Capturing the Thermal Performance of FOAMULAR® Extruded Polystyrene (XPS) vs. Polyisocyanurate

Technical Bulletin

Exploring the impact of temperature dependent R-values on rigid insulation and building performance

Summary

Extruded polystyrene (XPS) and Polyisocyanurate (polyiso) rigid foam insulation are both designed to provide thermal resistance in residential and commercial building construction applications. For example, in exterior above-grade wall assemblies, a layer of rigid insulation is often specified to comply with the prescriptive R-value requirements outlined in energy codes and standards such as the International Energy Conservation Code (IECC) and American Society of heating, Refrigeraton and Air-conditioning Engineers (ASHRAE) 90.1. However, despite being used in similar applications, XPS and polyiso have very distinct product compositions that can result in significant thermal performance differences.

This technical bulletin describes how the R-value of rigid insulation changes based on the temperature it is exposed to. In other words, it is temperature dependent. For example, the R-value of XPS *improves* as the temperature declines. However, the R-value of polyiso can decrease substantially as the temperature declines. New research also illustrates that wall assemblies built with XPS can provide greater thermal performance than those that are built with polyiso. This is especially true in colder climates.

Given the significant impact that continuous insulation has on the thermal and moisture performance of a building envelope, the differences in R-value performance between XPS and polyiso deserve careful consideration when selecting a rigid insulation.

Understanding Published R-values

To help consumers understand and compare the thermal performance of insulation products, the Federal Trade Commission (FTC) requires insulation manufacturers to publish the R-value of their product on the product packaging. R-values shown on packaging reflect the R-value of the product when it is tested at a mean temperature of 75°F.

XPS has a published R-value of R5.0 per inch and polyiso is listed at a range of R5.6 to R6.0 per inch.[1] Accordingly, for those seeking to specify a product with the highest R-value per inch, polyiso may appear to be the logical choice. However, the 3rd-party building science research described below illustrates that these published R-values can be misleading because they don't describe how products perform at colder temperatures. In other words, we know the R-value of each product at 75°F, but what is it at lower temperatures, such as 15°F?

Science Doesn't Lie

When comparing the R-value of insulating materials it is helpful to understand the thermal conductivity of each. Thermal conductivity is defined as the rate at which heat transfers through a material between points at different temperatures. Once the thermal conductivity of a material is known, the R-value can be calculated (e.g., R-value per inch = 1 divided by the thermal conductivity of the product). Products with a low rate of thermal conductivity have greater thermal resistance (and higher R-value) than products with a higher rate of thermal conductivity.

Recently, Building Science Corporation (BSC) published the *Thermal Metric Summary Report*[2] regarding their Thermal Metric Project and Reference Wall testing. The long-term goal of this project was to develop a new metric for the thermal performance of building enclosures that better accounts for known physical heat flow mechanisms (particularly natural and forced convection) and operating conditions. This project included a focus on better understanding the thermal conductivity of insulating materials at different mean temperatures. While experts have known for years that the thermal conductivity of insulation changes based on the temperature, they likely did not know how *differently* XPS and polyiso behave when exposed to cold temperatures. In fact, what BSC discovered was quite revealing.

As shown in Figure 1, the thermal conductivity of XPS steadily *decreases* as the mean temperature declines. However, polyiso (PIC Cartridge TB) does not follow the same pattern. Instead, the thermal conductivity of the polyiso sample actually *increases* as the temperature declines, resulting in a substantial loss in R-value.

Capturing the Thermal Performance of FOAMULAR® Extruded Polystyrene (XPS) vs. Polyisocyanurate

Technical Bulletin

Converting Thermal Conductivity to R-Value

When converting these thermal conductivity results to R-value performance, the differences between XPS and polyiso are readily apparent (see Table 1).

- **XPS:** At a mean temperature of 75°F, the thermal conductivity of XPS correlates well with its published R-value of R5.0/inch. Moreover, the R-value of XPS increases to approximately R6.0 as the mean temperature drops to 15°F.
- **Polyiso:** At a mean temperature of 75°F, the polyiso sample also exhibits a level of thermal conductivity which correlates to its published R-value of R6.0/inch. However, as the mean temperature drops to 15°F, the R-value decreases to approximately R2.0, representing a significant 66% loss in R-value.

