#5382

On The Real Cost of Electricity Versus Gas

Dear Mr. Nisson:

I am responding to an article that appeared in the Products section of the April 1991 issue of ***Energy Design Update***, entitled Dual-Fuel/Electric Residential Heat/Cool.

The efficiency comparisons that are cited in the article ignore the conversion losses associated with the combustion of fossil fuel to create electricity, transmission of the electricity, and conversion of the electricity back to heat. If these are considered, only very inefficient gas furnaces (which will be unavailable after 1992 as a result of the National Appliance Energy Conservation Act) use more source btu's than the electric heat pump/gas furnace backup heating system.

In addition, many residential customers are concerned about the environment. Congress has been sufficiently motivated by these concerns to implement the Clean Air Act Amendments of 1990, which may raise the cost of electricity in the upcoming years over the life of the heat pump system more significantly than would otherwise occur. This also changes the economics of the decision to install such a device.

The above points tend to argue for the installation of natural gas appliances. They provide heat more efficiently, economically, and cleanly. This is the information that your readers deserve to know.

Sincerely,

Adrian P. Chapman

Editor's reply

In order to keep ***EDU*** analyses consistent, we consider the cost of delivered energy to the homeowner and the efficiency of use on site only. We don't consider conversion losses and environmental externalities, partly because we don't know how to calculate them consistently.

For example, considering that electricity can be generated using either fossil fuels, hydropower, or nuclear energy, would we assign a different "real" cost for each fuel source? If so, how much?

In principle, we agree with your approach, but we haven't yet seen reliable tools for accomplishing it.

Thanks for your letter.

NN

RESEARCH AND IDEAS

Loose-Fill Fiberglass Versus Cellulose in Cold Attics

Tests performed at the University of Illinois and Oak Ridge National Laboratory show that loose-fill fiberglass suffers performance degradation under cold conditions, but that loose-fill cellulose, if installed at relatively high density, is apparently immune to the problem.

The Insul-Safe III tests — Trouble below 30°F

Certainteed Corporation is sponsoring a comprehensive research project at the University of Illinois Building Research Council to study the performance of fiberglass insulation under actual installed conditions.

Illinois researchers built a test building with eight separate test cells consisting of various combinations of vented, non-vented, flat, and vaulted ceilings. Each test cell is equipped with heat flux sensors that can measure the effective in-service R-value of the attic insulation system.

This past January, while monitoring the performance of four test cells, Project Leader Bill Rose observed that one attic, insulated with 14 inches (R-34) of Insul-Safe III loose-fill fiberglass, showed a noticeable loss of effective R-value at cold attic temperatures. During that one-month period, the "indoor" temperature in the space beneath the attic was maintained at 70°F, while the attic was allowed to track outdoor temperature, which varied from 0°F to 38°F.

Heat flow through the attic insulation performed as expected until the temperature in the attic dropped to about 30°F. Below that point, the heat loss increased geometrically with temperature difference, indicating a loss of effective R-value. The drop in measured R-value with temperature is plotted in the graph in Figure 1. At very cold temperature (10°F), the effective R-value dropped over 50%.

The apparent cause of the performance degradation is air convection into and within the insulation.

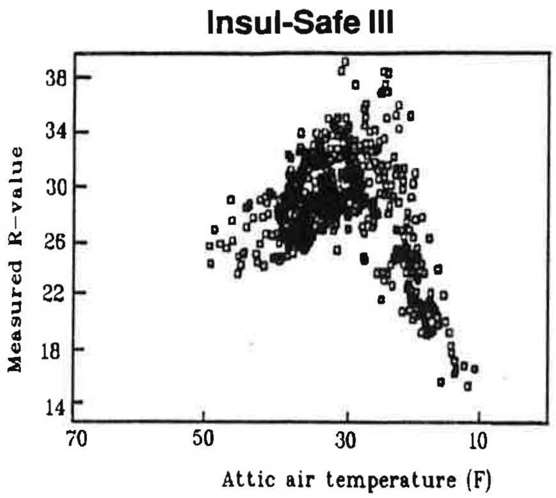

Figure 1 — Measured R-value of nominal R-34 loose-fill fiberglass attic insulation at various attic air temperatures. Tests were performed at the University of Illinois.

