R-value Fairy Tale: The Myth of Insulation Values

David B. South November 02, 2010, 3:10 p.m. **The President's Sphere**

The entire book, *Urethane Foam: Magic Material - And the Best Kept Insulation Secret*, can be purchased as an ebook by clicking here.

2.1 R-value

The R-value is a modern fairy tale. It's a fairy tale that has been so touted to the American consumer that it now has a chiseled in-stone status. But the saddest part of this fairy tale is that the R-value by itself is almost a worthless number.

It is impossible to define an insulation with a single number. To do so, we must know more. So why do we allow the R-value fairy tale to perpetuate? I don't know. I don't know if anybody knows. What we do know is that the R-value fairy tale obviously favors fiber insulation.

Consider the R-value of an insulation after it has been submersed in water or as a 20 mile-per-hour wind blows through it. In either of these scenarios, the R-value of fiber insulations goes to zero. But those same conditions barely affect solid insulations. That's why I believe that R-value numbers are misleading, meaningless numbers unless we know other characteristics.

In all probability, no one would ever buy a piece of property knowing only one of its dimensions. Suppose someone offered a property for $10,000 and told you it was a seven. You would instantly wonder what that number referred to: Seven acres? Seven square feet? Seven miles square? What? You would also want to know the property's location: In a swamp? On a mountain? In downtown Dallas? In other words, one number cannot accurately describe anything, and that includes the value of an insulation.

Nevertheless we have Code bodies mandating R-values of 20s or 30s or 40s. But a fiber insulation with an R-value of 25 placed in an improperly sealed house will allow wind to blow through it as if there were no insulation. Maybe the R-value is accurate when the material is lab tested. But a lab environment may not even remotely duplicate conditions in the real world.

Consequently, we must start asking for some additional dimensions to our insulation. We need to know its resistance to air penetration, to free water, and to vapor drive. We must begin demanding the R-value of an insulating material after it is subjected to real world conditions.

As it is currently used, an R-value is a number that is supposed to indicate a material's ability to resist heat loss. It is derived by taking the k-value of a product and dividing it into the number one. The k-value is the actual measurement of heat transferred through a specific material.

2.2 Test To Determine an R-value

The test used to produce the k-value is an ASTM (American Society for Testing and Materials) test. This ASTM test was designed by a committee to give us measurement values that — they hoped — would be meaningful. Unfortunately, the test was designed with a flaw or bias. Because of the way it's designed, the test favors fiber insulations: fiberglass, rock wool and cellulose fiber. Very little input went into the test for solid insulations, such as foam glass, cork, expanded polystyrene or urethane foam.

Nor does the test account for air movement (wind) or any amount of moisture (water vapor). In other words, the test used to create the R-value is a test in non-real-world conditions. For instance, fiberglass is generally assigned an R-value of approximately 3.5. It will only achieve that R-value if tested in an absolute zero wind and zero moisture environment. Zero wind and zero moisture are not real-world. Our houses leak air, all our buildings leak air, and they often leak water. Water vapor from the atmosphere, showers, cooking, breathing, etc. constantly moves back and forth through walls and ceilings. If an attic is not properly ventilated, water vapor from inside a house will very quickly semi-saturate the insulation above the ceilings. Even small amounts of moisture will cause a dramatic drop in a fiber insulation's R-value — as much as 50 percent or more.

2.3 Vapor Barriers

We are told, with very good reason, that insulation should have a vapor barrier on the warm side. Which is the warm side of the wall of a house? Obviously, it changes from summer to winter — even from day to night.

In a wintry 20 F below zero environment, the inside of an occupied house will certainly be the warm side. But during sunshiny summer months, the outside will be the warm side.

Sometimes a novice owner or builder will put vapor barriers on both sides of the insulation. Vapor barriers so placed generally prove to be disastrous. It seems the vapor barriers stop most of the moisture but not all. Consequently, small amounts of moisture move into the fiber insulation, between the two vapor barriers and become trapped. The moisture accumulates as the temperature swings back and forth. This accumulation can become a huge problem. It can eventually total buckets of water that saturate the fiberglass. We have re-insulated a number of potato storages that originally were insulated with fiberglass and a vapor barrier on both sides. Fiber insulation needs ventilation on one side; therefore, the vapor barrier should go on the side where it will do the most good.

