

## In-Service R-Values

Thermal performance of foam insulation has been increasingly debated among industry professionals. These discussions are peppered with varying definitions of R-value, which have become so subjective they are almost meaningless. To eliminate additional confusion, several state government agencies and standard testing organizations have taken proactive steps to provide the building and construction industry with definitive guidelines regarding design R-values for insulation.

The Building and Safety Division of the Municipality of Anchorage released Policy 83, "Insulation - Maximum R-Values", in February 21, 2001. It established a new benchmark in R-value requirements for foam insulation. City building officials will no longer accept the widely used 180-day conditioned R-value figures for affected rigid foam insulation materials, such as extruded polystyrene, phenolic, polyisocyanurate and polyurethane insulation. This action confirms that criteria to measure and compare R-value performance developed in the early 1970's did not provide accurate rates. Local expanded polystyrene manufacturers lobbied building officials to make this implementation. "The EPS industry presented an impressive amount of background information and technical substantiation that convinced us there would be a benefit in making this change," cited Pamela Ronning, Plan Review Engineer, Building and Safety Division of the Municipality of Anchorage.

For the past twenty years, this has been an on-going debate. In 1985, the Midwest Roofing Contractors Association (MRCA) developed a position paper to address interim in-service resistance R-value for urethane and isocyanurate roofing insulations due to the thermal drift experienced in these materials. And then in 1987, the National Roofing Contractors Association (NRCA) joined the MRCA announcing an identical recommendation to designers, users and other affected parties to utilize an R-value of 5.6 per inch of foam thickness as a reasonable guide when calculating thermal resistance of polyisocyanurate and polyurethane insulation boards over their normal life in a roofing system.

Recently, this debate has been played out on the federal level. Back in November 1999, the Federal Trade Commission announced an advance notice of proposed rulemaking to amend the Labeling and Advertising of Home Insulation to reflect new advancements in technology and the need to clarify and streamline the Rule's requirements. A final notice for public comment is expected to be announced by the end of 2001.

Testing and product standards are also reflecting this tide of change. The Standard Council of Canada has been published to provide a standardized test for estimating the long-term thermal resistance (LTTR) of foam plastic insulations, including polystyrene, polyurethane and polyisocyanurate. Test protocol, CAN/ULC-S770, "Standard Method of Test for Determination of Long Term Thermal Resistance of Closed-Cell Thermal Insulation Foams" is the stand test method identified in all National Standards of Canada for foam plastic insulation products.

The test has been in development for the last ten years to assist in eliminating the ongoing confusion between "aged" and "stabilized" R-value. Manufacturers are now required to retest their products based on the "slicing and scaling" method prescribed in CAN/ULC-S770 and report the LTTR. Third party certification and labeling laboratories must follow the same testing procedures to ensure consistent measurements.

ASTM C1303, "Standard Test Method for Estimating the Long-Term Change in the Thermal Resistance of Unfaced Rigid Closed-Cell Plastic Foams by Slicing and Scaling Under Laboratory Conditions" is the US equivalent of the Canadian standard. ASTM Sub-Committee C16.22 has approved standardized wording to include a reference to ASTM C1303 in foam plastic insulation standards. A recent ballot for Standard C578, "Standard Specification of Rigid, Cellular Polystyrene Thermal Insulation", requested approval of the proposed wording referencing the "slicing and scaling" method. Currently, ASTM C1303 is not a mandatory requirement like CAN/ULC-S770-00.

Although there will be a lapse between retesting materials and full integration into the building community, many industry professionals anticipate that LTTR will become the norm. This action provides architects and specifiers a clear-cut analysis of thermal performance of the various rigid foam insulation materials for the life of a structure.

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## **R Value**

As new building and insulation materials have entered the market, confusion over the nature and meaning of R-Value has raised questions among building professionals and consumers alike. What exactly is R-Value? Is it an effective and objective measure of the thermal performance of an insulation product or construction system? And how should the marketplace use it to compare the benefits of one insulation material over another?

