2

R-value Fairy Tale: The Myth of Insulation Values

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.

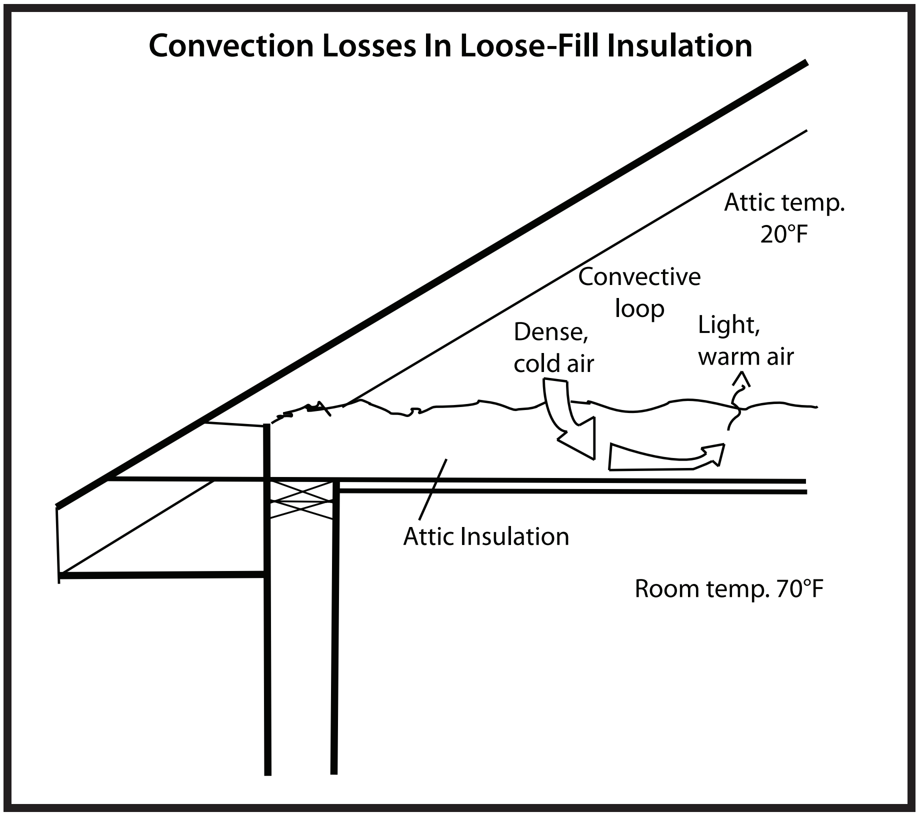

Figure 2.2 — At very cold temperatures, when the temperature difference across the attic insulation reaches a certain critical point, convection within the insulation can reduce r-value. (J.D. Ned Nisson, "Attic Insulation Problems in Cold Climates," ***Energy Design Update*****, March 1992, 42-43)**

In a wintry 20 F below zero environment, the inside of an occupied house will certainly be the warm side. But during sun-shiny 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

