Dow Building Solutions

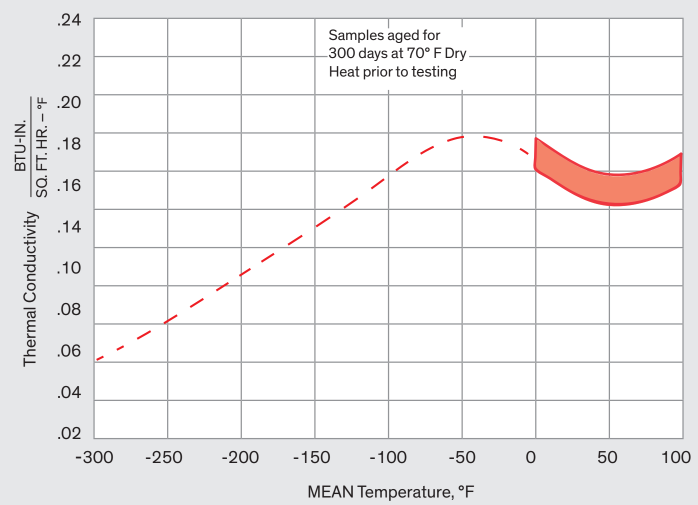
Tech Solution 538.0: Understanding Mean Temperature Phenomenon for Polyisocyanurate Insulations

Although insulation manufacturers have typically reported singular R-Values for their products, it has been known for more than a century that the R-Value of insulations, and indeed all materials, changes with the mean temperature at which it is measured. For virtually all materials this is a gentle curve of increasing R-Value with decreasing measurement temperature. This change in R-Value with the mean temperature of its measurement is sometimes referred to as the “mean temperature phenomena”.

But some materials exhibit strange behavior. Their gently curving line has a bump in it. These strange materials are typically insulations. More specifically, insulations that contain an insulating gas that enhances the R-Value of the material are known to exhibit the “mean temperature phenomena”. When the gas condenses to a liquid within the insulation at lower temperatures, the R-Value is slightly reduced as the condensed gas can no longer influence the R-Value of the insulation.

This phenomenon has been known and understood for a long time. Here is a graph from a polyisocyanurate technical publication in 1965 (See Figure 1). It uses conductivity (1/R-Value) rather than R-Value, but the distinctive bump is still there. So there is nothing surprising, unusual, or unknown about detecting this kind of curve with certain plastic foam insulations.

Figure 1 – Thermal Conductivity vs. Mean Temperature of Thurane



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

Modern Claims of Mean R-Value Are Incomplete

In the first decade of the twenty-first century, some building science researchers continued to investigate this mean temperature phenomena with modern insulations to determine how insulation R-Value changes with mean temperature and if the newer R-Value enhancing gases had the same mean temperature effect as their counterparts in the past.

The most popular and comprehensive study of the mean temperature phenomena for insulations is the Thermal Metric Project (along with associated related research), a multi-year collaborative research project headed by Building Science Corporation and a group of industry partners. The mean temperature phenomena portion of this data from these studies have been presented in a variety of forms, but a common summation is shown in Figure 2 below.

Although this graph includes many types of insulations--including polyisocyanurate foam insulation (shortened to "Polyiso" in the legend)--the type of polyisocyanurate foam insulation in the BSL Thermal Metric Project is only roofing Polyiso insulation, which is significantly different from THERMAX™ Brand Insulation, patented, designed and manufactured for wall applications. In fact, polyisocyanurate foams have a wide range of property variations as a result of varying/different proprietary formulations used by each manufacturer and for different grades of foam.