### **Defining R-Value**

During the 1970's demand for quality building insulation soared, when an oil crisis sent heating and cooling costs skyward, With many new products on the market -- and with so many conflicting claims pertaining to the insulating abilities of those products -- the Federal Trade Commission, with the participation and support of the insulation industry, created an objective method for reporting the performance of residential insulation materials. This method is called the R-Value Rule.

The rule provides requirements for product labeling (R-Value) and advertising, and mandates specific ASTM methods for thermal testing. The R-Value rule attempted to create a level-playing field for competing insulation materials. "The R-Value Rule has been helpful in comparing different brands of the same type of insulating material," said Betsy de Campos, executive director of EPSMA, "but as more sophisticated materials and higher technology construction systems are introduced into the building industry we find that the R-Value of a material does not tell the whole story."

R-Value is based on a mathematical term known as R-Factor. The term R-Value was developed to represent the ability of an insulation material to restrict heat flow. It is determined by placing test specimens between two plates in a laboratory apparatus and measuring heat-flow through the insulation. The test specimen usually consists of a square foot of material exactly one inch thick whose surfaces have a temperature differential of 1 degree Fahrenheit. The thermal conductivity (k) of a material is expressed as the rate of heat flow in BTUs per hour.

R-Value then, is the R-Factor of an insulation material multiplied by the amount of material used. For instance, if the specified insulation has an R-Factor of 3.8 and you are using 3.5 inches of insulation, the R-Value is 13.3. Thermal resistance (R) of a material is its resistance to heat flow, and R-Value is expressed as the reciprocal of the materials thermal conductivity.

Pretty technical stuff, but the idea that a consumer should be able to compare insulation is essential to ensuring homeowners and building professionals are capable of making informed product decisions. Simply put, the greater the R-Value the better the insulation.

But, there is more to consider when making those decisions today.

### **Clear Wall versus Whole Wall R-Value**

When the R-Value Rule was instituted, most homes and buildings were constructed and insulated using dimensional lumber, two by fours, and fiberglass insulation. To increase a home's insulation, generally, a builder would have selected a fiberglass insulation product that had a higher R-Value, but today we have learned that it isn't necessarily the R-Value of the insulation that makes the wall more efficient. It is a combination of insulation materials, construction details, and installation care that provide ultimate thermal performance.

Today we understand that to insulate the space between the studs with fiberglass is not the same as insulating an entire wall. We must consider the wall as a system. The lumber creates thermal bridging and air infiltration within the wall, around windows and doors and at connections between the wall, the ceiling and the floor. Now we know that it is important to insulate the wall and not just the area between the framing members.

Consider though, fiberglass insulation performs well in controlled laboratory tests, how does it perform when actually installed in a home? Fiberglass is susceptible to air exfiltration; when air enters a wall through a crack in the siding or near a window opening; it flows right through the fiberglass, significantly reducing its ability to resist thermal flow. Moisture, also, causes fiberglass to significantly lose its insulating ability. R-Value doesn't account for these problems.

In an effort to create more comprehensive standards, researchers at the Building Technology Center at the Department of Energy's Oak Ridge National Laboratory in Tennessee are proposing a system for rating "Whole Wall R-Value," which is the insulating value of a whole wall system.

According to Builder Magazine, most R-Value calculations are based on conventional wood frame construction using "clear wall" or "center of cavity" criteria. R-Value only takes into account the insulation and necessary framing members that make up the "clear" section of the wall, not the corners and intersections with the roof or floor. Further, the center-of-cavity method rates R-Value only at the point where the insulation is the thickest -- right between the studs -- and the rating is based on laboratory tests, not actual conditions. For these reasons, R-Values tend to be overstated.