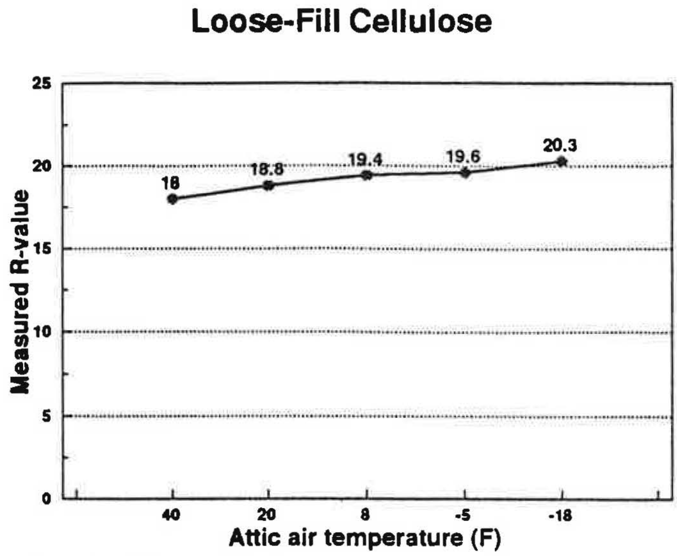

Figure 2 — Measured R-value versus temperature of nominal R-19 loose-fill cellulose installed in the Oak Ridge Large Scale Climatic Simulator.

Similar results for Advanced Thermacube Plus

The results observed at the University of Illinois for Insul-Safe III are very similar to those obtained at Oak Ridge National Laboratory for Owens Corning's Advanced Thermacube Plus (see ***EDU***, February and March 1991). The Oak Ridge tests suggest that convection begins to occur at about 50°F mean insulation temperature; the Illinois tests showed performance degradation at about the same point. Both experiments show about 40%-50% loss of R-value at extremely cold temperatures.

No problem with cellulose

After the initial tests on fiberglass were released, the Cellulose Industry Standards Enforcement Program (CISEP) hired Oak Ridge to run a series of tests on loose-fill cellulose in the Large Scale Climate Simulator (LSCS).

To provide a direct comparison with fiberglass, cellulose was installed in the LSCS at a thickness sufficient to obtain an R- value of R-19 (same as the fiberglass tests). It is important to note that the density of the installed cellulose ranged from 2.3 to 2.4 pounds per cubic foot — about 15%-20% above the bag label density. The "inside" temperature beneath the test attic was maintained at 70°F, while the "outdoor" temperature above the insulation was varied from 40°F down to -18°F.

The results showed no decline in R-value at cold temperatures (Figure 2). In fact, the measured R-value of the insulation system actually *increased* slightly from R-18 at 40°F to R-20.3 at -18°F (Figure 2).

[The observed increase in R-value of cellulose at colder temperatures is expected. In the absence of air circulation within the material, the R-value of most insulation increases as the temperature decreases. The reason is because radiant heat transfer within the insulation decreases with mean temperature. Tests on fiberglass *batts* show similar increase in R-value with declining temperature.]

Before switching away from fiberglass attic insulation...

Although these test results clearly make sensational promotional copy ("Tests at national lab show 50% loss of R-value with fiberglass and *zero* loss with cellulose"), we do not yet know exactly how significant they are. The bottom line factor is obviously the impact on seasonal energy costs.

The observed problem with fiberglass occurred only when the attic air temperature dropped below about 30°F, and it didn't cause excessive loss in R-value (30% or more) until the attic air temperature dropped to around 0°F. For mild climatic regions where the attic temperature drops to 0°F only a few hours per year, these findings are probably irrelevant. On the other hand, in Edmonton, Alberta, or Fairbanks, Alaska, where the average outdoor air temperature is below 0°F for several months each year, low-density, loose-fill fiberglass may be unsuitable unless covered (see the following article on convection blankets). Between those extremes lies an area of uncertainty. Is there a problem with low-density, loose-fill fiberglass attic insulation in Minnesota or Vermont? No good answer yet.

