PRELIMINARY STUDY OF A VENTED ATTIC RADIANT BARRIER SYSTEM IN HOT, HUMID CLIMATES USING SIDE-BY-SIDE, FULL-SCALE TEST HOUSES.

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ABSTRACT

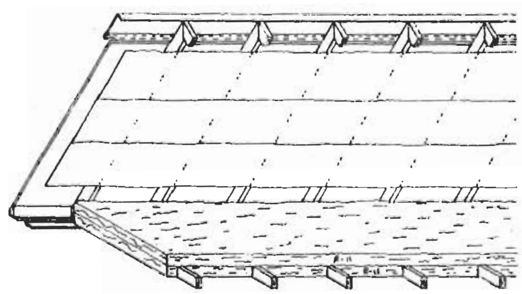
A series of side-by-side tests was performed using two full scale test houses to determine the effectiveness of a Vented Radiant Barrier System (VRBS) in reducing the ceiling heat flux during the summer cooling season in North Florida. Another series of side-by-side tests was conducted to evaluate the effect of a VRBS on ceiling heat losses under typical North Florida winter conditions. The effect of a VRBS on the expected life of roof shingles was also evaluated.

EXPERIMENTAL APPROACH

TEST FACILITIES

The test houses, located at the Energy Research and Education Park (EREP) on the University of Florida campus, have identical floor plans of approximately 1250 sq. ft. The attic/ceiling assemblies consist of an "under attic" ceiling below a roof with a 5/12 pitch. The pre-fabricated trusses are constructed of 2x4s. The ceiling insulation has an R-value of 22, achieved through the use of two R-11 batts. Both houses have dark gray shingles and are completely unshaded. Attic ventilation in the Control House is limited to "interrupted" soffit vents and relatively small gable end vents. This ventilation configuration, labelled Standard Venting, achieves at least minimum requirements for attic ventilation. The Test House is equipped with a full ridge vent and continuous soffit venting, as well as the standard gable end vents. This ventilation configuration was labelled Full Venting. The ridge vent and the soffit venting in the Test House can be modified to produce the Standard Venting configuration.

Two types of Vented Radiant Barrier Systems were installed in the Test House. The radiant barrier material used in both configurations was a sheet material in two feet wide rolls with one kraft paper surface and one low emissivity surface (an emissivity of approximately 0.05). In the first configuration, labelled Radiant Barrier Up (or RBUP), the sheet material was stapled to the bottom of the top chord of the trusses with the low emissivity surface facing upward toward the bottom of the roof sheathing.



Conceptual Drawing Showing Attic with Radiant Barrier Up

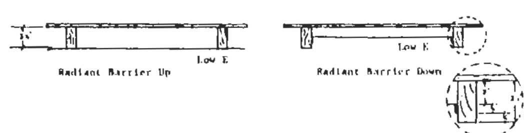


Fig. 1 Radiant Barrier Configurations

The radiant barrier material was rolled out parallel to the ridge line of the roof. This technique left a 3-1/2" air space between the low emissivity surface and the roof sheathing. The radiant barrier material extended along the slope of the roof from approximately six inches above the ceiling insulation at the lower end of the top chord to approximately six inches from the peak at the top end. This design allowed air exchange between the air channels above the radiant barrier material and the main part of the attic space. Attic air could also exit directly through the ridge vent.

In the second radiant barrier configuration, Radiant Barrier Down (or RBDN), the radiant barrier material was installed with the low emissivity surface facing downward, toward the ceiling insulation. Installed in the space between two adjacent top chords, the radiant barrier material was stapled to the opposing vertical sides of these top chords. This technique created a two inch air space between the kraft paper surface and the bottom surface of the roof sheathing. As with the Radiant Barrier Up configuration, the radiant barrier material extended from six inches above the ceiling insulation to six inches short of the peak.

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TESTING SEQUENCES

A sequence of four individual tests was performed to determine the effect of Full Venting and the two Vented Radiant Barrier Systems on the summer ceiling heat fluxes. In all tests, the Control House was left unchanged with Standard Venting and no Radiant Barrier System. The first test performed was the "null" test with Standard Venting in both houses. During the three other tests, the Test House was modified to represent Full Venting, Radiant Barrier Up and Radiant Barrier Down.

Detailed measurements of temperatures, ceiling fluxes and meteorological data were made during the test period. During each stage of testing the indoor ambient conditions of the two test houses were kept nearly constant.