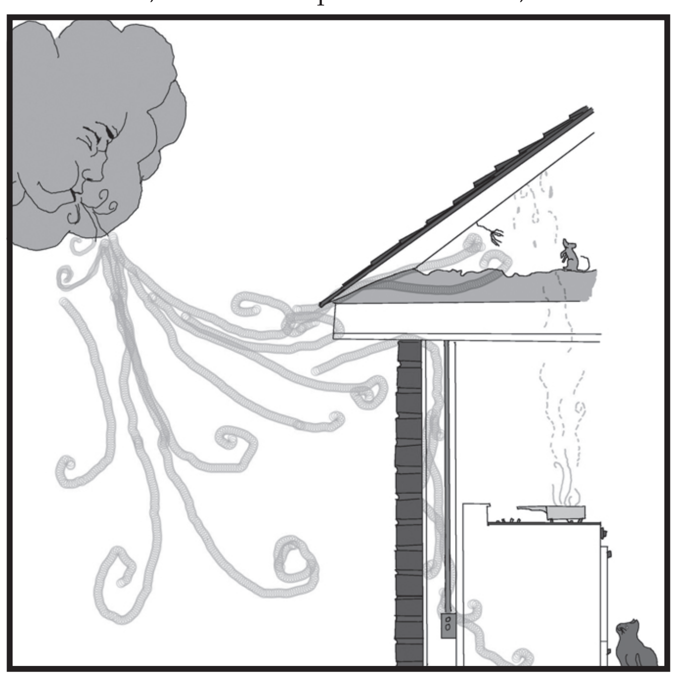

Figure 2.3 — Air penetration through walls and roof of a home with standard insulation.

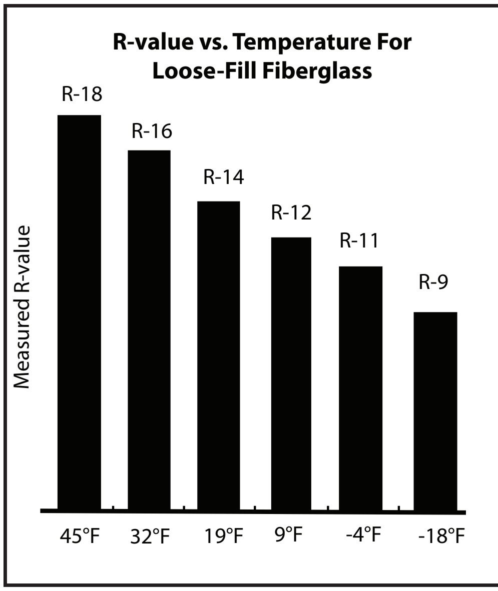

Figure 2.4 — There is a problem with loose-fill fiberglass attic insulation in cold climates. It appears that, as attic temperature drops below a certain point, air begins to circulate into and within the insulation, forming "convective loops" that increase heat loss and decrease the effective R-value. At very cold temperatures (-20F), the R-value may decrease by up to 50%.

In full-scale attic tests at Oak Ridge National Laboratory, the R-value of 6 inches of cubed loose-fill attic insulation progressively fell as the attic air temperature dropped. At -18F, the R-value measured only R-9. The problem seems to occur with any low-density, loose-fill fibrous insulation. (J.D. Ned Nisson, "Attic Insulation Problems in Cold Climates," ***Energy Design Update*****, March 1992, 42-43)**

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

Figure 2.5 — During the 2007-2008 winter, Caledonia, Missouri experienced ice and wind storms that covered their area with two to three inches of ice and left people without power for up to two weeks. Superintendent Steve Yount said that the domes were unaffected by the cold, and, although they were without power, the domes retained their heat, so people spent their days warming up in the Monolithic Domes. The community wants their domes certified by the Red Cross as a designated disaster shelter and is looking into grants that would finance a generator.

roof insulation, especially for hot mopped roofs. It is also widely used for exterior sheathing on many new houses. The R-value of the urethane board stock is of course better than any of the other solid insulations. All of these solid insulations perform far better than fiber insulations whenever there is wind or moisture involved.

Most solid insulations are installed as sheets or board stock, and most suffer from one very common problem. They generally don't fit tight enough to prevent air infiltration. And if the wind gets behind them, it matters not how thick these board stocks are. We see this often in masonry construction where board stock is used between a brick and a block wall. Unless the board stock is actually physically glued to the block wall, air will infiltrate behind it. When this happens, the board stock becomes virtually worthless, since the air flows through the weep holes in the brick and around the insulation negating its effectiveness. Great care must be exercised in placing solid insulations. The brick ties need to be fitted at the joints and then sealed to prevent air flow behind the insulation.

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 x 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 customers were savvy people. They would not have paid the extra to get the urethane insulation if it had not been better. Nevertheless, what I call "Case Studies," some people might call "anecdotal evidence." That's okay. Anecdotal evidence is also compelling and very real in our world.

