



Dow Building Solutions

Tech Solution 127.0: Understanding Roof Insulation Performance in Cold Storage Buildings



The thermal performance of insulation is measured by its thermal resistance or R-value. ASTM C518 or ASTM C177 are standard methods by which this property is determined. Figure 1 depicts a typical set-up for measuring R-value with one insulation face maintained at a high temperature and the opposing face at a lower temperature. The subsequent heat flow is measured and R-value determined. Insulation product standards specify that thermal resistance be reported at the standard 75°F.

Measurement of R-value at different mean temperatures can be determined using those same test methods. The relationship between R-value and insulation mean temperature is the so-called “mean temperature phenomena”. All insulation materials exhibit this phenomena in their own respective way. This phenomena has been known for decades by manufacturers and researchers ^{(1), (2), (3), (4)}.

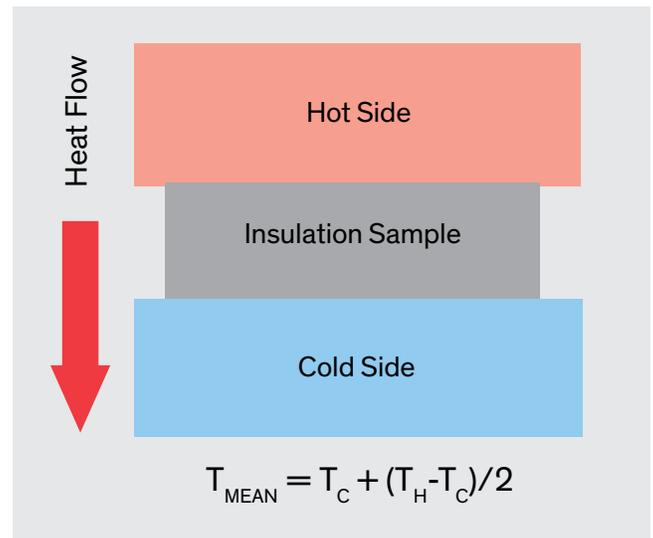


Figure 1. Thermal Resistance and Mean Temperature

Figure 2 specifically illustrates the temperature and thermal resistance relationship for most insulation types. There is a gradual increase in thermal resistance as the mean temperature is reduced. However this phenomena does not apply to all insulation types. Rigid foam plastic insulations rely on a mix of air and a low thermal conductivity blowing agent to provide high thermal resistance. Rigid foam plastic insulations use different blowing agents based on raw materials used in manufacturing, environmental regulations and physical properties required. These blowing agents possess different thermal and condensing/boiling points. Depending on the temperature in the foam cells some blowing agent may partially or completely condense out leaving only air as the insulating “gas” in the cells. Extruded Polystyrene insulation and roofing grade polyisocyanurate (ISO) currently use unique blowing agents that exhibit very different R-values versus

temperature behaviors. The ISO line in Figure 2 shows an increase in R-values down to a mean insulation temperature of about 55°F. As the mean temperature goes down the roofing ISO insulation R-values drop due to condensation of the blowing agent. STYROFOAM™ behavior (XPS in Figure 2) shows that STYROFOAM thermal resistance continually increases with reduced mean temperature.

NOTE: Not all polyisocyanurate foam insulations exhibit the same R-value relationship with temperature. DOW THERMAX™ brand polyisocyanurate Insulation gains R-Value at all lower mean temperatures, unlike roofing polyisocyanurate insulations that have been reported to lose significant R-Value in third party studies. This is because THERMAX™ Brand Insulation is different from other polyisocyanurate foam insulations in both the core properties and the facers.