Why Does the Thermal Performance of Polyiso Decline in Colder Temperatures?

The increased thermal conductivity and inconsistent performance of polyiso is primarily attributed to the amount and type of blowing agent used to manufacture the product. The blowing-agent (insulating) gases that are entrapped within the cells of polyiso begin to condense (change from a gas to a liquid) at colder temperatures and, as those gases condense, the thermal conductivity of polyiso increases.

Figure 1. Thermal conductivity test results from Building Science Corporation[2]

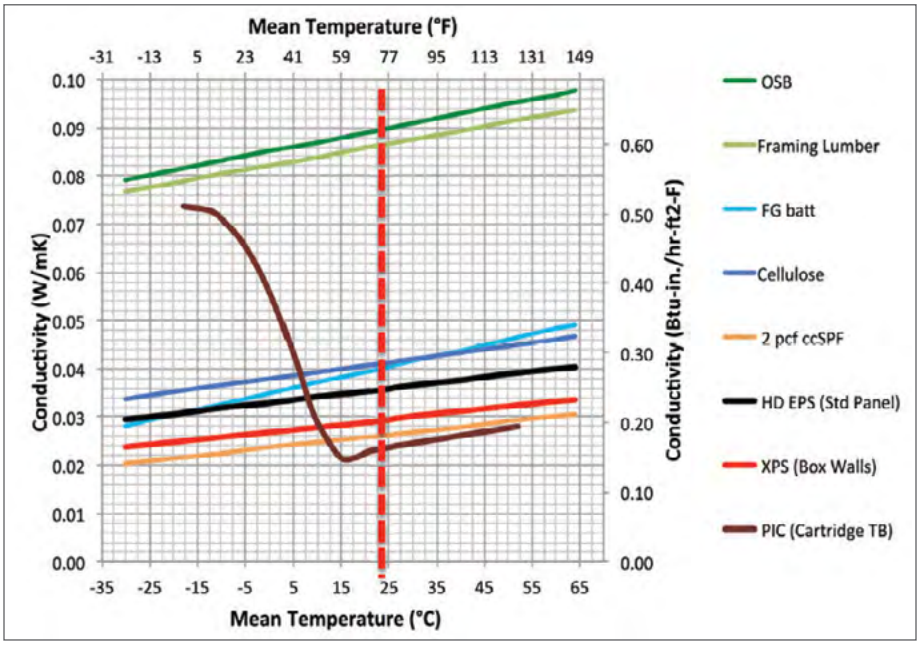
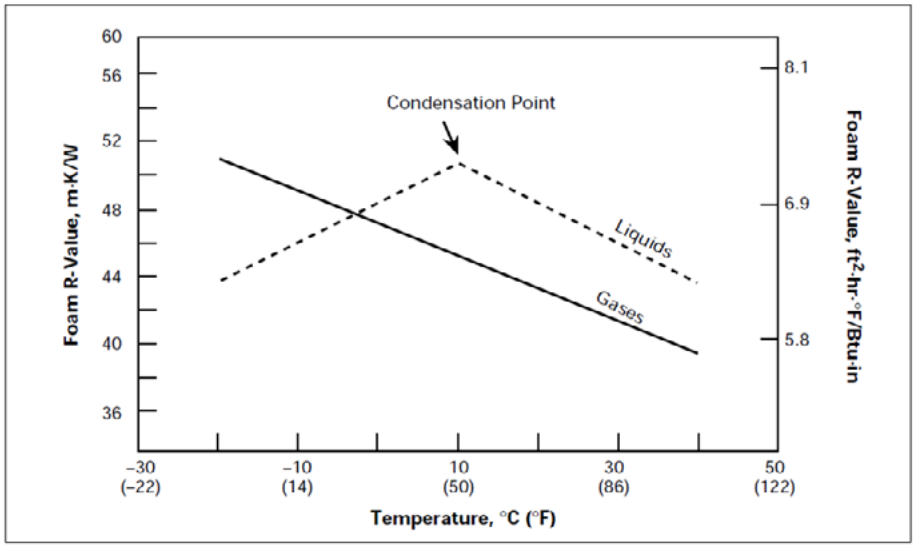