Whole R-Value, however, takes into account the interface details of an exterior wall, which are the intersections of the wall with other walls, the roof, deck, doors and windows. The framing and connections create what are called thermal shorts -- points that can detract from the wall's overall R-Value.

"EPS insulation used in structural insulated panels or insulating concrete form homes offer tighter interface details than fiberglass batts by eliminating air infiltration," said de Campos. "For this reason, the use of whole wall R-Value is more accurate in describing thermal performance of the system than the respective R-Values of the components. This is just one other consideration that consumers need to make when determining the best insulation system."

### **Thermal Drift**

There are other factors that affect the performance of insulation products after they are installed in a building, including thermal drift.

"Depending on the insulation material used, the R-Value can slowly be reduced over time as the material ages," said de Campos. "This should be considered when the designer calculates the expected performance of the insulation materials that he is recommending."

Some foam plastic insulation materials use blowing agents that have a high resistance to heat flow causing the insulation to have an abnormally high R-Value at the time of manufacture. It is now known that these blowing agents diffuse from the cellular structure of the foam until a level of

equilibrium is reached many years after it is manufactured. As the high R-Value gases diffuse out of the cellular structure, the ability of the insulation to prevent thermal flow is reduced, losing up to 30 percent of its original insulating ability. EPS foam does not use these types of blowing agents, therefore, its insulation performance remains stable over its entire life.

"If you compare EPS side-by-side with some foam plastic insulation materials right after they are manufactured, the other materials may have a higher R-Value," said de Campos. "But EPS is stable and does not experience any thermal drift and does not lose R-Value over its life. In the long run, the thermal performance of EPS insulation is constant, and when all cost and performance factors are considered, it typically provides the greatest insulating value available."

### **EPS Maintains R-Value**

In the "Report on Expanded Polystyrene Insulation for Use in Built-Up and Single Ply Roofing Systems," dated August, 1984, researchers Rene M. Dupuis and Jerome G. Dees show that samples of EPS insulation had no deterioration in R-Value. The test results at 70°F for thermal resistance of EPS insulation samples taken from roof systems of various ages indicated no deterioration in the R-Value over time.

### **Beyond R-Value**

Building codes require minimum levels of insulation in order to conserve energy and make the building more comfortable. Energy and resource conservation continue to be important issues in deciding what materials are used in today's construction. As technology improves and our understanding of thermal performance increases we now know that there are many more factors to consider than just R-Value. Thermal bridging, thermal shorts, air infiltration, poor construction details, and bad workmanship all are factors that contribute to the thermal performance of a material or insulation system beyond R-Value.

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## **Questions and Answers:**

### **Q: What is R-value and how is it measured? How does R-value relate to K-value?**

A: K-value is thermal conductivity, expressed as the quantity of heat (BTUs), which will flow through a one square foot section of a 1-inch thickness of a homogeneous material, during one hour when there is a 1 degree F difference in the hot to cold side temperature. R-value is a measure of the thermal resistance of a material. Thermal resistance is an index of a materials' resistance to the flow of heat. It is the reciprocal of the K-value. K-values are determined by either of two tests: ASTM C 177 or ASTM C 518. The higher the R-value, the better the resistance to the flow of heat (expressed in BTU's) and the better the insulation. R-values are reported for 1-inch of thickness and are not necessarily per inch of thickness (for residential construction only). R-values are usually reported at mean temperatures of 75 degrees F. per FTC regulations. In an article in the 1987 autumn issue of Exteriors magazine, Andre Desjarlais, then with Dynatech Scientific Inc., of Cambridge, Massachusetts, discussed the need for testing real-world roof environments when evaluating roof insulation. He said, "In addition, some isocyanurates may change chemically when held at 140 degrees F. for 90 days. Lab results can be used as valid representation of the product but the R-values one gets are not absolute." This further substantiates the issue that R-values must be explored not only from a laboratory perspective, but from their "real world" applications as well.

