulation present in the attic. The effectiveness of the existing insulation is dependent upon its thickness, so if it is compressed, its R-value is decreased. For instance, an R-19 batt compressed to 3-1/2 inches (to top of 2X4 attic floor joists) would now be approximately an R-13 batt.

Safety considerations

- The installer should wear proper clothing and equipment as recommended by the radiant barrier manufacturer. 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.
- Be especially careful with electrical wiring, particularly around junction boxes and old wiring. Never staple through, near, or over electrical wiring. Repair any obvious frayed or defective wiring in advance of radiant barrier installation.
- Work in the attic only when temperatures are reasonable.
- Work with a partner. Not only does it make the job go faster, it also means that you'll have assistance should a problem occur.
- If the attic is unfinished, watch where you walk. If you step in the wrong place, you could fall through the ceiling. Step and stand only on the attic joists or trusses or the center of a strong moveable working surface.
- Watch your head. In most attics, roofing nails penetrate through the underside of the roof. A hard hat may be of some use.
- Make sure that the attic space is well ventilated and lighted.
- Do not cover any recessed lights or vents with radiant barrier material (attic floor application).

DOE/CE-0335P
June 1991

Department of Energy
Assistant Secretary
Energy Efficiency and Renewable Energy