Insulating Homes

About mid 1975, I received a call from a division manager of a major fiberglass insulation manufacturer. The caller said, "I understand that you are spraying polyurethane in the walls of homes." I told him that was true. He was calling because we were cutting into fiberglass insulation sales in our area. He asked, “How can you do it?”

I knew what he meant. He wanted to know how I could look folks in the eye and sell them a more expensive insulation instead of cheap fiberglass. I told him the way I did it was with a spray gun. Of course, that wasn’t the answer he wanted. He wanted to know why I did not feel guilty. I told him about insulating one of two nearly identical houses built side-by-side. We insulated the walls of one with 1.25 inches of urethane. Its near-twin was insulated with full, thick fiberglass batts by a reputable installer. Not only did we use just 1.25 inches of urethane as the total wall insulation, but we had the builder leave off the insulated sheathing. At the end of the first winter, the urethane insulated home had a heating bill half of its neighbors. Again, such evidence is not terribly scientific, but it is very real. I am not sure that the manager was convinced, but it should be noted: in the following year, that same company jumped into the urethane foam supply business.

One and a quarter inch of polyurethane sprayed properly in the wall of a house will prevent more heat loss than all the fiber insulation that can be crammed in the walls — even up to an eight-inch thickness. Not only does the polyurethane provide better insulation, it provides the house with significant additional strength.

Brent was an early client of mine for whom I had insulated several potato storages. He knew what spray-in-place urethane insulation could do. When he decided to build his new, very large, very fancy new home, he asked me to insulate it. The builder pitched a fit. He didn’t need any of that spray-in-place urethane in his buildings. He made his buildings tight, and fiberglass was just as good.

Brent told the builder, “I know who is going to insulate the building. It is not as definite as to who is going to be the contractor. You can make up your mind. We are going to have the urethane insulation and you build the building, or we are going to have the urethane insulation, and I will have someone else build the building.” It didn’t take the contractor long to decide he wanted to use urethane insulation.

How it worked out amazed me. We sprayed a lot of foam in Brent’s house, and it cost him quite a bit of money because of the home’s size. But whenever I met him afterwards, he told me his heat bill was less than that of any of his rent houses or the homes of anybody else he knew. And his home was two or three times larger.

Brent’s experience convinced the builder as well. He started having me insulate most of his new custom built houses. The builder said that he would explain the benefits of spray-in-place urethane to his clients. While it cost a little more, it was by far the best. Most of the builder’s clients opted for urethane. Never have I had a customer tell me that he did not save money by using urethane spray-in-place insulation. You can spend all the time you

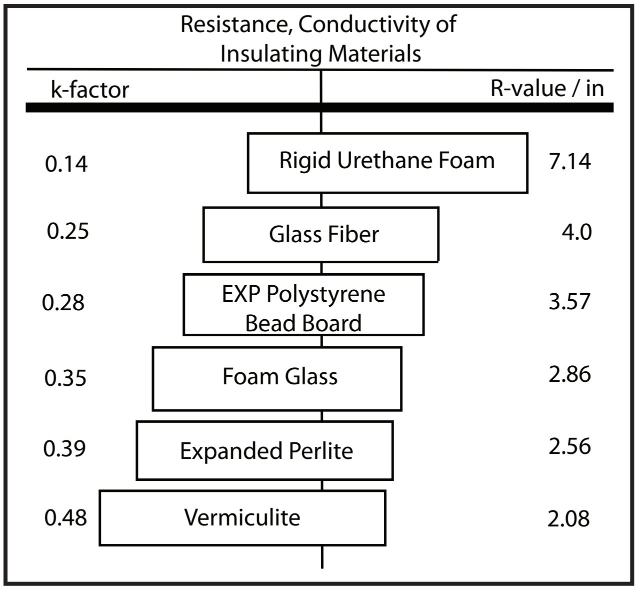

Figure 2.6 — With the lowest k-factor and highest R-value, urethane foam can provide more thermal resistance with less material than any other insulation.

want with R-values and k-values, and prove on paper that fiberglass, rather than urethane, is a superior insulation. But in the real world, I can assure anyone that there is no way fiber insulation can be as effective as spray-in-place urethane — not even close.

