AN EVALUATION OF THE PLACEMENT OF RADIANT BARRIERS ON THEIR EFFECTIVENESS IN REDUCING HEAT TRANSFER IN ATTICS

Srinivas Katipamula and Dennis L. O'Neal
Texas A&M University
Department of Mechanical Engineering
College Station, Texas

ABSTRACT

Experimental tests were conducted to measure the influence of radiant barriers and the effect of the radiant barrier location on attic heat transfer. All the tests were conducted in an attic simulator at a steady state. The heat flux through the attic floor was measured at two different roof deck temperatures (120°F and 140°F). The temperature distribution within the base fibrous insulation was also measured.

Three different solid kraft laminates with aluminum foil backing were tested. There was a 34 percent reduction (sample A) in heat flux through the ceiling for the case where the radiant barrier was placed 6 inches below the roof deck in addition to the base fibrous insulation (R-11), with the roof deck at 140 F. The reduction for the same sample with the radiant barrier placed on the studs of the attic floor was 46 percent. For all the three samples, the heat flux through the attic floor was reduced when the radiant barrier was placed on the attic floor studs.

INTRODUCTION

For summer weather, radiation exchange is the most significant mode of heat transfer in attics. Convection and conduction are important only as they interfere with or augment the primary mode radiation.

Recent studies have provided added insight into the relative benefits of radiant barriers in reducing attic heat transfer. Joy [1] used a highly reflective aluminum foil on top of the fibrous insulation in a ceiling and found that the resistance path of the insulation system was increased. Recent studies at the Florida Solar Energy Center (FSEC) have shown that the penetration of radiation from a hot roof deck may be significant enough to produce an effective R-value appreciably lower than the measured value in a standardized rating test [2]. Their studies indicated that natural convection to the attic insulation may account for as little as 10 percent of the total heat transfer through the insulation when the roof is sunlit. Another important finding from the Florida Solar Energy Center's study was that it pointed out the Benefit of radiation shields. Shielding the insulation from the high temperature roof deck will reduce the radiation on the insulation free surface and allow it to perform largely as it was intended. Such a shield could be at the insulation surface or at the roof deck surface and produce nearly the same effect. Their results indicated that shielding the insulation from the hot roof improved the overall thermal resistance by about 50 percent. The experimental studies conducted at Texas A&M University [3] also have shown that use of radiant barriers reduced the overall thermal conductivity of the insulation system.

Although, all the above studies did point out the benefits of radiant barriers, the effect of the placement of the radiant barrier inside the attic was not addressed. This study looks at the effect of placement of the radiant barriers inside attics and also the effectiveness of different kinds of radiant barriers on attic heat transfer.

EXPERIMENTAL SETUP AND PROCEDURE

Figure 1 shows the front view of the attic simulator. The outer dimension of the simulator is 4 ft x 4 ft x 4 ft. Materials used to construct the simulator are: 0.75 in. and 0.5 in. plywood for construction of the main chamber and the mount; a 0.38 in. aluminum plate (hot plate); a 0.5 in. gypsum board for the top and bottom of the simulator; 12 in. styrofoam for outer insulation; aluminum foil for lining the internal walls; an electric heating coil for heating the chamber; and a wooden frame to mount the simulator.

The box is divided into chambers. The top chamber is above the aluminum plate as shown in Figure 1, and is 4 ft x 4 ft x 6 in and holds the electric heating coil. The coil is rated at 555 watts at 115V. The top of this chamber is covered with a 0.5 in. gypsum board. The bottom chamber is 4 ft x 4 ft x 3 ft and is made of plywood. The simulator has a door on one side to facilitate changing the insulation systems. The walls of the simulator are all lined with highly reflective aluminum foil to minimize heat loss through the sides. Two 2 in. x 4 in. boards are installed on the 0.5 in. gypsum board to simulate the actual attic ceiling. A 2 in. x 4 in. stand is used for mounting the whole simulator. A 4 ft x 4 ft x 0.25 in. plate separates the two chambers. The aluminum plate is painted black to increase its emissivity and absorptivity. A caulk sealant was used on the all edges and joints to get an air tight seal on the box.

