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| Back to Contents Page | *Home Energy* Index | About *Home Energy* |
| *Home Energy* Home Page | Back Issues of *Home Energy* |

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INSULATION

Convective Loss in Loose-Fill Attic Insulation

by David W. Conover

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Yes, Virginia, there is convective loss through loose-fill fiber-glass attic insulation, and researchers at Oak Ridge National Laboratory have quantified it. They have also tested remedial measures-additional layering or "covers"- that reduce the losses.

Commonly held assumptions about how insulation works are being refuted, and some long-standing mysteries solved by experiments at a new, large testing facility at Oak Ridge National Laboratory (ORNL). This article is a progress report of recent testing there of low- density, loose-fill fiber-glass attic insulation.

A Mystery Revealed

Research in 1982 by Kenneth Wilkes and James Rucker at Owens- Corning Fiberglas first measured heat transport in fiber-glass loose- fill attic insulation (see *HE*, Oct/Nov '84, p.27). They found heat loss was greater than that measured in standardized small-scale test methods (ASTM C 687), or as predicted in conduction and radiation modeling. Until their study, conventional wisdom held that heat flowed through fiber-glass insulation only by conduction and radiation, i.e., through entrapped static air and the glass filaments of the insulation, and via the scattering and emitting of rays of heat through the material.

The Wilkes-Rucker tests revealed that the loss of heat through low- density, loose-fill fiber-glass attic insulation increased significantly as the temperature differential grew between the heated space below (e.g., a living space) and the cold space above (e.g., an attic). However, their tests reaffirmed that under normal conditions, convective heat loss through fiber-glass batt insulation was negligible.

On the Case: The Large Scale Climate Simulator

By 1990, Wilkes was established at Oak Ridge National Laboratory and began to test loose-fill fiber-glass attic insulation to determine whether his earlier findings could be substantiated and better understood.

Testing was done in the new testing facility at Oak Ridge, the Large Scale Climate Simulator. The experimental facility at the DOE- sponsored Roof Research Center is composed of three chambers: a climate chamber, a metering chamber, and a guard chamber. Test panels or assemblies are placed on the roof test platform between the upper climate chamber and the lower metering and guard chambers (see Figure 1). Climate chamber temperatures can be controlled from Ð40 degrees F to 150 degrees F under either steady-state or dynamic conditions, and, when using infrared lamps, heat on the upper surface of the test panel can reach 200 degrees F, so the lab can simulate climates from extremely hot to extremely cold.

The metering and guard chambers can be independently heated or cooled to temperatures from 45 degrees F to 150 degrees F. Normally, both chambers are kept the same temperature to minimize heat flow in all directions but towards the test panel. Automatic controls for the metering and guard chambers can maintain operating temperatures to within + or - 0.2 degrees F. Similarly, the climate chamber's temperatures can be accurately controlled except when the infrared lights are in use. When the infrared lights are in use, the control is by a sensor of the top surface of the test specimen.

The 14 ftx16 ft attic module built for this study was constructed of conventional wood framing materials and sized to fit the Large Scale Climate Simulator testing facility (see Figure 2). Slope of the roof is 5 in 12. Rafters and ceiling joists of the module are 2x4s, 24 in. on center, and roofing is medium grey fiber-glass shingles over roofing felt on 1/2 in. plywood sheathing. The attic floor is 1/2 in. gypsum board. Ventilation enters through the eaves with exhausting at ridge vents. During testing, ventilation was controlled mechanically by blowers at the eaves. The researchers assumed that vapor retarders would play no role in the thermal tests and therefore they were not utilized.

Before insulation testing, the reseachers tested the uninsulated attic module to establish baseline measurements and to correlate these measurements with the earlier work by Wilkes and Rucker.

After establishing the baseline references for the module, they tested two specimens of loose-fill fiber-glass insulation. Both specimens came from the same manufacturer and the same batch, and the same certified local insulating contractor installed both specimens with the same blowing machine and operators. The target nominal R-value for both tests was R-19 (19 hr-ft2-degrees F/Btu). For this test, label thickness was 8.25 in. and a label density was 0.5 lbs/ft3. Actual thickness of the first specimen was 9-10 in. with an installed density of 0.45-0.50 lbs/ft3, and the installed thickness of specimen 2, was 9 1/2 in. with a density of 0.40 lbs/ft3.