Table 1

Rigid Insulation	R-value at 75°F Mean	R-value at 15°F Mean	R-value % Change
XPS	1/.200 = R5.0	1/.165 = R6.0	+20% ⬆
Polyiso	1/.166 = R6.0	1/.500 = R2.0	- 66% ⬇

Note: R-value per inch = 1 divided by thermal conductivity.

Figure 2. Foam Insulation Value Versus Temperature for Liquid and Gaseous Blowing Agents[3]



The blowing agent (insulating) gases that are entrapped within the cells of the XPS, however, remain as a gas over the tested temperature range. Figure 2 uses averaged data to illustrate the effect of blowing agent boiling point on a foam's insulation value. This data demonstrates one of the advantages of low-boiling blowing agents: improved insulation performance over a broader operating temperature range. And, the better the insulation performance, the lower the energy consumption of products that rely on these high-value foam insulations[3].

Comparing XPS and Polyiso in Wall Assemblies

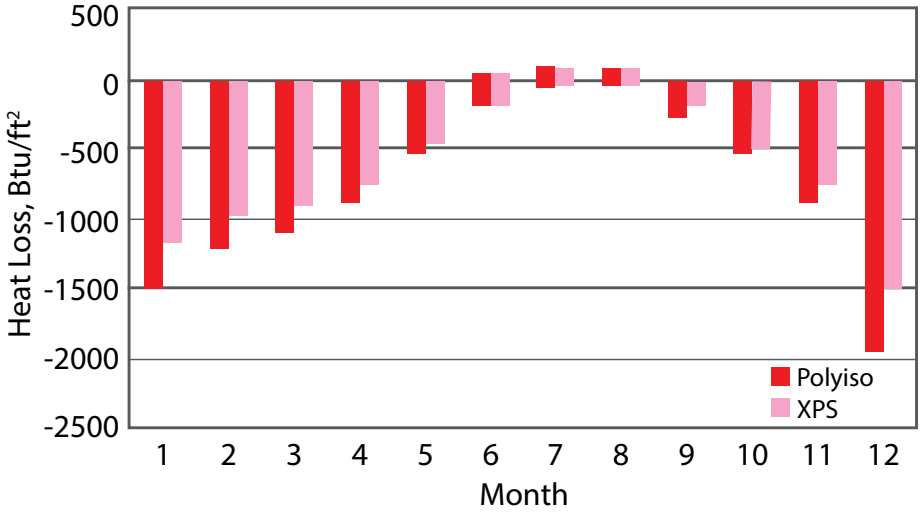
Taking into account the thermal conductivity data shown above, Owens Corning used WUFI, a leading hygrothermal modeling software program, to explore how wall assemblies that are built with XPS and polyiso would perform in a variety of climates. The study included Chicago, Minneapolis and Toronto, where winter temperatures are often in the single digits for prolonged periods of time. Two exterior wall types (each with brick veneer cladding) were evaluated, including:

- 2' x 4' wood-framed, fiberglass-insulated wall with XPS continuous insulation
- 2' x 4' wood-framed, fiberglass-insulated wall with polyiso continuous insulation

