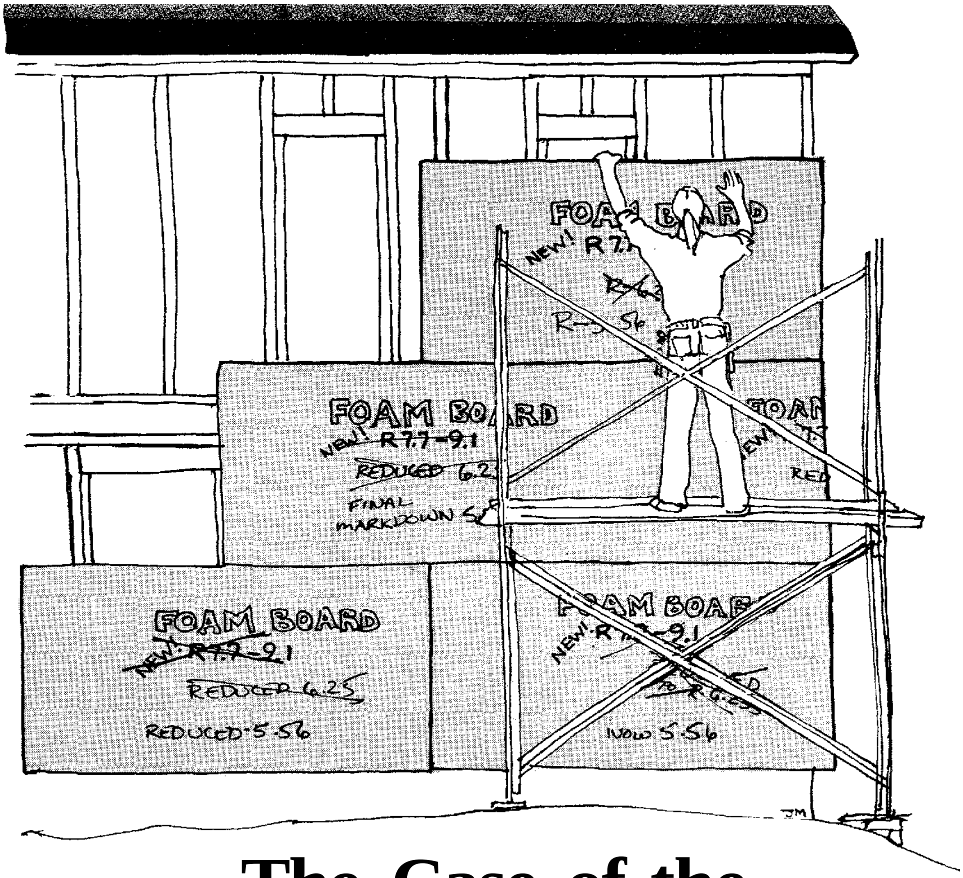

The Case of the Disappearing R-Value

The latest word on urethane and polyisocyanurate: The older they get, the worse they look

by Paul Hanke

Most engineers, architects and builders probably know that rigid foam insulation boards (such as polyurethane and polyisocyanurate) have relatively high R-values per inch of thickness at the time of manufacture, but that these values decline as the products age. For this reason, the products have been marketed on the basis of the so-called "aged R-value, " which is determined by standard testing procedures.

But now these aged R-values are coming under fire by the Midwest Roofing Contractors Association (MRCA). Citing MRCA field tests of urethane and polyisocyanurate materials, a group of panelists at the association's convention in November called for substantial reductions in the previously used R-values.

Background

Rigid foam insulation boards are manufactured by a foaming process that gives them a cellular structure. For urethane and polyisocyanurate, the "foaming agent" is Freon, which has a higher resistance to heat transfer than air, resulting in a higher R-value per inch compared to competing products. R-values at time of manufacture may range from 7.7 to 9.1.

