Fine Homebuilding

Understanding R-Value

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R-value measurements are subject to a fair amount of ridicule, especially by marketers of radiant barriers. As it turns out, however, the ridicule is mostly unwarranted.

R-value is a measure of a material's resistance to heat transfer. Before 1945, resistance to heat flow was measured by referring to a material's U-factor. The lower a material's U-factor, the better the material is at resisting the flow of heat. Because many people assume that high numbers on a scale are "better" than low numbers, insulation manufacturers found it hard to market insulation by bragging about low U-factors. So the R-value — which is simply the inverse of U-factor — was proposed by Everett Shuman, the director of Penn State's Building Research Institute. Since $R = 1/U$, the higher the R-value, the better the insulation.

The job requires special equipment. Measuring a material's R-value according to the ASTM C518 test procedure requires a heat flow meter like this German appliance manufactured by Netzsch-Gerätebau. After a sample is placed between a hot plate and a cold plate inside the calibrated testing apparatus, the heat flow occurring at a defined temperature difference is measured with a heat flux sensor.

Photo: NETZSCH-Gerätebau GmbH

Does It "Only Measure Conduction"?

Some manufacturers of radiant barriers falsely claim that R-value measures only conductive heat flow while ignoring the other two heat-flow mechanisms, convection and radiation. In fact, R-values include all three heat-transfer mechanisms.

The usual procedure for testing a material's R-value is ASTM C518, Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. The test method requires a technician to measure the thermal resistance of a specimen placed between a cold plate and a hot plate.

When a fiberglass batt is tested, heat flows from the hot side of the batt to the cold side. Wherever individual fibers of insulation touch each other, heat is transferred from fiber to fiber by conduction. Where fibers are separated by air, the heat is transferred from a hot fiber to a cooler fiber by radiation and by conduction through the air. Finally, the effects of any convective loops within the insulation are also captured by the test procedure.

Since a material's R-value is the measurement of its resistance to all three heat-flow mechanisms — conduction, radiation, and convection — it is a useful way to compare insulation products.

R-Value Matters, But So Does Air Leakage

Of course, an insulated wall is affected by many factors not addressed by R-value testing. Although the R-value test captures the effects, if any, of convective loops within the insulation, it obviously cannot be expected to measure the amount of air leakage through a wall assembly once the insulation is installed. The rate of air leakage is affected by the density of the insulation, the presence or absence of an air barrier in the wall assembly, wind speed, and the stack effect.

Because of these factors, a leaky wall assembly insulated with fiberglass batts will usually perform worse than a wall assembly insulated with spray foam having the same R-value as the batts. The performance differences are due to spray foam's ability to reduce air leakage, not to any difference in R-value between the two materials. It doesn't make any sense to blame the R-value test for differences in air leakage between the two wall assemblies.

To obtain the best performance from fiberglass insulation, the Energy Star Homes program requires most fiberglass-insulated framing cavities to be enclosed by air barriers on all six sides. While the recommendation is sensible, it's hard to achieve in the field. If such a six-sided air barrier can be created, however, fiberglass insulation will meet the performance expectation promised on the product's R-value label.

Some marketers of radiant barriers or spray foam insulation imply that R-value measurements are meaningless. On the contrary, R-value is a useful measurement. But just because you know a product's R-value doesn't mean you know everything necessary to predict heat flow through a wall or ceiling. R-value is just one factor among many to be considered when deciding which insulation to use. Builders must also understand many other topics, including air leakage and moisture movement. No one has yet invented a "magic number" that replaces the requirement for builders to study and understand building science principles.

Does Radiant Heat Pass Through Insulation Like Radio Waves?
Another scare tactic employed by some marketers of radiant barriers is the idea that conventional insulation materials — sometimes called "mass insulation" — allow radiant heat to pass right through them. Scam artists have been known to warn builders that "mass insulation is transparent to radiant heat." The implication is that a layer of aluminum foil is necessary to prevent radiant heat from traveling like radio waves right through a deep layer of cellulose.

In fact, most mass insulation products do a good job of stopping radiant heat flow. Radiant heat easily travels through air (for example, from a wood stove to nearby skin) or a vacuum (for example, from the sun to the earth). But radiant energy can't travel through a solid material.

If the sun is shining on a concrete patio, for example, the heat travels to the soil below by conduction, not radiation. Here's what happens: the concrete is first warmed by the sun (by radiation), and then the warm concrete gives off some of its heat to the ground below (by conduction). There is no radiant heat transfer from the sun to the soil.

When radiant heat hits one side of a deep layer of insulation, only a tiny percentage of that heat is "shine-through" radiation that manages to miss all of the fibers in the insulation blanket and emerge unscathed on the other side.

The fact that heat flows through a layer of insulation doesn't mean that the insulation isn't working. By definition, insulation slows down heat flow; it doesn't stop it. Heat will always flow from hot to cold. The more insulation, however, the slower the heat flow.

To read more blogs by Martin Holladay, visit the "Musings of an Energy Nerd" page at GreenBuildingAdvisor.com.

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