To evaluate the winter performance of a Vented Radiant Barrier System, two side-by-side tests were performed. In the first test, both houses were in Standard Venting configuration. The results of this test were used as a null test to normalize the data. In the second test, the Test House was configured as Radiant Barrier Down and the Control House remained configured in Standard Venting configuration.

DATA POINTS

A total of 176 data points were monitored in the two houses. The bulk of the data points consisted of thermocouples in vertical profiles positioned in the four quadrants of each house (NE,SE,SW,NW). Each of the four vertical profiles had thermocouples in the following 12 locations: roof shingle, roof sheathing, radiant barrier space, radiant barrier material, attic air, top of insulation, middle of insulation, bottom of insulation, ceiling surface, room air, and two floor surface temperatures.

A Large Area Heat Flow Meter (LAHFM) was installed in the ceiling at each vertical profile location. The eight LAHFMs were constructed from 1/2" gypsum board and contained 13 thermocouple pairs. These calibrated panels measuring 42" by 42", were inserted in place of the ceiling material (1). Additional instrumentation measured indoor and outdoor ambient conditions, including dry bulb temperature, relative humidity and solar insolation.

DATA ACQUISITION AND REDUCTION

All data points were monitored every five minutes by two Kaye Remote Analog Multiplexing Processor (RAMP) scanners. A Digital Equipment Corporation PDP-11/34 minicomputer remotely controlled the scanners and stored the data in hourly files on disks and magnetic tape.

DISCUSSION OF RESULTS

SUMMER CEILING FLUXES

The effect of different attic configurations on ceiling heat fluxes was analyzed by comparing hourly results from the test house to the control house. Other analyses indicated that the effect of radiant barriers was a strong function of time of day but not of horizontal insolation or sol-air temperature. Consequently, the ensuing analysis focused only on the time of day relationship.

A normalization procedure was devised to compensate for differences in the heat fluxes in Standard Venting configuration (null test) of 25 percent. In order to avoid difficulties of forming heat flux ratios when the denominator (Q control) is near zero, the ratio of test house to control was shifted by adding a constant (3 BTU/hr. ft^2), approximately equal to the maximum heat flux magnitude to both numerator and denominator. Normalized hourly values of the Test House ceiling flux were then generated. These Test House values could be compared to the measured Control House values for any chosen attic configuration and period of the day. Analysis of general trends indicated that the period of typical summer ceiling heat gain occured between 10am and 10pm (DST). During the remainder of the day ceiling fluxes were nearly identical for all configurations. (Refer to Figure 2.)