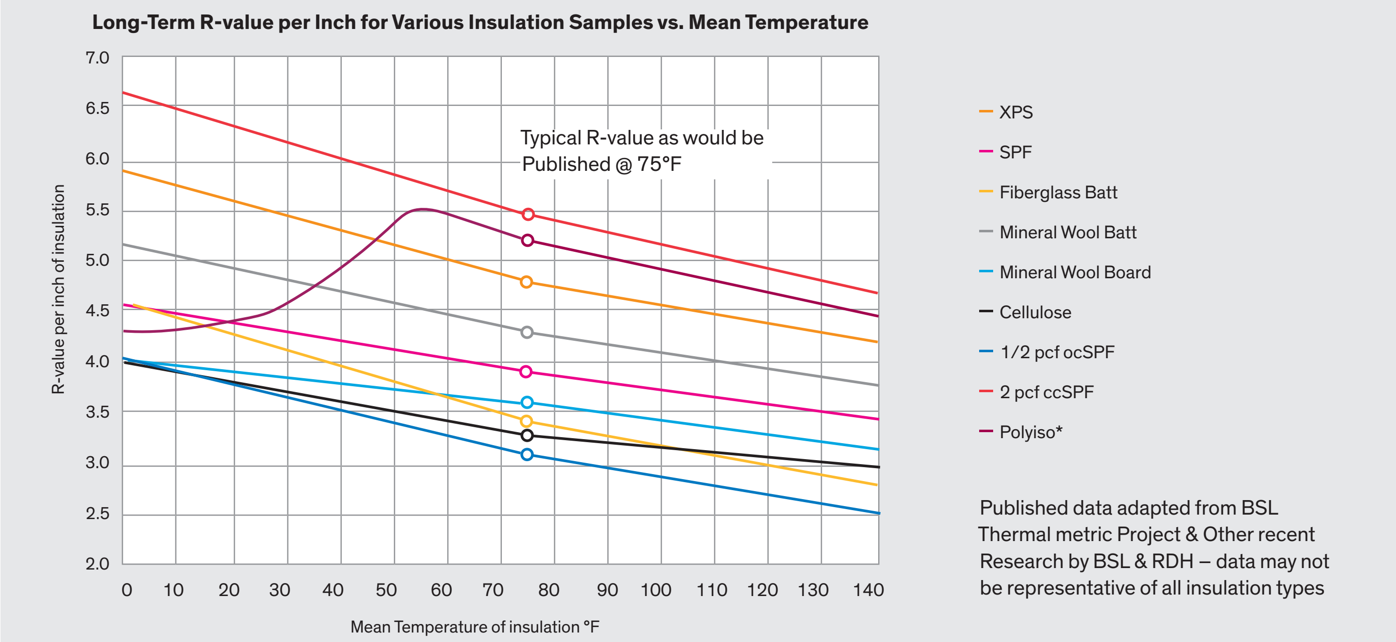


Figure 2: Common representation of selected insulation R-Values as a function of Mean Temperature