The side insulation was an expanded polystyrene 1 in. board stock insulation with an R-value of 3.9 (h-ft-F0/(Btu-in). Twelve boards were glued together to get a thickness of 12 in. and a total R-value of 47 (h-ft-F)/(Btu-in) on the four sides and on top of the simulator.

Four heat flux meters were installed at the bottom of the simulator. The flux meters were constructed of two 0.13 in. thick aluminum plates (6 x 6 in,) with 0.38 in bakelite (k=0.18 Btu/hr-ft-F) sandwiched between them. The thermocouples were placed on the top surface between the bakelite and the aluminum and on the bottom of the bakelite between the other aluminum plate. Because, the thermal conductivity of the bakelite was known, the heat flux was computed by measuring the temperature drop across the bakelite. The flux meters were attached to the gypsum board by nylon bolts to minimize heat transfer through the bolts.

DATA AQUISITION

A sixty channel data logger was used to scan the thermocouples at specific required time intervals; and each channel of the data logger was verified for accuracy. The data logger directly converted the voltage from the thermocouples into degrees centigrade or degrees Fahrenheit. A printer, interfaced to the data logger, recorded the channel temperatures at required time intervals.

TEMPERATURE CONTROLLER

The experiments were conducted in a controlled steady-state condition. The roof temperature was maintained at a constant preset temperature by means of a temperature controller.

TEST METHODS

INSULATION SYSTEMS TESTED

To determine the effects of the placement of radiation barriers on the attic heat transfer, a series of tests were conducted. Tests were performed for base fibrous insulation thickness of 3.5 in. and roof temperatures of 120 F and 140 F. The insulation systems included:

(i) Fibrous insulation (3.5 in.)
(ii) Fibrous insulation with reflective sample A
(iii) Fibrous insulation with reflective sample B
(iv) Fibrous insulation with reflective sample C
(v) Fibrous insulation with reflective sample D

The 2--4 tests were conducted by placing the reflective sample at two different positions: (1) 6 in. from the roof deck as in Figure 1 and,(2) placing it on the studs of the attic floor as shown in Figure 2. The last test was done with the reflective foil on the attic floor. Sample A is a solid kraft laminate with aluminum foil backing on one side. Sample C is also a solid kraft laminate with aluminum foil backing on one side. (The aluminum foil backing on sample C is more diffused than that of sample A). Sample B is a solid kraft laminate with diffused aluminum foil was maintained at the required temperature for more than 5 hours before the data was collected. This procedure gave sufficient time for steady state conditions to be achieved. Temperatures at various locations were recorded at 30 second intervals over a period of 20 to 30 minutes. The temperatures were later averaged over the same period.

RESULTS AND ANALYSIS

The temperature profile for the base run with 3.5 in. fibrous insulation is shown in Figure 3. The temperature profile is non-linear because of the penetration of infrared radiation into the low density fibrous insulation. Figure 4 shows the temperature profile within fibrous insulation, and with a radiant barrier placed 6 in. below the roof deck. Because the radiant barrier cuts off most of the infrared radiation, the temperature profile within the base fibrous insulation is linear. Figure 5 shows the comparison of heat flux (sample A) for base case with a radiant barrier placed 6 in. below the roof deck and with a radiant barrier placed above the ceiling studs. Figure 6 and 7 show the same comparison for samples B and C.

The reduction in heat flux for sample A when placed at the roof, as compared to base case, was 34 percent and there was 41 percent reduction when the same sample was placed on the ceiling studs. Table 1 shows the reduction of heat flux for all the samples when the radiant barrier was placed 6 in below the roof. Table 2 shows the reduction for the radiant barrier placed on the studs of the attic floor. In each case, the reduction of heat flux was greater when the radiant barrier was placed on the ceiling studs. Also, the reduction in heat flux was greater in the case of sample B because this laminate had both its sides coated with reflective material.