### **Q: How does the R-value of EPS compare with other insulations?**

A: The R-value of EPS is stable and does not change over time. The R-value performance for EPS insulation is discussed in the report, "Report on Expanded Polystyrene Insulation for Use In Built-Up and Single Ply Roofing Systems" by Rene M. Dupuis and Jerome G. Dees, dated

August 1984. The report shows that samples of EPS insulation had no deterioration in R-value.\* The test results at 70 degrees F. for thermal resistance of EPS insulation samples taken from roof systems of various ages indicated no deterioration in the R-value over time. The following table compares two examples of published R-values to samples taken from actual roof decks<sup>1</sup>:

	AGE	DENSITY	R-VALUE
Published Initial Values	at time of manufacture	1.00 pcf	3.85
		1.25 pcf	3.92
EPS Insulation Samples	13 years	1.28 pcf	3.94
	15 years	1.09 pcf	4.07

Those who specify or purchase insulation pay for a certain amount of R-value per inch according to their needs and budget. To invest in a product where the dollar value drifts as the thermal values shrink can be a costly mistake. In November 1987, the National Roofing Contractors and the Midwest Roofing Contractors Association issued a joint technical bulletin on in-service R-values for polyisocyanurate and polyurethane foam roofing insulation boards. In that bulletin the associations recommended that designers and users use an R-value of 5.6 per inch for polyiso and urethane products, not the higher value often referenced by manufacturers' literature. In November 1992, NRCA issued another bulletin in which it reaffirmed recommending an in-service R-value of 5.6 per inch of foam thickness for HCFC-blown polyisocyanurate board products. In the manufacturing process for polyisocyanurate, blowing agents defuse from the cellular structure of the foam for many years after manufacture. The initial loss of blowing agent has been associated with a loss of R-value. This may be referred to as short-term thermal aging. This loss of blowing agent continues for many years after manufacture. These gases are replaced by air which has a lower thermal resistance than the initial blowing agent. This phenomenon has a significant influence on the long term thermal performance of the insulation material. The paramount issue to consider is the long-term thermal performance (10-15 years), not the short-term. Often manufacturers of polyisocyanurate insulations report their R-values after 180 days, a short-term loss period only. Although polyisocyanurate producers may be reporting 6-month aged R-values in accordance with federal regulations, the R-value of these products continues to decrease for years. This is not the case with EPS thermal insulation. Ask your EPS supplier about R-value warranties available with their products.

**Q: What is cost per "R"?**

A: An effective approach to a specifier is a comparison of dollar cost per unit of resistance (R). For example, Product "A" may cost \$.10 per board foot and provide an "R" of 4. Its cost per unit of resistance is then  $\$.10/4$  or  $\$.025$ . Product "B" may cost \$.24 per board foot but provide a higher "R", say 6 units. Its cost per unit of resistance is then  $\$.24/6$  or  $\$.04$ . Conversely, Product "A" delivers 40 units of "R" per dollar of cost; whereas Product "B" only provides 25 units of "R" per dollar. Make sure you get what you pay for over the entire life of the project.

Notes 1 Chart reprinted from Report on Expanded Polystyrene Insulation For Use In Built-Up and Single Ply Roofing Systems; Rene M. Dupuis, Jerome G. Gees; August 1984. If you want more information on stable R-values, optimal vapor transmission, low water absorption, and superior design flexibility with EPS, call 1-800-607-EPISA, or any member of the association.

Filename: Document1  
Directory:  
Template: Normal.dot  
Title:  
Subject:  
Author: Carol Cinnamon Bason  
Keywords:  
Comments:  
Creation Date: 11/12/2001 7:43 PM  
Change Number: 1  
Last Saved On:  
Last Saved By:  
Total Editing Time: 2 Minutes  
Last Printed On: 11/12/2001 7:43 PM  
As of Last Complete Printing  
Number of Pages: 5  
Number of Words: 2,758 (approx.)  
Number of Characters: 15,721 (approx.)