Most people know that air penetrates the walls of a house. In fact, when the wind blows across some homes, its tenants can feel it. But what most people, including many engineers, do not realize is that there are very serious convection currents that occur within fiber insulations (Figure 2.2). These convection currents rotate vast amounts of air, but they are not fast enough to feel or even measure, with any but the most sensitive instruments. Nevertheless, the air constantly carries heat from the underside of the fiber pile to the top side, letting it escape. If we seal off the air movement, we generally seal in water vapor. That additional water often condenses and can become a moisture-source that rots the structure. The water, as a vapor or condensation, seriously decreases an insulation value — the R-value. The only way to deal with a fiber insulation is to ventilate. But ventilating means moving air that also decreases the R-value.

2.4 Air Penetration

The filter medium for most furnace filters is fiberglass — the same spun fiberglass used as insulation. Fiberglass is used for an air filter because it has less impedance to the air flow, and it is cheap. In other words, air flows through a furnace filter very readily. All well and good for a furnace filter — but can that same material effectively insulate a structure? Can you imagine insulating a house by stuffing furnace filters into the walls and ceiling? Tremendous air currents blow through the walls of a typical home. To demonstrate, hold a lit candle near an electrical outlet on an outside wall when the wind is blowing (Figure 2.3). That flame will flicker and may even go out. The average home with all its doors and windows closed has a combination of air leaks equal to the size of an open door. Even if we do a perfect job of installing fiber insulation in our house and bring the air infiltration close to zero from one side of the wall to the other, we still do not stop air from moving vertically through the insulation itself, in ceilings and walls.

2.5 Solid Insulations

The best known solid insulation is expanded polystyrene. Other solid insulations include cork, foam glass and polyisocyanate or polyisocyanurate board stock. The last two are variations of urethane foam. Each of these insulations is ideally suited for many uses. Foam glass has been used for years on hot and cold tanks, especially in places where vapor drive is a problem. Cork is of course a very old standby, often used in freezer applications. EPS or expanded polystyrene is seemingly used everywhere — from throw away drinking cups and food containers to perimeter foundation insulation, masonry insulations, etc. Urethane board stock is becoming the standard for spray-in-place polyurethane is the only commonly used solid insulation that absolutely protects itself from air infiltration. When it is properly placed between two studs or against a concrete block wall or wherever, the bonding of the spray plus the expansion of the material in place creates a total seal. It's almost impossible to overestimate this total seal. In my opinion, most of the heat loss in the walls of a home has to do with the seal, rather than the insulation.

Heat does not conduct horizontally nearly as well as it does vertically. Therefore, if a home had no insulation in its walls, but did have an absolute airtight seal, there would not necessarily be a huge difference in heat loss. But this would not be the case if ceiling insulation was missing.

Spray-in-place polyurethane can most effectively stop air infiltration. It is the only material that properly applied fills in the corners, cripples, double studs, bottom plates, top plates, etc. The R-value of a material is of no interest or consequence if air can get past it.

2.6 Case Studies

During the 1970s in Idaho's Snake River Valley, my firm insulated the walls of many new homes with 1.25 inches of spray-in-place polyurethane foam. In 1970, the popular number for the R-value of one inch of urethane foam was 9.09 per inch. Using this value, we were putting an R of $1.25 \times 9.09 = 11.36$ in the walls. This was much less than the $R = 16$ claimed by fiberglass insulators. Today, using ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) published charts, we would only be able to claim an R-value for the 1.25 inches of 7.5 to 9. Neither of these numbers make for a very high R-value. But in reality, our insulation customers invariably thanked us for the savings in their heat bills. Many told us that their heating bills were half of what their neighbors paid. They felt that they saved the cost of the polyurethane in one or, at most, two years. Most of these *a freezer down to 10 F below zero — the temperature needed for ice cream. So, Chet turned on the new freezer with its one compressor. By the second morning, the temperature dropped to 18 F below zero! Chet and Meadow Gold had their freezer. It ran the entire summer using only the single compressor.*

A few weeks after the freezer's start-up, a Meadow Gold engineer from Chicago visited me. He wanted to know exactly what we had done to insulate the freezer. One compressor should not have been able to hold the temperature as it did. I explained exactly what we had done. He seemed satisfied and left.