R-value tables are truly part of the fairy tale. They chart solid and fiber insulations side by side, implying that they can be compared. The fact is, without taking installation conditions into account, comparisons are meaningless. Spray-in-place urethane foam provides its own vapor barrier, water barrier and wind barrier. None of the other insulations are as effective without special care taken at installation. Fiber insulations must be protected from wind, water and water vapor. Again, the tables need a second table to state installation conditions.

Meadow Gold Freezer

Meadow Gold, a dairy product company, was going to build a freezer in Idaho Falls, Idaho. Chet, Meadow Gold's plant manager, was a good friend of the local Butler Building dealer, who was a good friend of mine. A Butler Building insulated with expanded polyurethane does not make an efficient freezer. The three of us knew that, so we got together and planned a freezer that would accommodate Meadow Gold's needs, yet be built of a Butler Building and be properly insulated. This transpired during my first year of

Urethane Conserves Energy

Excellent thermal resistance is the primary performance benefit of urethane foam insulation, but it is not the only one. Urethane also has these advantages as a construction material:

1 — Its closed cell structure makes urethane most effective initially and in the long run.
2 — When protected by skins or other covering, urethane will not absorb water. Consequently the x-factor (thermal conductivity) is virtually constant.
3 — Sprayed-on foam has the advantage of no seams or joints.
4 — Urethane's thermal resistance means that only one thickness of material is needed for most jobs.
5 — It has a low moisture permeability (1-3 perms).

Where circumstances demand thinner walls or roofs, urethane, with its superior insulation capability, makes it possible to reduce the thickness of the insulation component with no loss of thermal resistance. Or the thermal resistance of an assembly can be increased without enlarging the size of the member. Urethane helps to offset the design restrictions imposed by the fact that most building materials are constant in thickness and weight.

(Mobay Chemical Corp. "Urethane Foam as an Energy Conserver," *How to Conserve Energy: in commercial, institutional and industrial construction*, Pittsburgh, PA, 1975, 3)

spraying polyurethane foam; I believed all the literature and knew that what we were doing was going to be just right.

It turned out even better. The then current R-value table showed one inch of urethane equal to 2.5 inches of expanded polystyrene. So, I suggested we spray the metal building with four inches of urethane to replace the 10 inches of expanded polystyrene normally used by Meadow Gold for freezers.

I sprayed the walls and under the slab with four inches, and I sprayed the underside of the roof with five inches of urethane. (Fifth inch was added as a safety margin.)

During this process, Chet began worrying. After all, he had stuck his neck out by going with a nontraditional insulation in a nontraditional structure. Well, the building progressed on schedule, but the equipment to cool it did not arrive on time. By summer, only one of two refrigeration compressors had arrived. But based on using 10 inches of polystyrene and per Meadow Gold's engineers, two compressors were needed for efficient freezing.

Faced with this predicament, Chet considered an alternative: one of the older freezers that had been used as a cooler could be turned back into a freezer. Then, with just one compressor, the new building could be made into a cooler. It was not a satisfactory arrangement, but it maybe could work.

Chet also insisted that as soon as he turned on the freezer equipment he would know if the building would work. When I pressed him, he said that normally it takes five days to bring 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