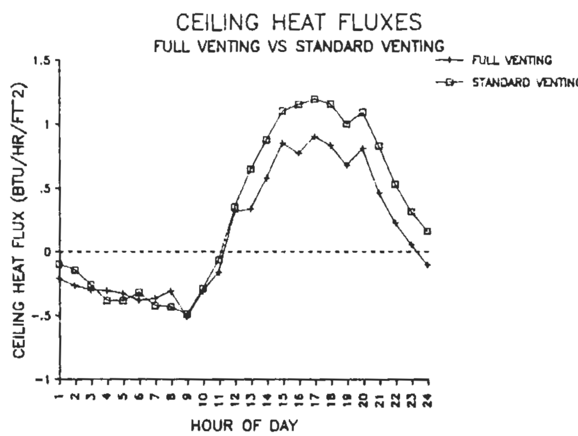

Fig. 2A

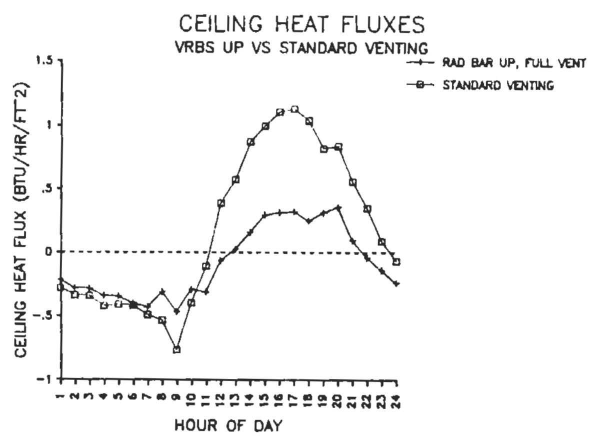

Fig. 2B

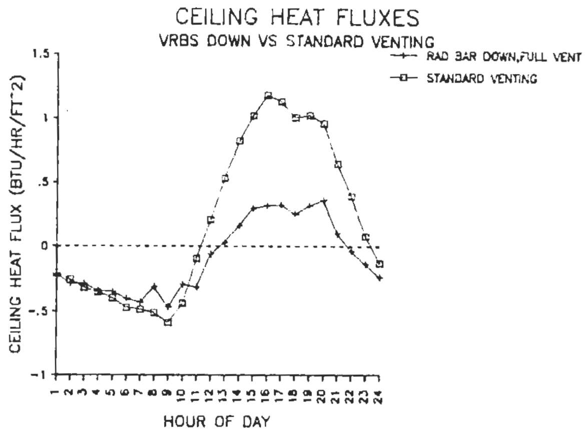

Fig. 2C

The normalized Test House fluxes from 10am to 10pm, all positive, were summed and divided by the sum of the fluxes for the same hours in the Control House. The resulting ratio represents the relative ceiling heat flux of the tested attic configuration to the ceiling heat flux for the Standard Venting case.

TABLE 1
RATIO OF ALTERNATIVE ATTIC CONFIGURATION CEILING FLUX TO STANDARD CEILING FLUX
10 am to 10 pm

	FULL	RB UP	RB DN
LAHFM	0.67	0.25	0.19

The results indicate a substantial decrease in the ceiling heat flux (approximately 30%) is realized through the use of Full Venting. An additional substantial decrease (approximately 40% relative to Full Venting) is realized by the addition of a Radiant Barrier System to the fully vented attic. The orientation of the radiant barrier material, either upward or downward, does not significantly affect the results. (Refer to Figure 3.)