However, from the time the material is produced, the Freon gradually is lost by diffusion—that is, it's replaced by gas (primarily nitrogen and oxygen) from the air. Just how long this process continues and how low the R-value falls before reaching equilibrium is the subject of the present debate.

The phenomenon of aged R-values has been recognized for some time. In 1981, the Rigid Insulation Committee of the Thermal Insulation Manufacturers Association (RIC/TIMA) issued a standard (Bulletin 281-1) to deal with what it called "thermal drift." The bulletin, based on ASTM testing procedures, calls for storing samples at 73.4 F and a relative humidity of 50 percent for 180 days, and then testing the specimens to determine their "aged" R-value.

As a result of this test, which is designed to approximate the equilibrium R-value that might be obtained in the field, RIC/TIMA recommended that an aged R-value of 6.25 be used for urethane and isocyanurate products. TIMA members subsequently used this figure to promote their products, and people in the building professions used it as a point of reference for long-term performance. Now, it is this figure that is being called into question by the MRCA.

The Problem

According to the MRCA, its own tests on field samples indicate that the R-values of certain polyurethane and polyisocyanurate foam boards can "continue to deteriorate" to the point that they "approach the range" of R-5—which is about the same value as cheaper polystyrene products. As a result of its investigations, the MRCA has recommended that an interim aged R-value of 5.56 per inch be used until a new industry standard can be established based on field tests by "an independent national laboratory."

MRCA based its recommendation on an analysis of field samples performed for the association by Dynatech Laboratories of Cambridge, Mass. According to a source at MRCA, the association has no quarrel with the RIC/TIMA test, which the MRCA believes gives accurate results *at the time of testing,* but the MRCA maintains that these results are not necessarily related to what happens under field conditions.

What *Does* Happen?

Why does the foam age and experience lowered R-values in the first place? According to Dr. Leon Glicksman, a mechanical engineer at the Massachusetts Institute of Technology who has researched the phenomenon, the major causes are moisture and gas diffusion.

Glicksman says that all urethane and isocyanurate foams have a "closed" cell structure at the time of manufacture, which greatly restricts the passage of Freon from the cells to the surface. But gas exchange does occur slowly by diffusion through the cell walls, which gradually causes Freon to be replaced by other gases until equilibrium is reached. (This process is driven by the higher pressure of the Freon compared to that of the air.) According to Glicksman, equilibrium should occur within one year for one-inch samples.

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The rate of diffusion is based on several factors, including the percentage of "open" (or broken) cells, the percentage of materials in the cell walls, and thickness of the material.

Broken cells enhance diffusion for obvious reasons: they permit gas to escape much more easily. Surface cracks also contribute to the problem, of course—and according to Dave McElroy of the Oak Ridge National Laboratory in Tennessee, cracks through the skin of the boards can be quite common.

Similarly, it takes longer for escaping (or incoming) gases to travel through thicker samples, so they will age more slowly, all other things being equal. In fact, the rate of diffusion is based on the square of the thickness; therefore, a two-inch sample takes four times as long to reach equilibrium as a one-inch sample.

At the same time, a high percentage of polymer material in the cell walls should help to slow diffusion. As currently manufactured, urethane and related products tend to have about 20 percent of their material in the cell walls, with the balance in connecting "struts," according to Glicksman.

What About Foil?

In theory, the foil facing on many such products should reduce diffusion, but Glicksman's research indicates that this is not necessarily the case.

First, the aluminum can be too thin, allowing pinholes to penetrate the surface. In addition, the foil may not adhere well to the surface of the foam. Voids in the adhesive allow gas to move laterally across the surface, aiding the diffusion process that the foil is meant to resist. On the positive side, however, Glicksman says that MIT's research on foil facings could "improve the product or even eliminate the problem" in the future.

Asked whether it would help to apply foil to the edges of unsealed foam boards, Glicksman points out that the *edge* is not a particular problem, as the gas must travel quite a distance to escape at the perimeter. (Dave McElroy at Oak Ridge expands on this by noting that gas would have to diffuse only half an inch to reach the surface of a one-inch board, but it would have to travel as much as a foot to get to the edge.)