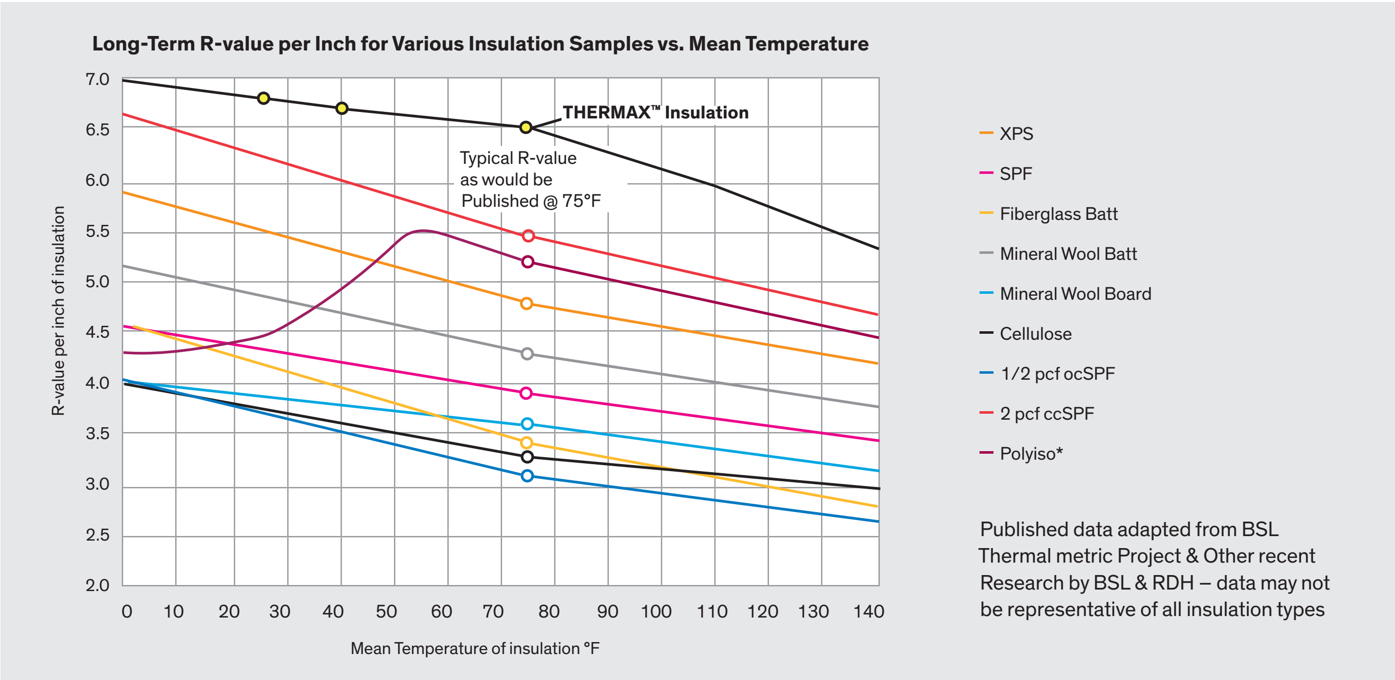


Figure 3: Common Representation of Selected Insulation R-Values as a function of Mean Temperature with THERMAX Brand Insulation properties added.

In Figure 3, the same graph has been altered to include the R-Value of THERMAX Brand Insulation at three different mean temperatures to show just how much the lack of THERMAX Insulation data represents. This further illustrates how polyisocyanurate insulations can differ from one another. Wall-polyisocyanurate foams are designed to meet the fire and vertical application performance requirements through use of different chemical formulation, which inherently separates the Polyiso foam for walls from those used in roofs even if offered by the same manufacturer. The labeled THERMAX Brand Insulation R-Values are all above the 6.5 R-Value mark, significantly higher than the other polyisocyanurate insulations shown.

Real World Test Results

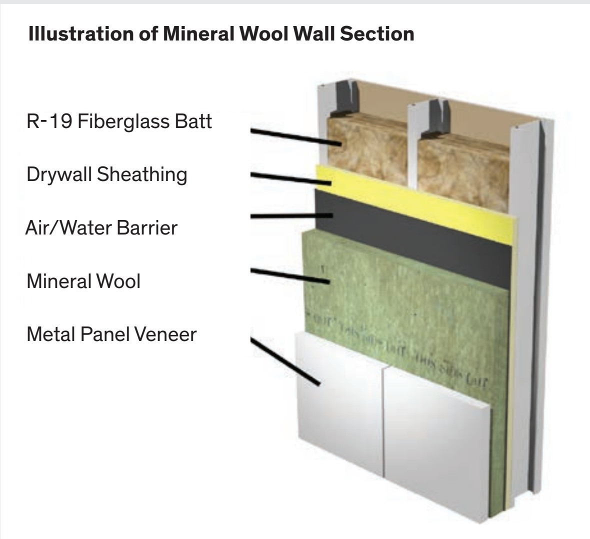
The laboratory test results shown above are accurate, but may be limited in that they do not represent the product's performance in an actual assembly under real exterior conditions. To better understand the performance of THERMAX Brand Insulation in actual use, a full scale assembly was tested in real world climate conditions.

As part of an effort to investigate a wide range of Building Science phenomena, The Dow Chemical Company built a long term field testing facility in Midland, Michigan, the Dow Building Solution's Wall Assembly Research Center.