To verify the accuracy of the attic module test measurements the researchers then substituted a 5 in.-thick panel of expanded polystyrene foam for the loose-fill fiber glass. Climate chamber temperatures of the Large Scale Climate Simulator ranged from 45 degrees F to -18 degrees F, with accuracy of 2.3% as compared to a simple straight-line path calculation of the known thermal conductivity of the foam.

R-Value Divided by Two

Tests of both specimens revealed that as the temperature differential increased, apparent conductive resistance (R-value) of the insulation decreased (see Figure 3). Thermal resistance at the greatest temperature differential was as much as half the estimated nominal thermal resistance of the insulation. For specimen 1, thermal resistance dropped to R-9.2, and for specimen 2, measured thermal resistance was as low as R-11.1 when the attic temperature was at -8 degrees F.

The investigations confirmed that natural convection occurred within the insulation itself. The reason is that air densities changed with the temperature differences. As warmer air from the heated space below reached the top of the insulation, the air cooled, became more dense and fell back into the insulation. As part of these observations, the researchers made infrared scans of the upper surface of the insulation. The heat patterns resembled the traditional hexagonal Benard cell pattern of natural convection occurring in fluids heated from below (see Figure 4).

Cellulose Holds its Own

Loose-fill cellulose, initial testing indicates, allows no such convective patterns to develop. Using a similar test procedure on the Attic Test Module, Wilkes and Childs recently completed the first phase of testing for the Cellulose Insulation Standards Enforcement Program, using a product, Forest Wool brand, selected by the standards group as an average or typical cellulose product. R-values increased as the temperature difference across the cellulose increased-the opposite effect that the fiber glass exhibited. The researchers concluded that the cellulose tested did not allow convective losses as the fiber glass had. Oak Ridge plans to test more samples and types of insulation in the future.

Pull Up the Covers The Oak Ridge researchers have also tested insulation covers to measure their effect on the convective loss of fiber glass. A sampling of experiments follows:

Spunbonded polyolefin radiant barrier film was laid over the top of the insulation, low-emittance side facing up. The effect was to increase the thermal resistance an average of 27%-with the percentage increasing as temperature differential grew. The radiant barrier reduced heat flux approximately 20%. The effect of the radiant barrier under winter conditions appears to block the flow of air from the attic space into the insulation, but did not eliminate convective transport within the loose-fill insulation itself.

A second cover of **perforated polyethylene film** over the loose-fill insulation increased thermal resistance only 5-10%, and lowered heat flow 4- 9%. It was much less effective than the radiant barrier in blocking convective air exchange because of the perforations.

Another cover experiment tested a patented product developed by Attic Seal, Inc., consisting of 'pillows' made of 1-in. (0.8 lb/ft3) **fiber-glass blankets sandwiched between two layers of perforated polyethylene film**. The pillows increased the thermal resistance by as much as 104%, and decreased the heat flow by approximately 48%. In this experiment, minor compression of the original fiber- glass occurred.

One of the final experiments included the additional layer of a 1-in. unfaced fiber-glass insulation 'blanket' (density of 1 lb/ft3) over the loose-fill insulation. Thermal resistance increased 12 to 16%, with a heat flow of 10-13% lower than the results with the pillow in place. The blanket was actually or slightly more effective than the pillow. This is believed to be due to the blanket having a slightly larger thermal resistance and/or air flow resistance due to its higher density. (see Figure 5.)

Conclusion

In all cases with the convective cover experiments, thermal performance of the loose-fill insulation improved. Open questions remain about vapor entrapment, the additional costs of the covers, or the possibility of other remedies to unwanted convective flow. When researchers are able to answer these and similar questions, manufacturers will probably develop more "convection retarder" products. These will be useful for retrofitting fiber-glass insulation; but for new installations, cellulose alone, while less expensive, will out perform fiber-glass loose fill, especially in cold climates. Of course, only two types of insulation have been tested before and it is probably too soon to jump to conclusions.

New research facilities such as the Large Scale Climate Simulator and the cooperation and support from insulation material manufacturers will enable researchers to analyze the characteristics and properties of insulating materials in greater detail and with much more accuracy than ever before.