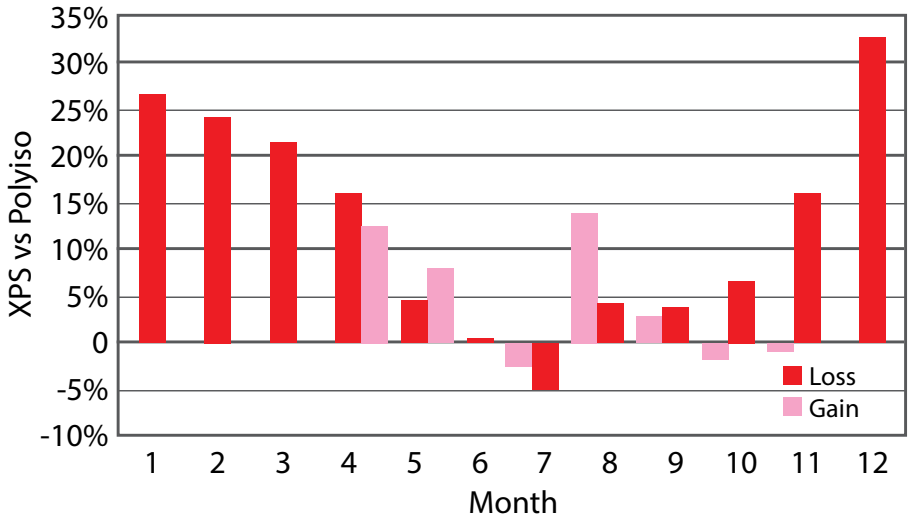
The WUFI results for Chicago (Figure 3) are expressed in terms of heat loss and heat gain on a month-by-month basis. As

Figure 3. *(R10 board for both XPS and Polyiso)*

Heat Flows - XPS vs. Polyiso



Differences in Heat Flow: Polyiso Heat Loss or Gain versus XPS



shown, both XPS and polyiso wall assemblies perform about the same during the summer. However, in the winter months, it's clear that walls built with XPS perform better than those constructed with polyiso. On an annual basis, the heat flow results show that 2 inches of XPS is 21% more efficient than polyiso (and 1 inch of XPS is 12% more efficient than polyiso).

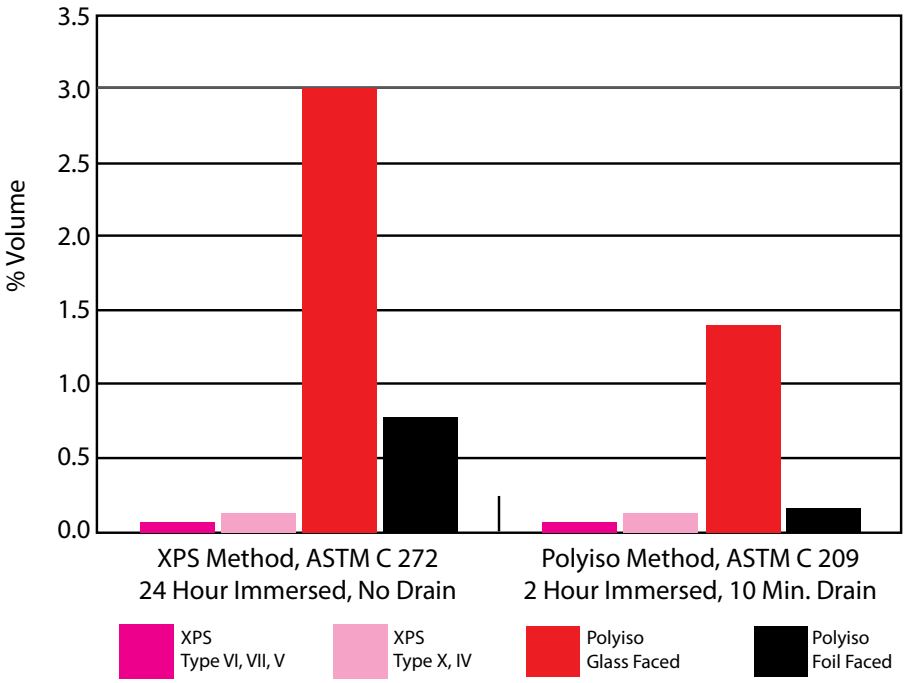
Water Absorption

The material standard that defines properties for all XPS and EPS is ASTM C578[4]. It requires that polystyrene insulation be tested for water absorption in accordance with ASTM C272[5]. C272 requires the polystyrene sample to be immersed in water for 24 hours, and weighed immediately upon removal from immersion to determine the