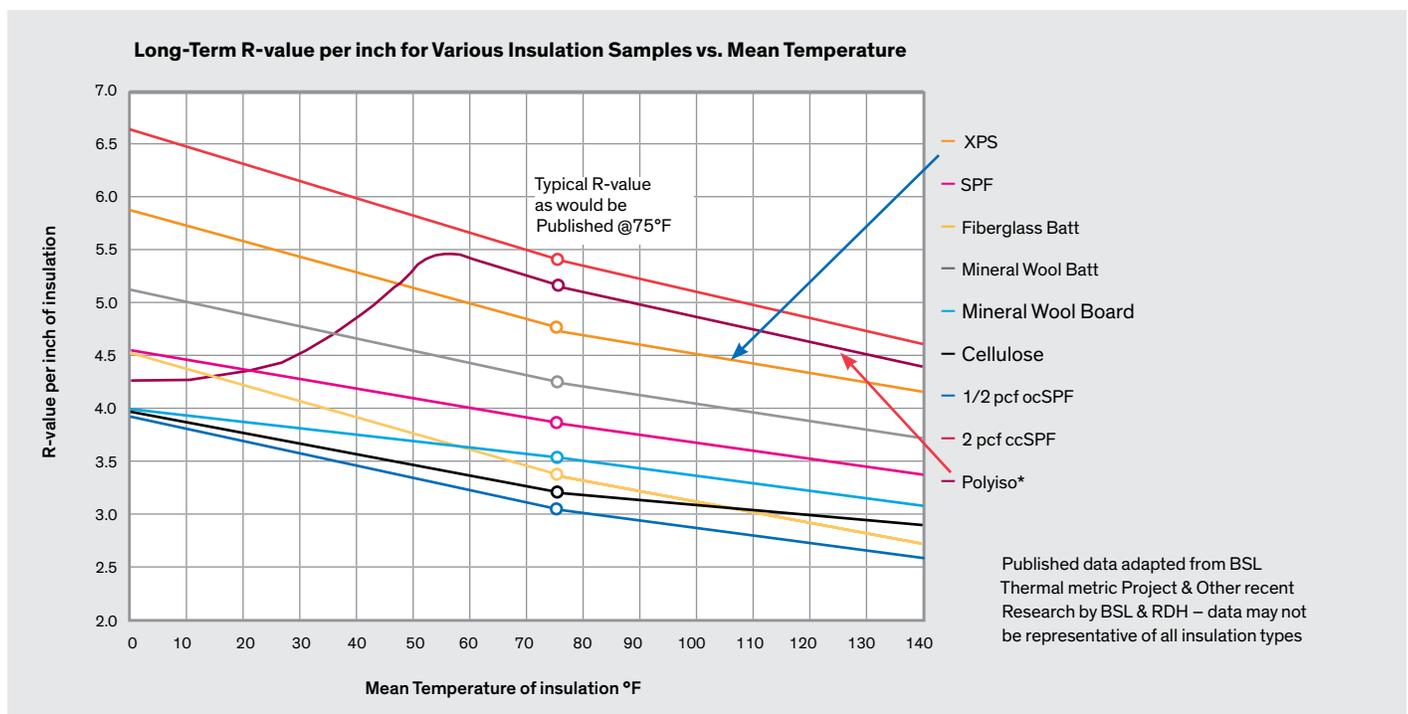


Figure 2. Thermal Resistance versus Insulation Mean Temperature

Cold Storage Buildings Temperatures and their Impact on Insulation R-value

A cold storage building will be designed to maintain constant **interior** operating temperatures between -20°F to 55°F. The **exterior** temperature above the roof line is dictated by the building location and that city’s mean exterior temperature.

Both temperatures determine the mean temperature of the insulation and thus its Effective R-value. Figures 3, 4 and 5 show the R-value of roofing ISO and STYROFOAM™ insulation for low temperature buildings maintained at -20°F, 0°F and +20°F. The R-values for these three cold storage conditions are shown as a function of mean outside temperature.