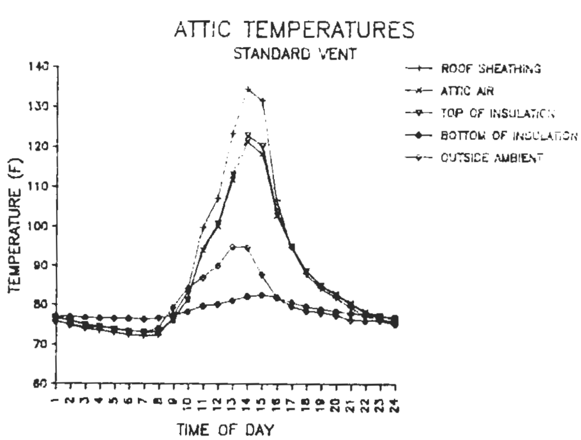

Fig. 3A

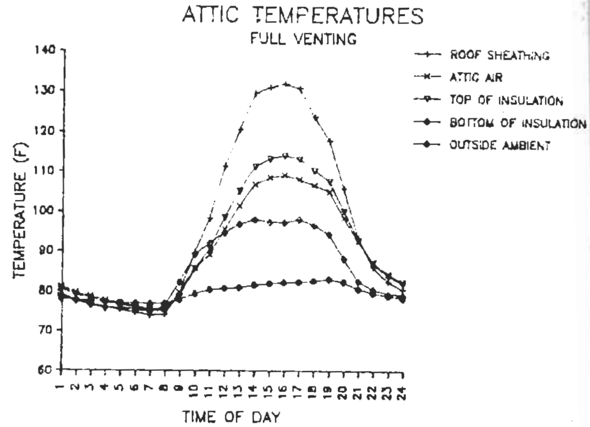

Fig. 3B

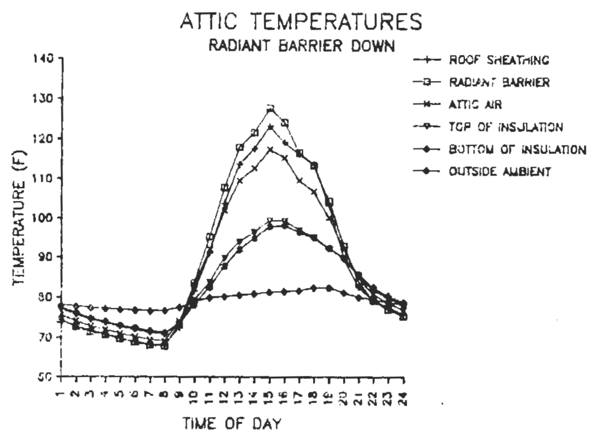

Fig. 3C

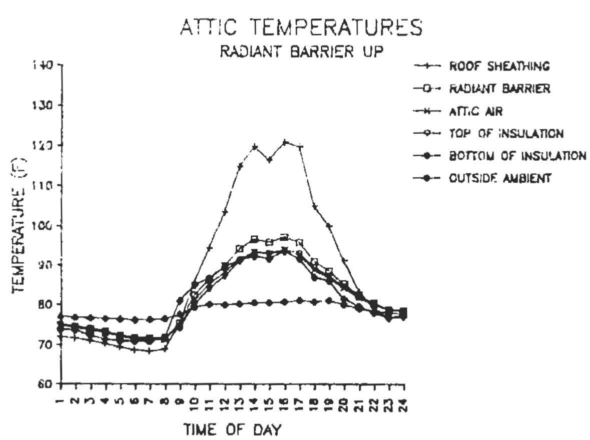

Fig. 3D

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Comparing the Radiant Barrier Up and Radiant Barrier Down graphs, it is clear that the radiant barrier material, when facing downward, is much hotter than when facing upward. Attic air temperatures, however, appear to be unaffected by the radiant barrier material temperature and are nearly equal to the temperature of the top surface of the ceiling insulation.

In the case of Full Venting the attic air temperatures are significantly higher than in either of the VRBS configurations. Yet the attic air temperature is lower than the top surface temperature of the ceiling insulation. This suggests that the insulation is heated by radiation exchange with the bottom surface of the roof assembly and that the ceiling insulation loses heat to the attic air.

WINTER CEILING FLUXES

The results of a set of tests designed to evaluate the effect of a Vented Radiant Barrier System on the ceiling fluxes during the heating season in North Florida indicated that these fluxes were a strong linear function of outdoor ambient temperature. A side-by-side test with Standard Venting in the Control House and Radiant Barrier Down in the Test House was conducted. The hourly results were normalized based on a null test and plotted versus outdoor ambient temperatures ranging from 30 F to 70 F. Although the slopes of the two lines were slightly different, within the degree of accuracy of the experiment, the two ceiling systems appear to perform identically.

SHINGLE TEMPERATURES

The effect of a Vented Radiant Barrier System on the temperature of roof shingles between 10 am and 10 pm was analyzed based on both average and peak temperatures. As with the evaluation of ceiling heat fluxes, it was necessary to normalize the average shingle temperature values to remove any pre-existing differences between the two houses. The results in Table 2 are presented in two ways, the actual temperature value in the Test House (Test Temp.) and the normalized difference between Test House and Control House temperatures (Test minus Control).

TABLE 2
AVERAGE SHINGLE TEMPERATURE COMPARISONS

10 am to 10 pm

Average Temperatures

	STD	FULL	RBUP	RBDN
Test Temp.	109	131	117	116
Test-Control	0	-5	-1	-1

Peak Temperatures

	STD	FULL	RBUP	RBDN
Test Temp.	146	151	150	150
Test-Control	0	-6	-2	-2

KEY: STD=Standard Venting
FULL=Full Venting
RBUP=Radiant Barrier Up
RBDN=Radiant Barrier Down

An analysis of the results of both methods yields nearly identical results. The Full Venting attic configuration results in cooler shingle temperatures than the Standard Venting configuration. Both the Radiant Barrier Up and the Radiant Barrier Down configurations produce shingle and sheathing temperatures slightly lower than Standard Venting, but warmer than Full Venting. The magnitude of the temperature differences is too low to have any effect on the life expectancy of shingles. These results are not unexpected considering the increased air flow below the roof sheathing due to the presence of a ridge vent. Shingle temperatures could be considerably higher if a radiant barrier material was installed in an attic with only Standard Venting.

CONCLUSIONS

Based on data collected during the summer of 1986 for four different attic configurations, it is possible to reach a number of conclusions relating to the effect of Full Venting and Vented Radiant Barrier Systems (VRBS) on summer ceiling heat fluxes in hot, humid climates.

By enhancing the natural venting of an attic, through the use of a full ridge vent and increased soffit venting, the ceiling fluxes of attics exposed to relatively high insolation values can be significantly reduced. The use of a Radiant Barrier System, in conjunction with enhanced attic venting, can result in even further significant reductions in ceiling fluxes of attics that are exposed to relatively high insolation values. Further testing is required to determine the effect of this potential ceiling flux reduction on the year-long cooling load. Therefore caution should be exercised when relating this potential decrease in ceiling fluxes to reduced cooling loads.

The use of a Vented Radiant Barrier System does not seem to affect the winter performance of the ceiling in North Florida.

The use of a Radiant Barrier System in conjunction with enhanced venting does not increase either roof shingle or roof sheathing temperatures. In fact, these temperatures are slightly lower than those measured during Standard Venting tests. The lowest temperatures were measured during the Full Venting tests.

REFERENCES

(1) T.E. Barrup,"Calibration of Large Area Heat Flow Meters and Small Area Heat Flow Meters for Full-Scale Testing of a Radiant Barrier System", SEECL, University of Florida, 1986.