But several more weeks went by and he showed up again — this time with his boss. We went to the plant; using an ice pick, we verified the foam's thickness. It was, indeed, four inches in the walls and five inches in the ceiling. But again, both engineers reiterated that the building should not be operating as it was. What they were telling me was that even though I had used one inch of urethane to replace 2.5 inches of expanded polystyrene, the building was still requiring only 50 percent of normal compressor power for cooling. As you can imagine, the experience made me a lot bolder, and I used the information to sell more freezer insulation jobs.

Clearfield, Utah Freezer

A 60,000 square foot freezer in Clearfield, Utah became one of our largest freezer insulation projects. I persuaded Bob, my friend and the general contractor building this new, all-concrete freezer, into letting us insulate it with spray-in-place polyurethane foam. This building was the twelfth in a chain of freezers. Bob took it upon himself to switch from the usual ten inches of expanded polystyrene to four inches of urethane with a fifth inch on the roof. The building was built with tilt-up concrete insulated on the interior side of the concrete with spray-in-place urethane. We then sprayed on a three-fourths of an inch thick layer of plaster as a thermal (fire) barrier. Over the prestressed concrete roof panels, we put five inches of spray-in-place urethane and then, following the urethane manufacturer's specifications, covered it with hot tar and rock.

On my last day on this job, the owner showed up. He had expected to see ten inches of expanded polystyrene — not four inches of urethane. I told him he would like the four inches of urethane and that, based on my experience, urethane was a far better insulator than expanded polystyrene. He told me he felt sick — there was no way that could be true. But it was too late for him to do anything about it. If he could have, he would have changed the contract instantly, but he was stuck and he felt stuck.

He owned twelve other similar-size freezers, all insulated with expanded polystyrene. They normally operated with three large compressor assemblies. During the summer, two compressors kept the building cold, while the third stood by in case one of the first two had a problem.

About a year later, I received a phone call from one of the managers. He asked me if I had time to insulate another 60,000 square foot freezer in Clearfield, Utah. I assured him we had the time, the inclination, and the excitement to do it, but I thought the owner wanted *nothing to do with urethane foam insulation. The manager explained that not only had the Clearfield freezer operated better than any other freezer in their line, it had operated for less than half the cost of the others. So, they were adding another 60,000 square feet without adding more compressors. The compressor power available to them because of the urethane insulation's efficiency allowed them to do that. The building had run very nicely through the hot part of the summer with just one compressor. Now they would be able to run two buildings off two compressors and still have a spare.*

Again, this is anecdotal evidence, but let me assure you that you will get the same results if you do as we did. I have insulated many buildings and I know what results you can expect. You cannot get a R-value from a fiber insulation and compare it to the R-value of a foam insulation. Nor can you use the R-value of a foam insulation if it is in sheet form and compare it to the R-value of spray-in-place foam insulation. Spray-in-place polyurethane is an absolute minimum of three to ten times as effective as any other insulation available today.

During the late 1970s, the FTC (Federal Trade Commission) went after urethane foam suppliers for misleading advertising, especially regarding fire claims. A consent decree followed. It destroyed a tremendous amount of confidence in the use of urethane. Up to that point, Commonwealth Edison gave Gold Medallion approval to homes insulated with only one quarter inch (0.25") of spray-in-place urethane in the side walls of masonry constructed homes. Much work was done in the early 1970s using a 1.25 inches urethane as a replacement for wall insulation in a home. Not only did it replace the wall insulation, it also replaced the exterior sheathing. Buildings are stronger and better insulated when sprayed with the 1.25 inches of urethane.

2.7 Insulation has two purposes: to cut heat loss and to control surface temperature.

2.7.1. Heat loss

This next section covers aspects of insulation that most people are unfamiliar with or don't know very well. There is a substantial difference between insulation for temperature control and insulation for heat loss control. For instance, the graph shows the heat loss control of spray-in-place urethane foam insulation. Any insulation will have a similar graph but with thicker amounts of insulation. This graph (Figure 2.7) points out that more insulation is not necessarily cost effective. From a heat loss perspective, there is a point at which more insulation is pointless.

The graph shows that 70% of heat loss from conductance is stopped by a one-inch thickness of spray-in-place urethane foam. Note: Nearly 100% of the heat loss from air infiltration is stopped with the first one-fourth of an inch of urethane foam. The second inch of spray-in-place urethane stops about 90% of heat loss, and the third inch stops about 95% and so forth.

It should be noted here that when urethane is used on the exterior of a heat sink, such as concrete, the actual effective R-value is more than doubled. Consequently, for a Monolithic