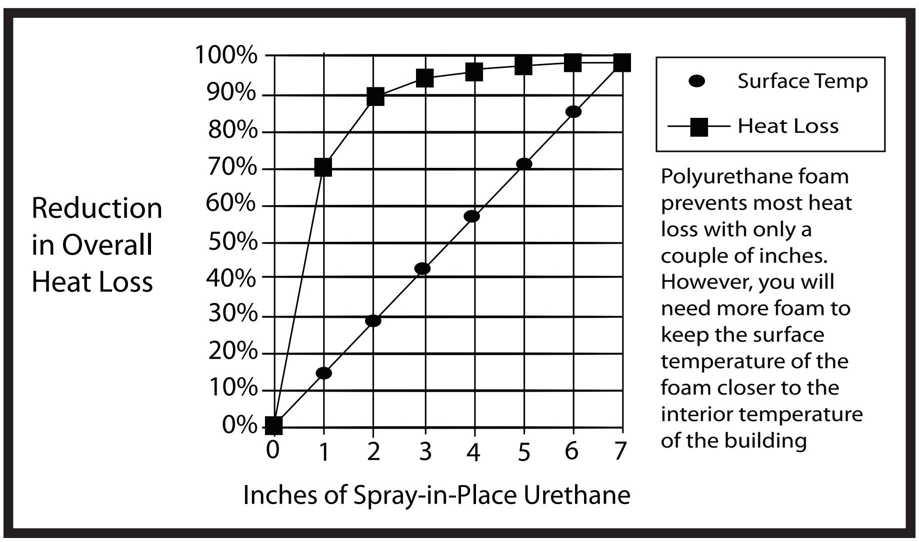

Figure 2.7 — This graph illustrates a building's reduction in heat loss when it is insulated with various thicknesses of spray-in-place urethane foam. Note: Above 3 inches, the insulation benefit tops off quickly. The graph is not exact, but it shows, in general, what happens as additional insulation is added to the surface temperature. In other words, by super-insulating, the surface temperature of the inside of the exterior walls comes very close to the room temperature. This prevents condensation, that, in turn, prevents mold growth.

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 Dome, we are able to calculate effective R-values in excess of 60. A heat sink is any substance capable of storing large amounts of heat. Most commonly, we think of concrete, brick, water, adobe and earth as heat sink materials used in building. The property of a heat sink to act as an insulation is called thermal diffusivity.

Here is a simple explanation for the way it works: As the temperature of the atmosphere cycles from cold to hot to cold to hot, the heat sink absorbs or gives up heat. But because the heat sink can absorb so much heat, it never catches up with the full range of the cycle. Therefore the temperature of the heat sink tends to average. Large heat sinks will average over many days, weeks or even months.

An adobe hacienda with its two-to-six-foot thick walls exemplifies this process. By the time the adobe walls begin to absorb the daytime heat, it is night time, and the same heat then escapes into the cooler night. Therefore the temperature averages. Because of the adobe's large mass, the temperature averages over periods of months. So, adobe acts as an insulation even though adobe has a minimal R-value.

According to the graph, urethane thicknesses beyond four or five inches are practically immaterial. We use three inches for most of our construction. Two inches will do a very superior job. We have insulated many metal buildings with one inch of urethane and got a dramatic drop in heat loss. Obviously the first quarter inch takes care of wind blowing through cracks. (It usually takes an inch to be sure the cracks are all filled.) The balance of the inch adds the thermal protection.

March 2009 *National Geographic* featured an article entitled, "Saving Energy: It Starts at Home," focusing on heat loss. Included here is a series of photos of a Monolithic Dome insulated with urethane foam and a few other buildings. These images were taken using a $50,000 thermographic camera, which is designed to take pictures showing the amount of heat emitted by the objects in the photographs.

The minus 13 degrees Fahrenheit temperature shows up as black. The warmer temperatures show up in various colors and the hottest is the red. In a quick look you can see that the heat loss from the urethane insulated Monolithic Dome is virtually zero, except through doors and / or other openings. This verifies what I have witnessed: The last snow that melts will be on the north topside of a Monolithic Dome.

We advise those building Monolithic Domes to ignore heat loss or gain when sizing HVAC equipment. The activities within, the windows and doors, the lights and all else are far more important for determining how much equipment is needed for heating and cooling. We have had engineers check the building by actually measuring total energy consumption. In all cases the Monolithic Dome shell is shown to have an equivalent r-value of more than 60.