The Illinois tests on Insul-Safe III found that the *average* increase in heat loss through the attic over the month of January due to convection was about 25%. Assuming that the attic accounts for about 20% of the total heat loss of an average house, that increase translates into about a 5% increase in overall fuel costs for the month of January.

Oak Ridge scientists are now running bin weather analyses to calculate the actual impact of the observed degradation on fuel consumption in various climates. CertainTeed Corporation is running full-year monitoring of test attics at the University of Illinois to measure the actual impact in that climate.

Batts not a problem

To avoid misunderstanding, it is worth noting that tests on batts at the University of Illinois showed no evidence of convection or loss of R-value, even at low temperature.

R-values not enough; What's your Rayleigh number?

These test results point out that thermal resistance (R-value) alone may not always adequately describe the in-service performance of insulation. Resistance to air circulation is also important.

The ability of an insulation *system* to resist convection depends on several factors, including insulation thickness, air flow permeability, and temperature difference across the insulation, as well as R-value per inch. These factors can all be combined to calculate a physical property known as the "Rayleigh number." The higher the Rayleigh number of an insulation system, the more likely that convection will occur.

Because cellulose is more dense, less permeable to airflow, and has a higher R-value per inch than fiberglass, a cellulose insulation *system* will usually have a lower Rayleigh number, and thus be less prone to air convection, than a loose-fill fiberglass installation of the same R-value.

Concern over fiberglass "fluffing"

The University of Illinois and Oak Ridge test results create additional concern over the practice of fiberglass "fluffing" which has been commonly observed in some regions of the US. Fluffing produces lower installed density. Lower density means a higher Rayleigh number and greater likelihood of convection in the insulation.

Laboratory R-Values and the Rest of the Story

When seeing results such as those presented in this article, one might ask why similar results don't turn up in small-scale laboratory tests, which are used to assign "rated" R-values to various insulation products.

The most common test used to rate loose-fill insulation is ASTM C518 (heat flow meter), in which a sample of insulation is sandwiched between two metal plates — one heated to 95°F and the other cooled to 55°F. Under those conditions, convection is much less likely to occur than in a full-scale attic test for two reasons: first because the cold side of the insulation is in contact with a metal plate rather than free air, and second because the temperature difference across the insulation is not extreme.

Tested by the C518 method, the R-value of 12 inches of loose-fill fiberglass may indeed be R-30. But tested under conditions more similar to those in a very cold attic, the R-value of 12 inches of loose-fill fiberglass may only be R-15.

Some researchers are calling for new test methods and reporting conventions for insulation to better represent actual performance in real-life situations (see News story, page 1).

This concern probably does not extend to cellulose, which is much more difficult to fluff. The Oak Ridge tests included measurements of cellulose at two different densities. In both cases, there was no indication of convection within the insulation.

Concern over new "lightweight" cellulose products?

A couple of manufacturers now produce and sell lightweight cellulose with installed density around 1.6 to 1.7 pounds per cubic foot. Theoretically, those products are more prone to air convection than the product tested at Oak Ridge, which had a density of about 2.4 pounds per cubic foot. At this time there are no test data and no reliable models to predict under what conditions convection might occur in these lightweight cellulose products.

For more information, contact Ken Wilkes, Oak Ridge National Laboratory, Box 2008, Building 4508, Oak Ridge, TN 37831-6092; (615) 574-5931, or William Rose, Building Research Council, University of Illinois at Urbana-Champaign, One East Saint Mary's Road, Champaign, IL 61820; (217) 333-1801.

Wilkes' and Rose's reports are published in the proceedings of the ASTM symposium, (*ASTM STP 1116*, Graves/Wysocki, editors), available from ASTM, 1916 Race St., Philadelphia, PA 19103; (215) 299-5400.♦