When the radiant barrier is placed on the studs, it not only reduces all the radiation exchange between the roof and the fibrous insulation, but also between the walls and fibrous insulation thereby increasing the resistance of the insulation system. Therefore, the reduction of heat flux is greater when the radiant barrier is placed on the attic floor studs.

CONCLUSIONS

The data indicates the placement of a radiant barrier on the attic studs (or on top of the insulation) yields highest reduction in heat transfer. Because it is easier and less costly to retrofit an existing home by placing the radiant barrier on the attic floor, this could help the penetration of radiant barriers in the retrofit market.

REFERENCES

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3. Katipamula, Srinivas: "Heta Transfer in Attics with a Small Scale Simulator," Master's Thesis, Department of Mechanical Engineering, Texas A&M University, College Station, Texas.

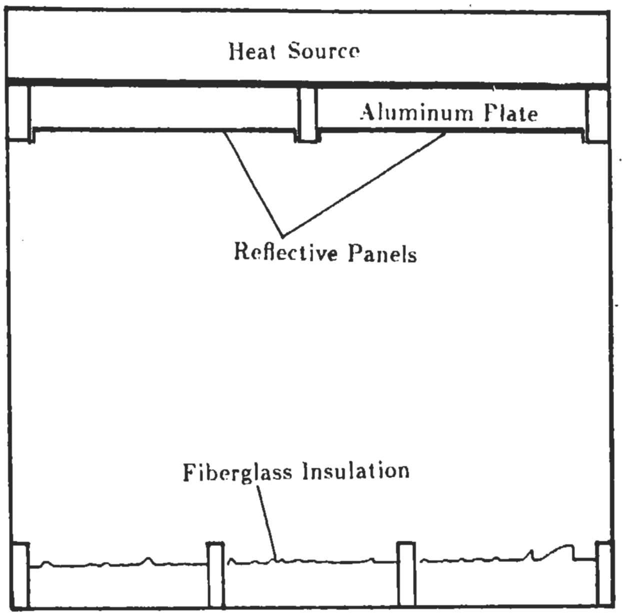

Figure 1 - Attic simulator showing the placement of radiant barrier 6 in below the roof deck.

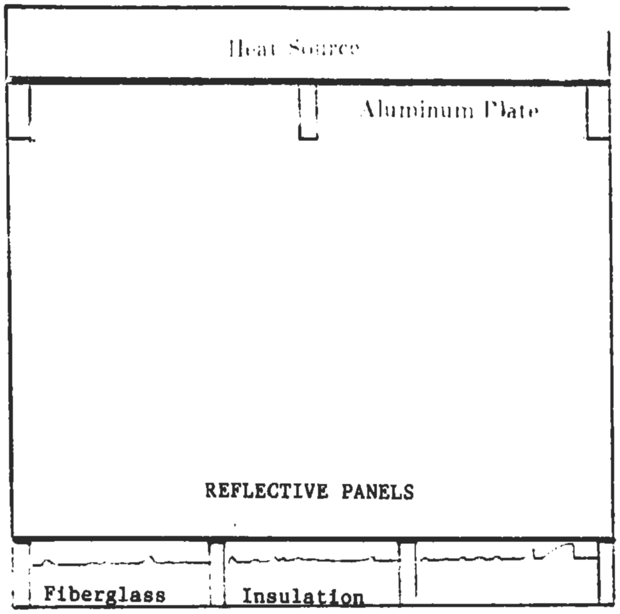

Figure 2 - Attic simulator showing the placement of radiant barrier on the studs of the floor.