amount of absorbed water. The material standard for polyiso is ASTM C1289[6]. It requires that polyiso be tested for water absorption in accordance with ASTM C209[7]. C209 requires the polyiso sample to be immersed in water 2 hours, and drained for 10 minutes before weighing for water absorption. Figure 4 shows the significant differences in XPS and polyiso water absorption that result from using different measuring techniques. Note that the water absorption level for polyiso increases greatly when tested by the same method used for XPS. Glass faced polyiso goes from absorbing 14x more water than XPS, to absorbing 30x more water than XPS, when measured using the same method. Foil faced polyiso goes from absorbing 1.5x more water than XPS, to absorbing over 7x more water than XPS. Because the presence of foil makes such a difference in water absorption, the long-term durability of the foil is critical. If the foil is punctured or corrodes while in service, the polyiso core is unprotected from water, and is even more prone to higher water absorption, like the condition with glass facers.

Figure 4

Heat Flows - XPS vs. Polyiso



Resisting Water Absorption, the Key for High Performance Insulation

Moisture gets into all types of buildings. Unless the building insulation is highly resistant to water absorption, moisture can degrade insulation R-value, structural integrity and provide an essential ingredient to support mold growth. Water is a good conductor of energy, so if insulation is water soaked, R-value is lost. Also, compressive strength may be reduced by water absorption depending on the make-up of the foam plastic insulation, hydrophobic/closed cell XPS or hydrophilic/more open cell polyiso. Therefore, absorbed moisture is to be avoided to achieve sustainable quality construction. One of the greatest attributes of XPS is its ability to retain R-value and compressive strength even when exposed to water.

Conclusion

In the BSC testing described above, the XPS and polyiso samples both performed as expected when tested at a mean temperature of 75°F. However, when tested at lower temperatures, each behaved quite differently. The R-value of XPS improved as the temperature declined, while the R-value of polyiso decreased substantially as the temperature declined. Further analysis, using WUFI, illustrates that these differences can have a significant impact on the thermal performance of a construction assembly.

Accordingly, when specifying rigid insulation, it is important to understand the R-value performance of each product being considered. In addition, architects and engineers should consider researching the thermal conductivity of products when they are exposed to cold temperatures (when R-value matters most) and account for any unusual performance variations when conducting energy modeling.

Capturing the Thermal Performance of FOAMULAR® Extruded Polystyrene (XPS) vs. Polyisocyanurate

Technical Bulletin

Owens Corning® FOAMULAR® XPS

Available in a variety of compressive strengths, Owens Corning® FOAMULAR® XPS insulation delivers exceptional moisture resistance and provides long-term durability and performance by retaining its high R-value. In addition it is a recyclable material with the following recognition:

- FOAMULAR® XPS is the first XPS with a third party, independently certified, minimum 20% recycled content by SCS Global Services.
- FOAMULAR® XPS is the only XPS that is GREENGUARD Gold certified.
- FOAMULAR® XPS has an industry-leading lifetime limited warranty* across all thicknesses and compressive strengths.

For more about Owens Corning® FOAMULAR® XPS insulation and applications that can benefit from XPS insulation, visit: www.OCBuildingSpec.com.

For more information about the Building Science Corporation testing, read the *Thermal Metric Summary Report*[2]. Additional resources are available via phone call at 1-800-GET-PINK®.

[1] http://www.astm.org. C578. C1289.

[2] *Thermal Metric Summary Report*. Building Science Corporation. http://www.buildingscience.com/documents/special/content/thermal-metric/BSCThermalMetricSummaryReport_20131021.pdf, 2013.

[3] DuPont™ Formacel®. "Temperature Effect on the Insulation Value of Polyurethane Foams," 2011.

[4] ASTM C 578-06, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation; ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959

[5] ASTM C 272, Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions; ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959

[6] ASTM C 1289-06, Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board; ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959

[6] ASTM C 209, Test Methods for Cellulosic Fiber Insulating Board; ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959

OWENS CORNING FOAM INSULATION, LLC
ONE OWENS CORNING PARKWAY
TOLEDO, OHIO, USA 43659
1-800-GET-PINK®
www.owenscorningcommercial.com

Pub. No. 10019949. Printed in U.S.A. June 2015.