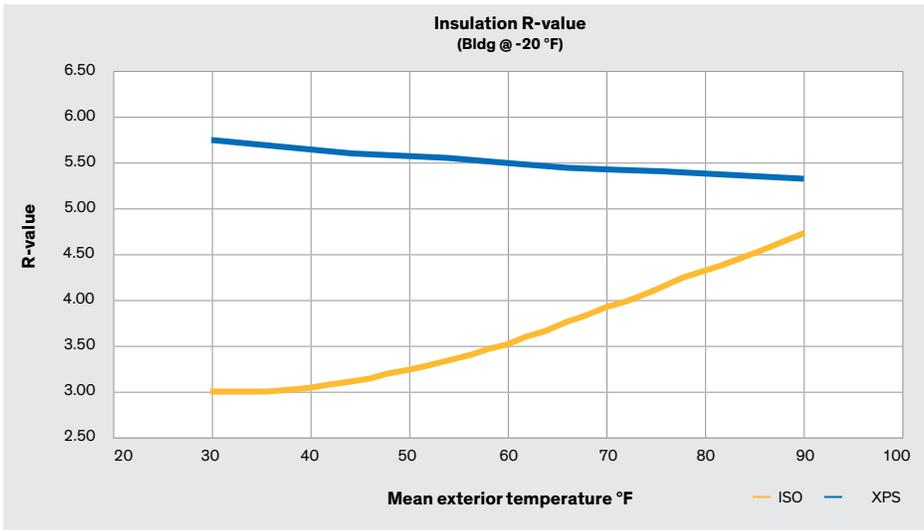


Figure 3. Effective R of Roofing ISO and STYROFOAM™ for Building Maintained at -20°F

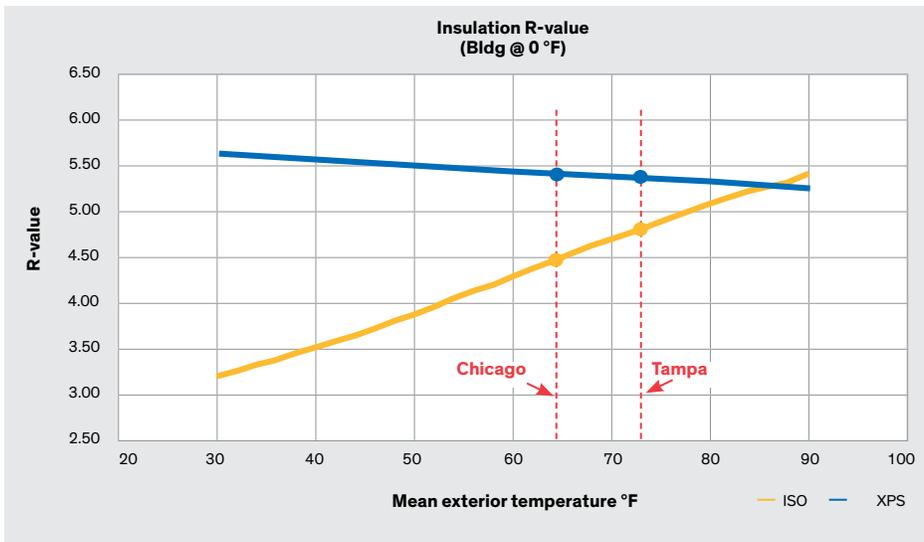


Figure 4. Effective R of Roofing ISO and STYROFOAM™ for Building Maintained at 0°F

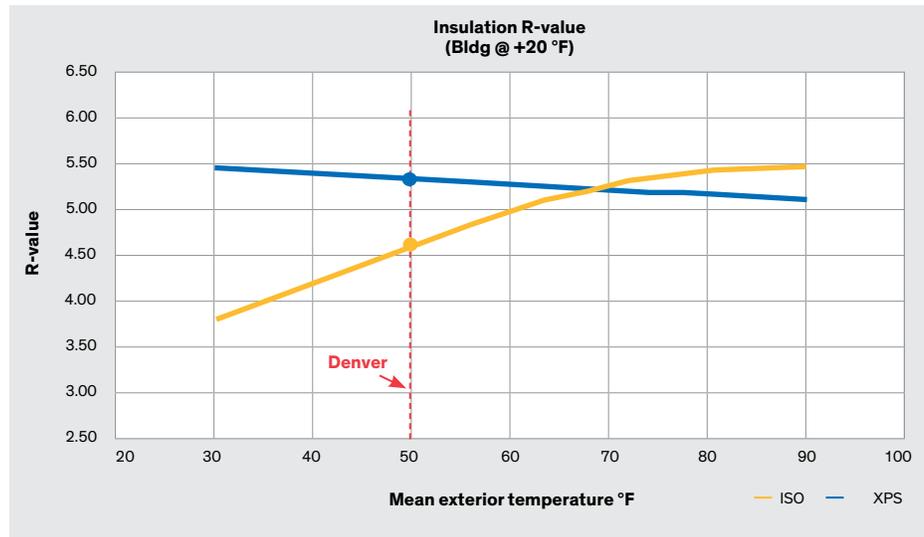


Figure 5. Effective R of Roofing ISO and STYROFOAM™ for Building Maintained at +20°F