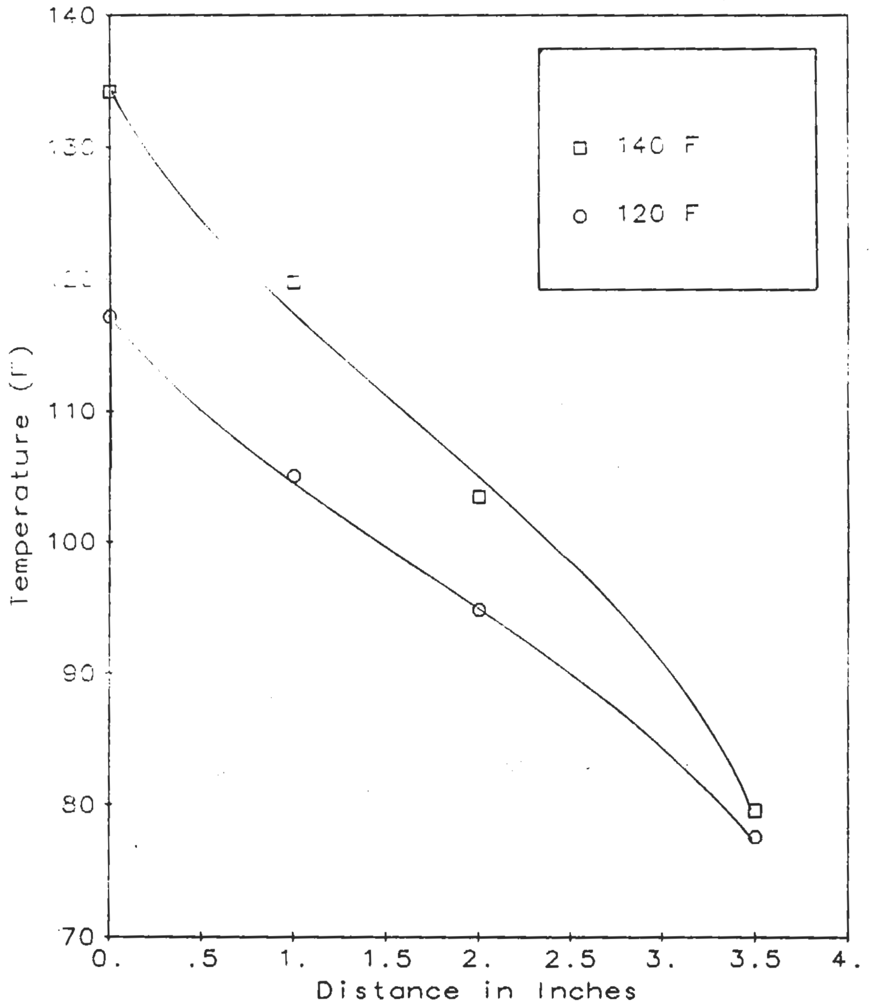

Figure 3 - Temperature profile in base fibrous insulation without radiation barrier.