These thermographic photos give us a great visual picture illustrating this phenomena. Between the mass of the concrete and the spectacular values of the urethane insulation, for all practical purposes, there is no heat loss through the Monolithic Dome's shell.

For those who would like to learn more about this science of energy we suggest you go to the website of UCLA (www.energy-design-tools.aud.ucla.edu). It demonstrates why an R-value alone is not acceptable for thermal performance.

2.7.2. Surface Temperature Control

Surface temperature control is the second reason for insulation. In many cases, it is the most important reason. I noticed this phenomena first while insulating potato storages.

We had various customers ask us to insulate buildings with anywhere from two to five inches of urethane. But the building insulated with two inches would hold the temperature of the potatoes properly and just as well as the building insulated with five inches. The difference came in the condensation. Potato storages are kept at very high humidity levels. So, buildings with two inches of urethane would have far more condensation than those with five inches.

An engineer from the Upjohn company explained this to me. He stated that thicker insulation is absolutely necessary to maintain higher interior surface temperatures. One and a half inches of urethane on the walls and ceiling of a potato storage would control the heat loss from the building, but it took a minimum of three inches of urethane to control the interior surface temperature. Four inches was even better. With five inches the difference is practically negligible. The only place where we have felt the need for five inches of urethane was in insulating the roof or ceiling of a sub-zero freezer.

2.7.3 Underground housing — surface temperature control vs. heat loss control

Most underground housing gets in trouble from mold and mildew growth. The cause is not enough insulation to control interior surface temperatures. Rarely is there a problem with total heat loss. Water vapor condenses on the surface, allowing mold to grow. Mold makes people sick. The only solution is using lots of insulation for temperature control and ignoring total heat loss since it is not a factor.

2.8 Conclusion

Experience has taught me that R-value tables can be used as indicators. But they need modifications to make them equal to real world conditions.

Part 2 — R-value Fairy Tale

Allowances must be made. They must show equivalents. These equivalents should indicate that one inch of spray-in-place urethane equals four inches of fiberglass in normal installations. Footnotes to the table should define degradation of insulations in real world conditions. Only then will the R-value Fairy Tale become a real world success story.