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Acknowledgements

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Figure 1

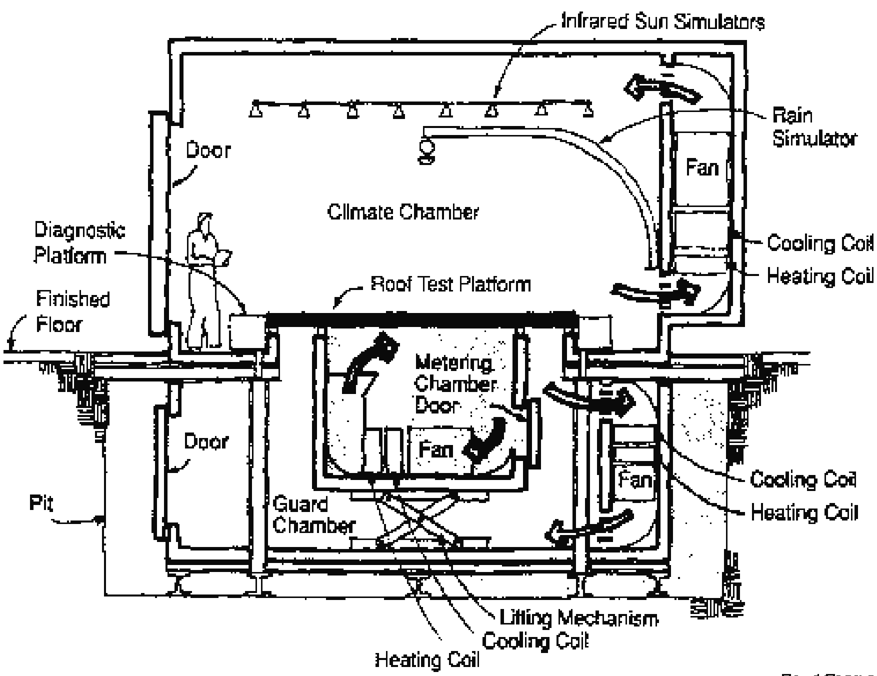

Figure 1. The Large Scale Climate Simulator without attic module.

Figure 2

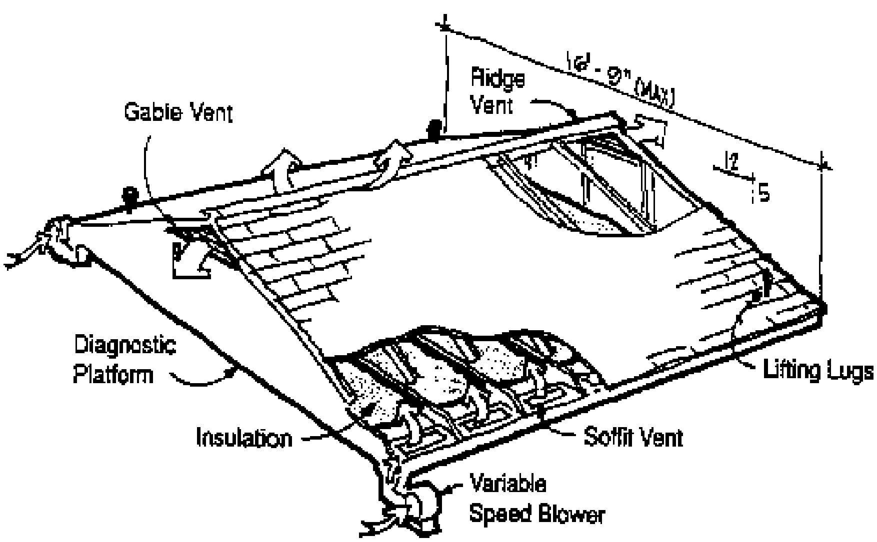

Figure 2. The Attic Test Module.This module was placed on the roof test platform of the Large Scale Climate Simulator.