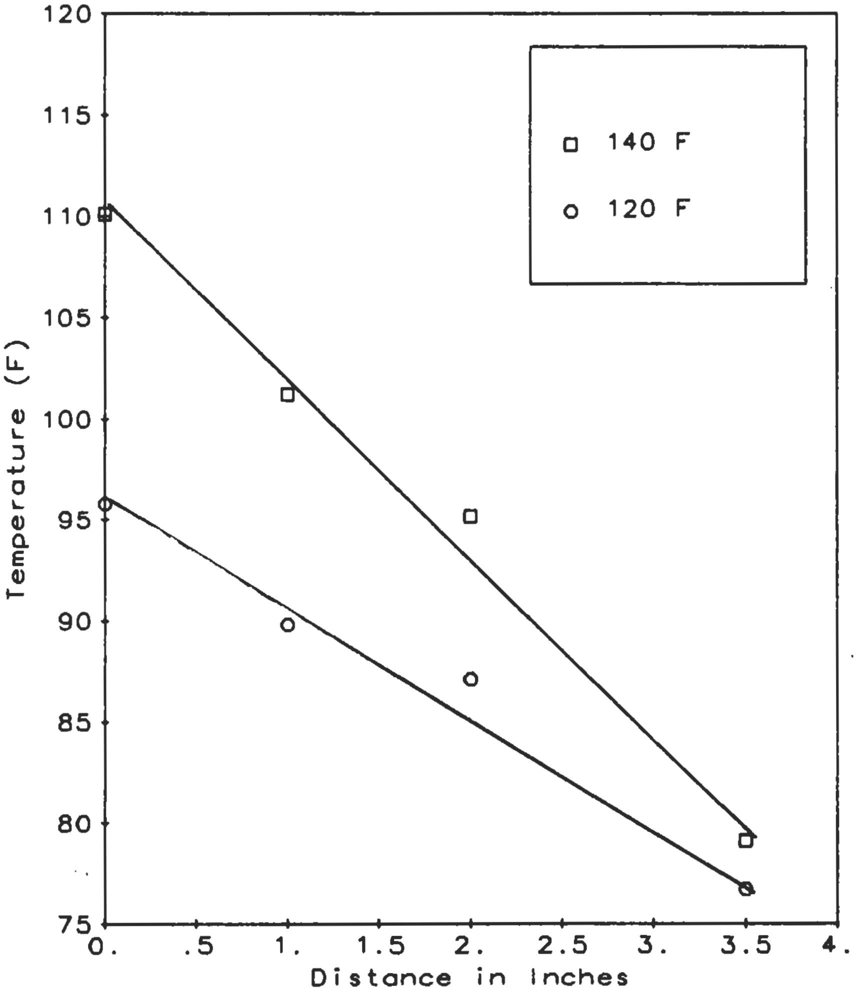

Figure 4 - Temperature profile in fibrous insulation with radiant.