How does your roof insulation perform in your particular Cold Storage building? Table 1 lists the mean annual temperature for selected USA cities. Used with Figures 3, 4 and 5 those mean exterior temperatures one can predict the operating R-value of ISO and XPS insulations.

Figures 3, 4 and 5 provides the designer with the effective R-value of Roofing ISO and XPS insulation for any city location.

Mean Annual Temperature (°F)	
Tampa	73.0
Denver	50.0
Houston	79.0
Boston	64.0
Chicago	65.0
Dallas	78.0
Los Angeles	69.0
Atlanta	74.0

Source: weatherbase.com

For example consider a 0°F cold storage building (Figure 4) located in Chicago (mean annual temperature 65°F). The Figure 4 predicted R-values of ISO and STYROFOAM™ are R-4.5 and R-5.4 respectively.

However the same 0°F cold storage building (Figure 5) operating in Tampa (mean annual temperature 73°F) predicts ISO and STYROFOAM™ R-values as 4.8 and 5.3 respectively.

Another example where we have a +20°F (Figure 6) Cold Storage building located in Denver (mean annual temperature 50°F). The predicted R-values of ISO and STYROFOAM™ are now R-4.7 and R-5.3 respectively.

The Impact of Reduced Thermal Resistance

Reduced roof insulation R-value results in higher heat gains and energy usage for Cold Storage buildings at its design operating temperature. The mean temperature of the insulation dictates its operating R-value. In Cold Storage buildings the mean temperature of the insulation will never be 75°F but much less. STYROFOAM™ insulation's R-value continually increases with reducing mean temperature. Roofing ISO R-value also increases with reduced temperature but only to about 55°F. Below that mean temperature ISO R-value decreases with a drop in temperature.

Choosing the right insulation can lead to substantial savings in cooling to a building owner over the life of the facility. In addition to increased efficiency, as its temperature reduces, STYROFOAM™ possesses moisture performance superior to roofing grade ISO insulation. In the event of a roofing failure, moisture leakage in the assembly will be partially absorbed by ISO insulation. Water that is not absorbed into the ISO foam will make its way into the climate controlled facility causing significant damage and possible contamination.

If a repair or reroofing the structure is needed, STYROFOAM™ insulation can be re-used. This can save the building owner significant money, eliminating unnecessary disposal charges and limiting the environmental impact. Only high performing insulation can help with common moisture problems often seen in these structures. Also important to building operation is moisture control through proper air sealing and vapor control. These controls can help eliminate ice buildup and stored content contamination concerns.

STYROFOAM™ insulation is time-tested with proven performance for over 70 years. With our industry leading 50-year thermal warranty in North America, you have chosen the highest quality rigid insulation regardless of temperature or weather conditions your building is subjected to.

¹ "The influence of environmental factors on thermal resistance of rigid polyurethane foams",

M. T. Bomberg, M.K. Kumaran, M. R. Ascough, SPI Polyurethane World Congress, 1991.

² 1965 Product Information Sheet for THURANE™ Brand Plastic Foam made by The Dow Chemical Company.

³ "Dow Building Insulation Products and Systems", Dow Technical literature, 1963

⁴ "Permanent Insulation for Buildings – STYROFOAM™, DORVON™ and THURANE™ Brand Plastic foam, Dow technical literature, January 1968

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WARNING: Rigid foam insulation does not constitute a working walkable surface or qualify as a fall protection product.

Building and/or construction practices unrelated to building materials could greatly affect moisture and the potential for mold formation. No material supplier including Dow can give assurance that mold will not develop in any specific system.