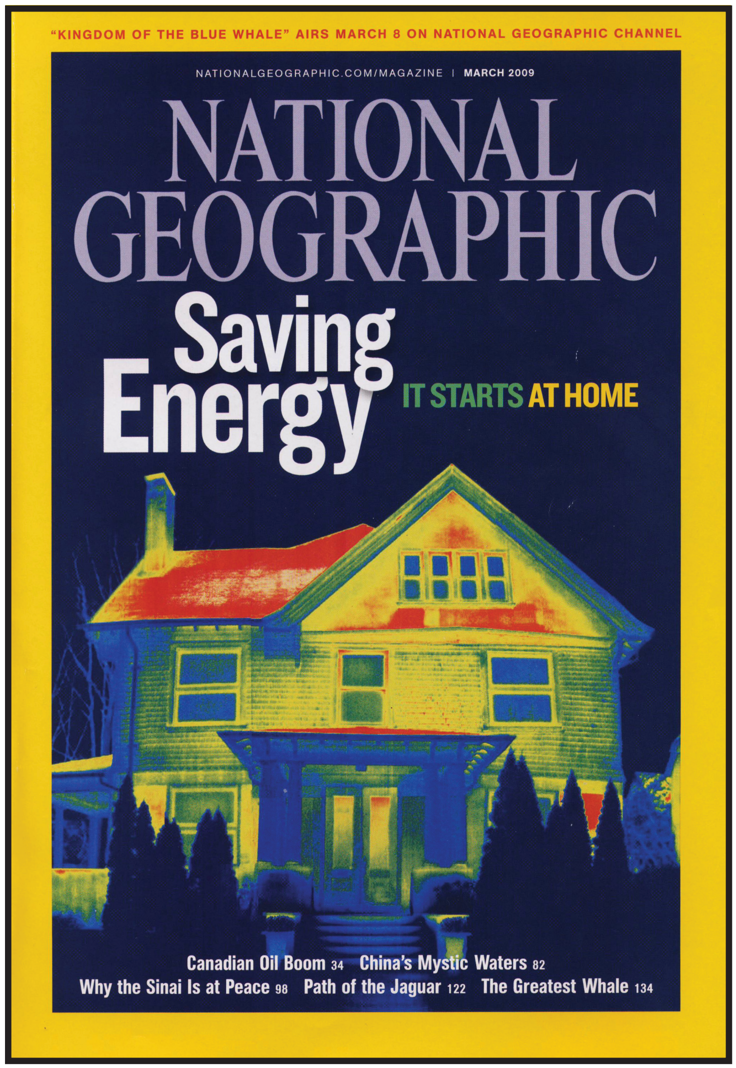

Figure 2.8 — March 2009 National Geographic features thermograph of conventionally insulated home. Note heat loss, especially through the roof.

Figure 2.9 — Heated Monolithtic Dome shop in Sasketoon, Saskatchewan, Canada. The outside temperature at this time was 13 degrees Fahrenheit below zero (-25C). This is a standard color photograph taken by a standard camera. Note the metal buildings in the background.

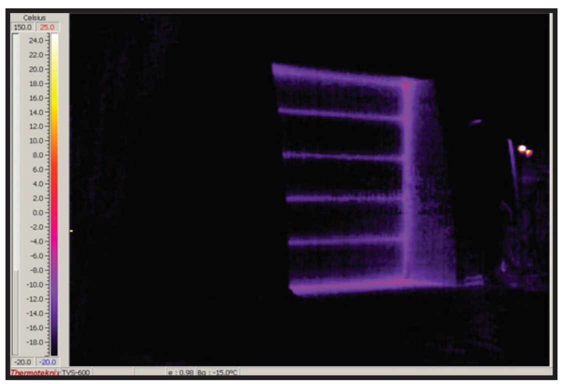

Figure 2.10 — This picture shows the same Monolithic Dome through the thermographic camera at the same 13 degrees F below zero. Note the Monolithic Dome is black. This is a heated shop. There is no heat loss through the dome shell. The door (insulated) is leaking heat, especially at the cracks between the sections and along the edges.

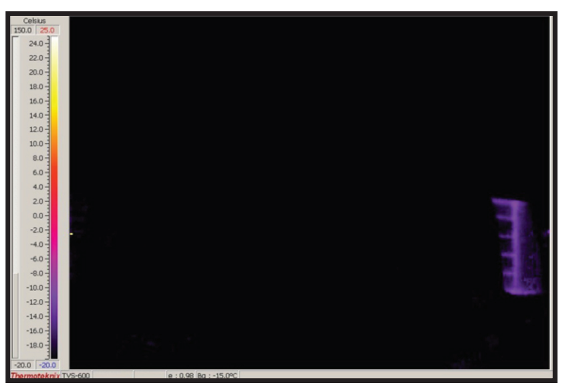

Figure 2.11 — Same building, same situation but further around the building. Note the temperatures on the side bar. The black is about 25 degrees Celsius below zero (-13F) The colors denote higher temperatures.

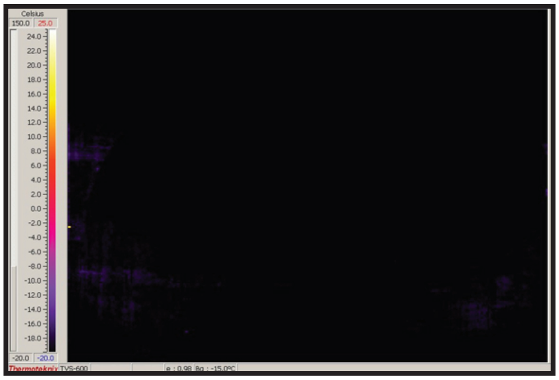

Figure 2.12 — The back side of the Monolithic Dome shows virtually no heat loss as there is no color.