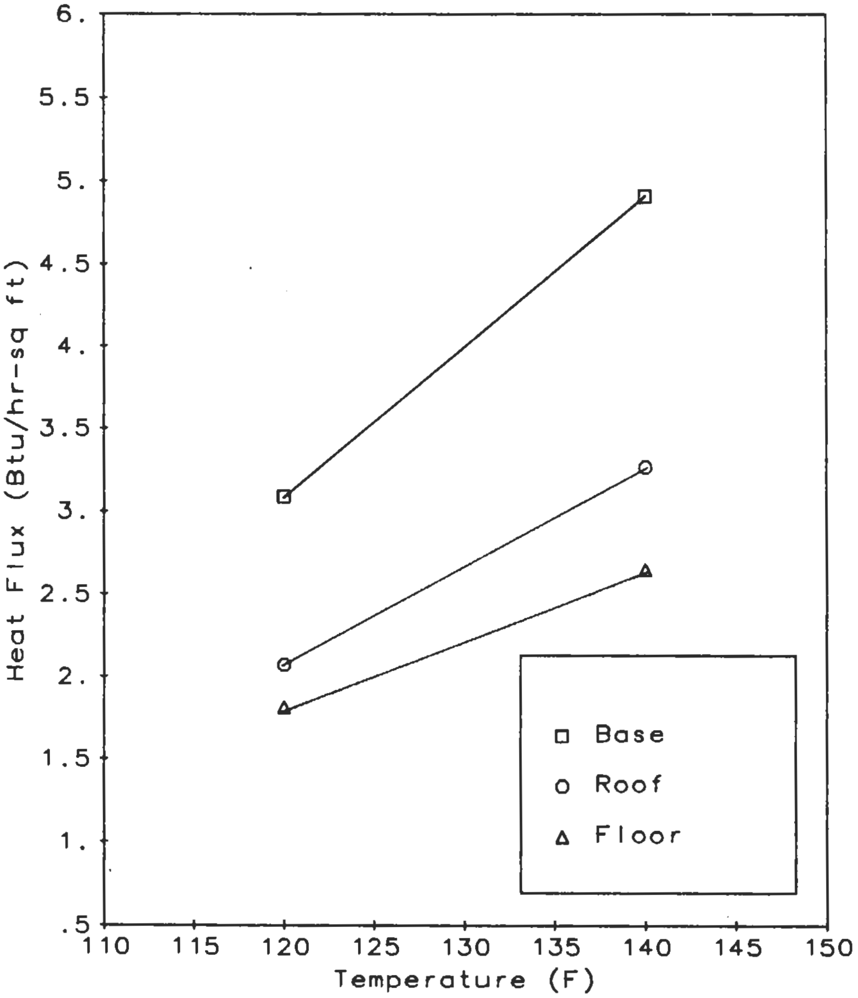

Figure 5 - Comparison of heat flux for base, with radiant barrier (sample A) 6 in below the roof deck and with radiant barrier on the studs of the floor.

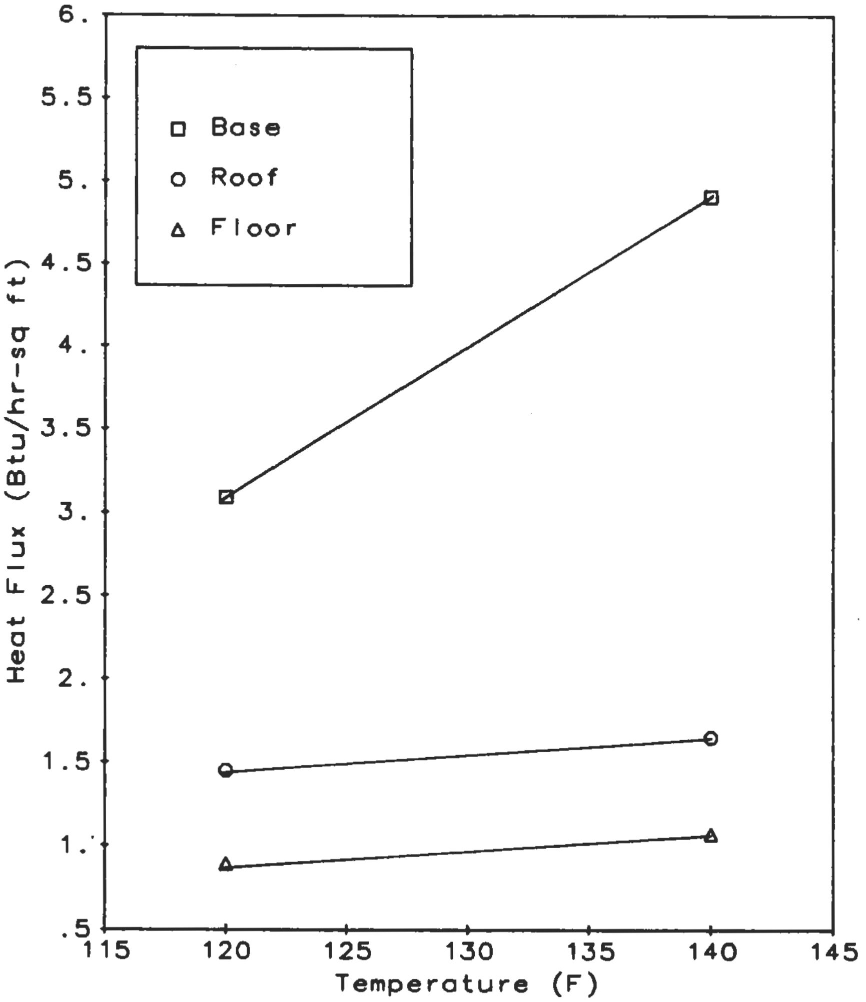

Figure 6 - Comparison of heat flux for base, with radiant barrier (sample B) 6 in below the roof deck and with radiant barrier on the studs of the floor.