Figure 3

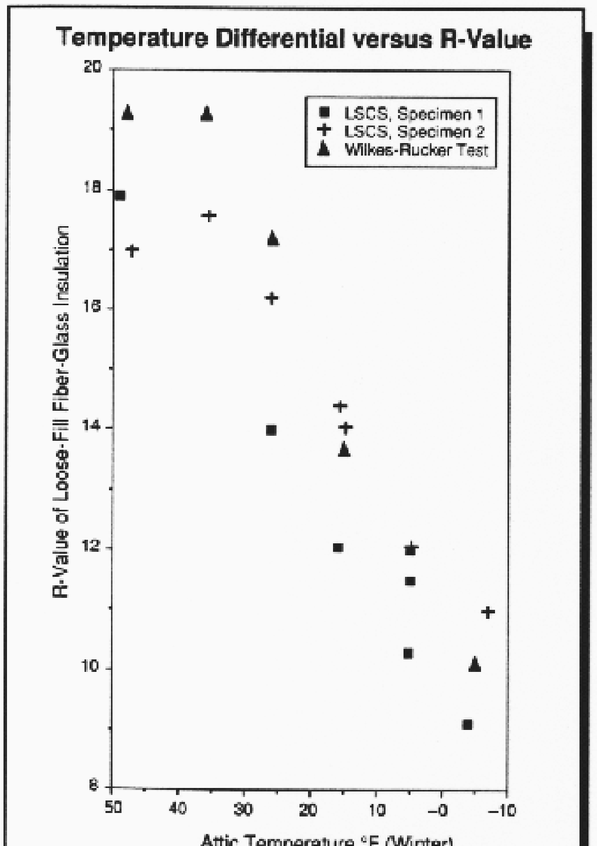

Figure 3. Since the metering chamber's temperature was kept constant, attic temperature correlates with temperature differential.

Figure 4

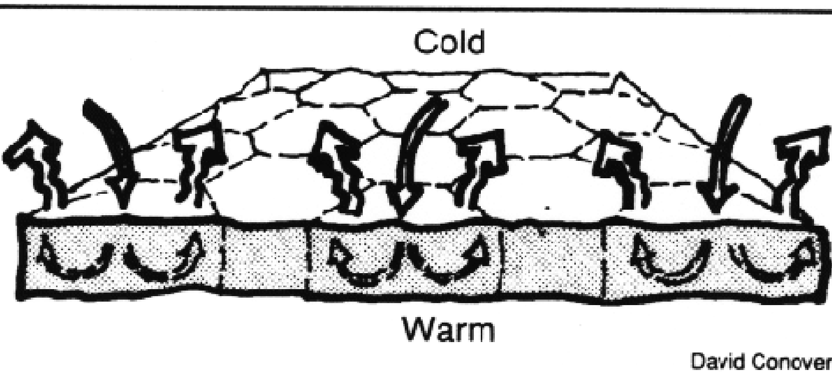

Figure 4. The Bernard cell pattern for a fluid layer heated from below. Scientists have long recognized this honeycomb pattern's role in natural formation of convection loops within porous media.

Figure 5

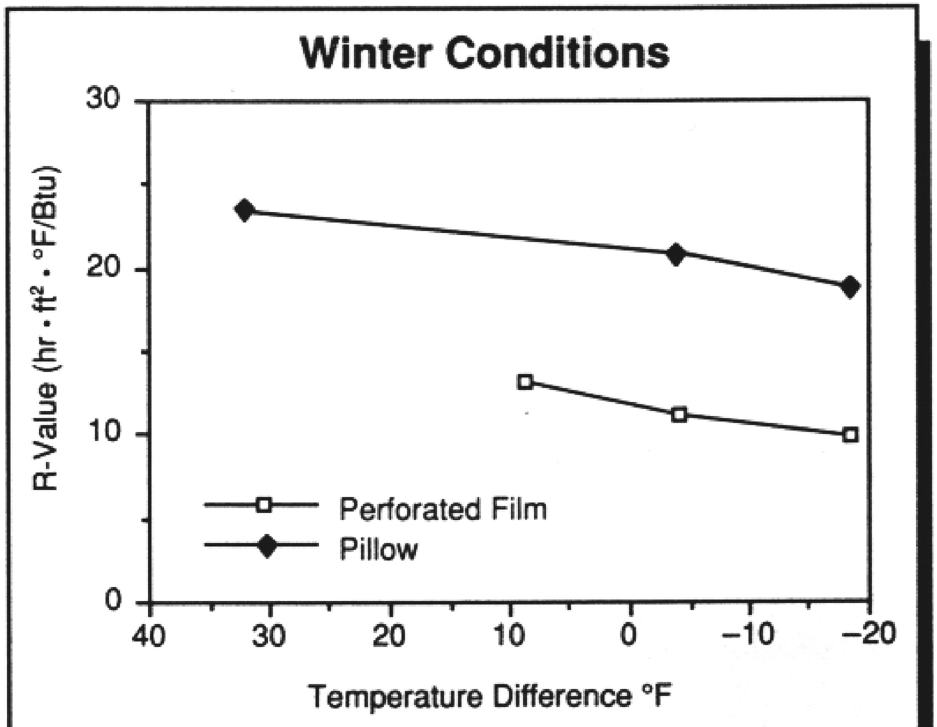

Figure 5.

| Back to Contents Page | *Home Energy* Index | About *Home Energy* |
| *Home Energy* Home Page | Back Issues of *Home Energy* |