Figure 2.13 — Another thermograph taken of the west face of the dome. Note the small amount of heat loss around the personnel door.

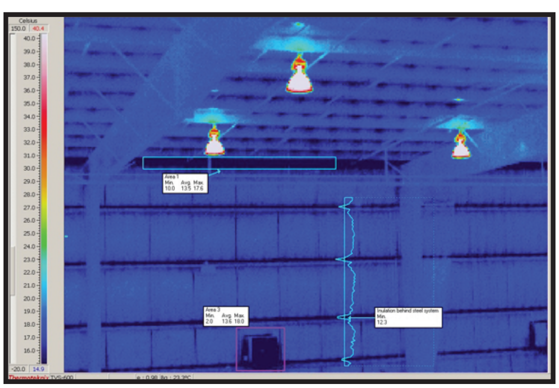

Figure 2.14 — Internal image of the shop next door to the Monolithic Dome shop. Note the black areas. This is the -25C (-13F) temperature showing on the inside of the building. This insulated building shows virtually no insulation along the metal framing

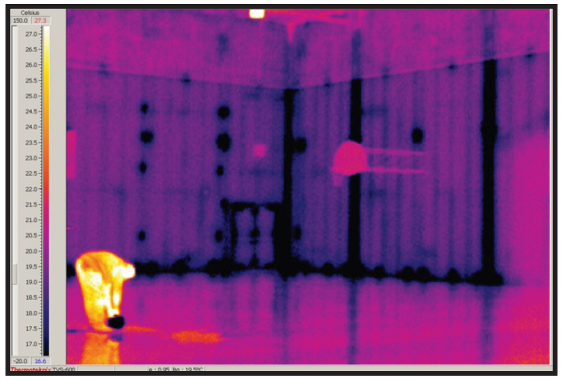

Figure 2.15 — Internal image of a metal gymnasium near by. Note the bright colors of the student and the below-zero colors of the exterior walls.

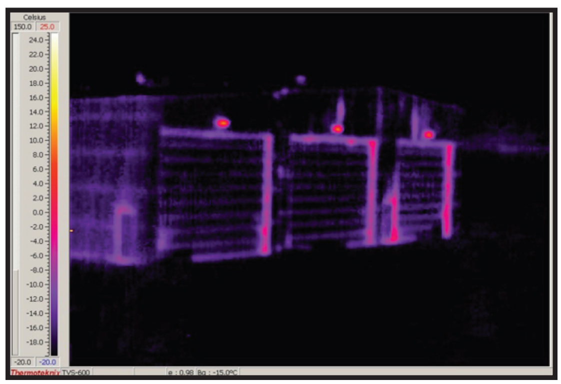

Figure 2.16 — This thermograph is of a 1980 vintage metal building that is considered well insulated. The picture indicates this is true for a metal building. But even this well-insulated building shows heat loss.

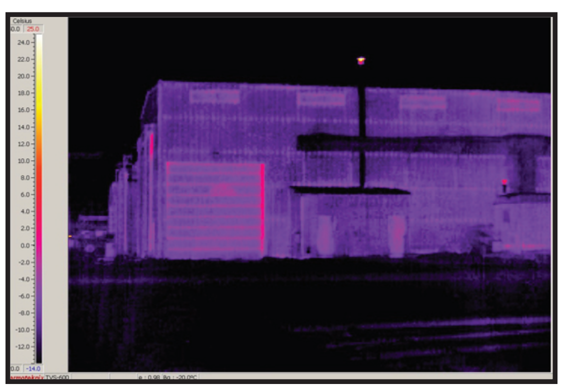

Figure 2.17 — Another metal shop building adjacent to the dome. Note the brighter colors indicate more heat loss (obviously) than that of the super-insulated Monolithic Dome.