Can the Freon ever be completely replaced by air? According to Glicksman, some studies indicate that there may be a "reservoir" of Freon in the solid material that acts to replace the Freon lost by diffusion, but other studies indicate the opposite.

What About Phenolics?

What about the new phenolic foam boards, which also are made with Freon? Are they also subject to "aging," and if so, to what degree?

Early research seemed to indicate that phenolics had a greater percentage of material in their cell walls than urethane, but Glicksman now thinks the two materials may be about the same in this respect. He notes that the chemistry of the two plastics is different, but he could not comment on the consequences of this difference for thermal resistance.

However, Glicksman does say that *"very* preliminary" findings indicate that phenolics age slower than urethane relatives, so they may be "slightly superior" in the long run. He speculates that it may take four to 15 years for phenolics to reach the equilibrium point, adding, "We just don't know yet."

A footnote to the MRCA position paper supporting its recommendation explains that because phenolics have not been in field service long enough, they were not included in its study. But a representative of the Koppers Corp. recently told me that the company has in-house data on five-year-old samples that indicate no decline in R-value. He attributed the difference between his company's claim of R-8.3 per inch and lower R-values reported by other manufacturers to his firm's "patented closed cell structure." (Dynatech reportedly is doing research on this material as well.)

At the same time, Glicksman notes that builders in the field have found phenolic boards to be brittle and crumbly at the edges, which is another factor to consider—along with cost, availability, fire resistance and R-value—when evaluating competing products.

Evaluating the Tests

As mentioned earlier, MRCA believes that the RIC/TIMA test is reliable *at the time of testing*, but it says that the R-values of urethane and isocyanurate may *continue* to decline over time under field conditions.

The standard test does in fact produce aging. But Glicksman believes that the test may "not be adequate for thicker samples."

According to RIC/TIMA materials, the association is doing *in-place* testing on several samples with fiberglass and perlite control units. This differs from the MRCA research, which removed samples for analysis, and implies disagreement over more than R-values alone.

Finally, Dave McElroy points out that there is now "a big fuss brewing over how you actually test thermal conductivity." This was to have been discussed at last month's annual ASTM meeting and may add further fuel to the debate.

What's the Point?

What difference does all this make to builders, specifiers and manufacturers?

The difference between the RIC/TIMA figure of R-6.25 for six-month aged material and the MRCA interim recommendation of R-5.56 is 11 percent. Over the years, this could make a noticeable difference in the energy consumption of buildings insulated with these products—and apparently we still don't know whether R-5.56 actually is the equilibrium value.

Even if these products *do* stop deteriorating at R-5.56, this value is very close to the R-value of less expensive polystyrene board. And if the R-values are that close, why would anyone pay a premium for urethane?

Finally, some liability claims have been awarded involving insulation products rated higher than their actual R-values.

In one case, the Wood County Circuit Court in Wisconsin awarded $42,000 to the Wisconsin Rapids School District for "excess energy expense—due to reduced thermal efficiency" of the urethane insulation board installed on one of its buildings. The manufacturer had claimed an R-value of 10, but samples removed from the building and tested by Dynatech showed an average R-value of only 7.32.

The amount of the award was based on an engineer's calculations of the excess energy that escaped over four years through the building's 193,000-square-foot roof. The insulation manufacturer is appealing the decision.

In another case, the Federal Trade Commission (FTC) filed a complaint in 1983 against a manufacturer of cellulose insulation, charging the manufacturer with violating the FTC's "R-value Rule," which requires the disclosure of coverage-area values. A $42,500 civil judgment was awarded. The case created controversy over acceptable testing methods for the "settled density" of cellulose products.

Given such precedents, specifiers and sellers of thermal insulation products must keep an eye on the performance ratings of such products to avoid potential claims. If nothing else, it would be prudent to err on the conservative side and try to cover your fanny in this age of litigation. ■