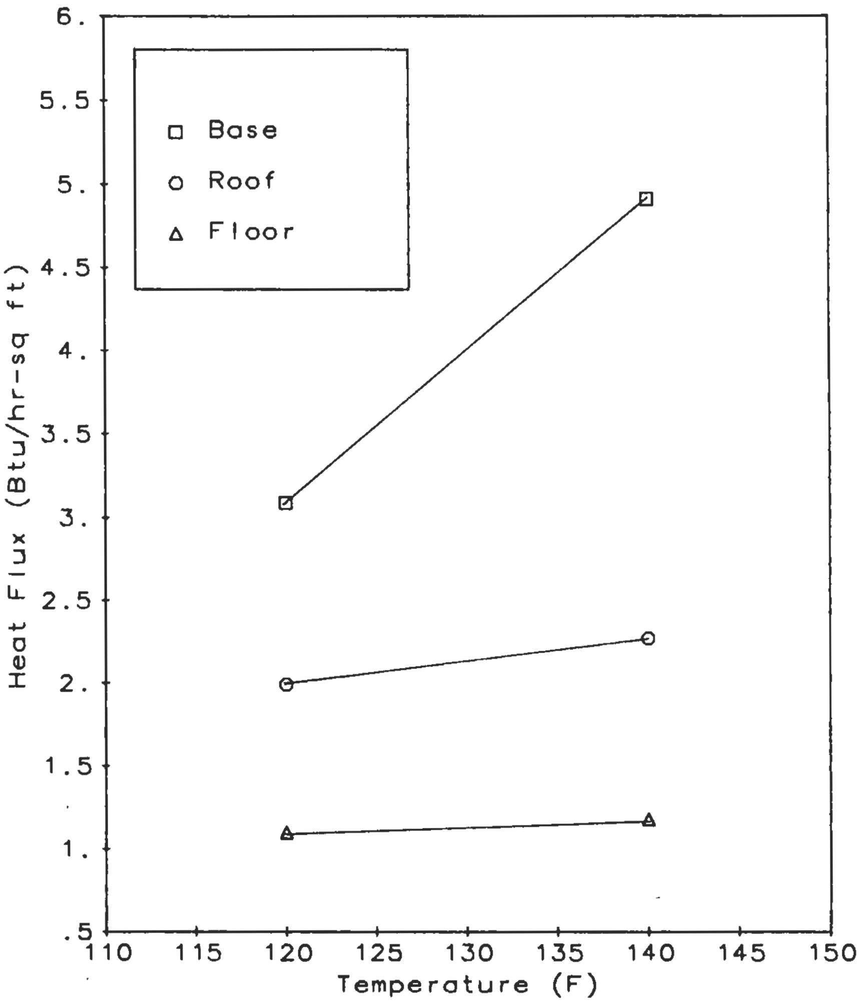

Figure 7 - Comparison of heat flux for base, with radiant barrier (sample C) 6 in below the roof deck and with radiant barrier on the studs of the floor.

Table 1. Comparison of heat flux for base insulation and with radiant barrier placed 6 inches below the roof deck.

Sample	Heat Flux (Btu/hr-sf)		% Reduction	
	120 F	140 F	120 F	140 F
BASE	3.09	4.91	-	-
A	2.07	3.27	33	33.4
B	1.45	1.65	53.1	66.4
C	1.99	2.27	35.6	53.8

Table 2. Comparison of heat flux for base insulation and with radiant barrier placed on the attic floor studs.

Sample	Heat Flux (Btu/hr-sf)		% Reduction	
	120 F	140 F	120 F	140 F
BASE	3.09	4.91	-	-
A	1.81	2.65	41.1	46.0
B	0.89	1.07	71.2	78.2
C	1.10	1.18	64.4	76.0
D	1.90	2.80	30.5	43.0