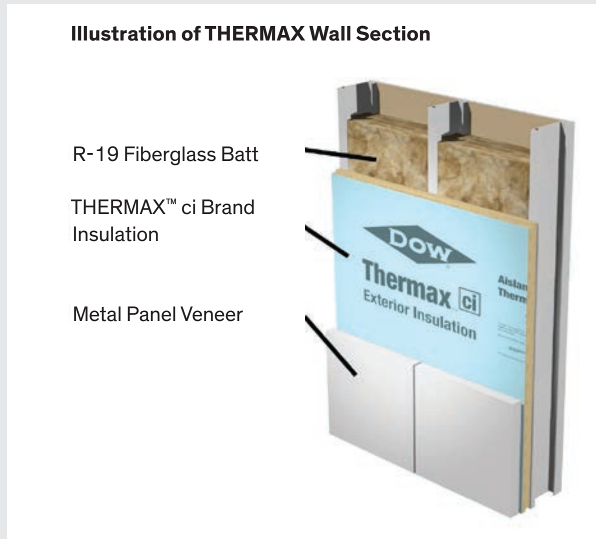
Within this test facility, various wall configurations can be built, and their long term thermal and moisture properties can be measured with state-or-the-art scientific instruments, which give our building science experts access to hundreds of thousands of data points of the performance of several wall assemblies in real world conditions. These sensitive instruments were installed and monitored with the help of Building Science Corporation, a consulting company known for its building science expertise. A picture of the state of the art, Wall Assembly Research Center is shown below.

Wall Assembly Research Center: A laboratory built by The Dow Chemical Company in Midland, Michigan to test the performance of several different wall assemblies in real world conditions.

This testing facility was recently used in a multi-year study of the real world performance of both THERMAX insulation and mineral wool sheathing insulations to better understand the actual effects of the mean temperature phenomena. Two wall sections were built into the test hut and were carefully instrumented to measure heat flow. These two wall systems are described and illustrated below:



Mineral Wool Wall Section – R10 CI (2.4") + R19 Cavity



THERMAX Insulation Wall Section – R10 CI (1.55") + R19 Cavity

Both wall sections were built with R-19 fiberglass batts between steel studs and R-10 sheathing insulation covering the studs as continuous insulation. The R-10 Continuous sheathing insulation corresponds to a 2.4 inch thickness of Mineral Wool and a 1.55 inch thickness of THERMAX Brand Insulation. Although both of these walls use R-10 continuous insulation outboard of the steel studs, they are not the same when it comes to practicality. The water resistive and rigid nature of THERMAX Brand Insulation results in a much simpler system where the insulation provides all the necessary barrier layers of the wall system. Using water and vapor permeable layers will result in the need for additional layers (a support layer and water/vapor barrier layer) to achieve an acceptable design.

In theory, these walls should perform in a nearly identical manner at higher temperatures (like 75°F) when it comes to heat flow. If the mean temperature phenomenon has a significant effect on the real world thermal performance of THERMAX insulation, then the thermal performance of these two wall systems should diverge as the exterior temperature gets lower and lower.

The measured data from these two wall systems was taken from the month of February, 2015. This was an excellent time for such a study as exterior temperatures were significantly lower than normal. See Figure 4 for these real world measured results.

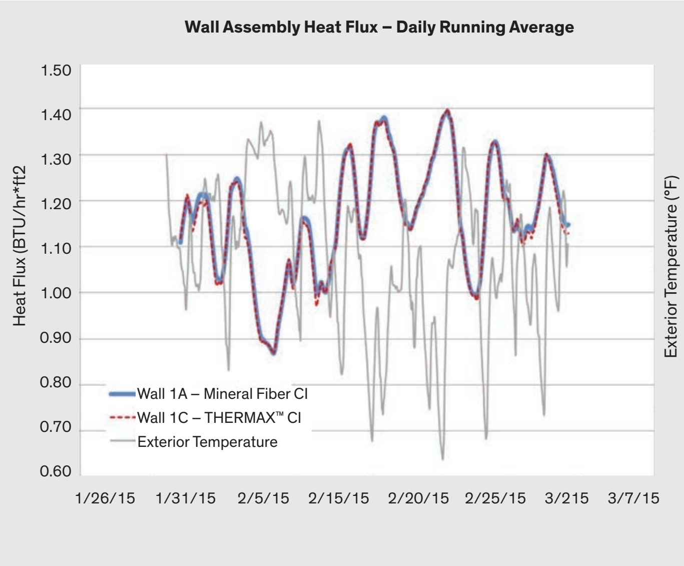


Figure 4: Real World Heat Flux through Two Wall systems (Both R10 CI) in Midland, Michigan during February, 2015.

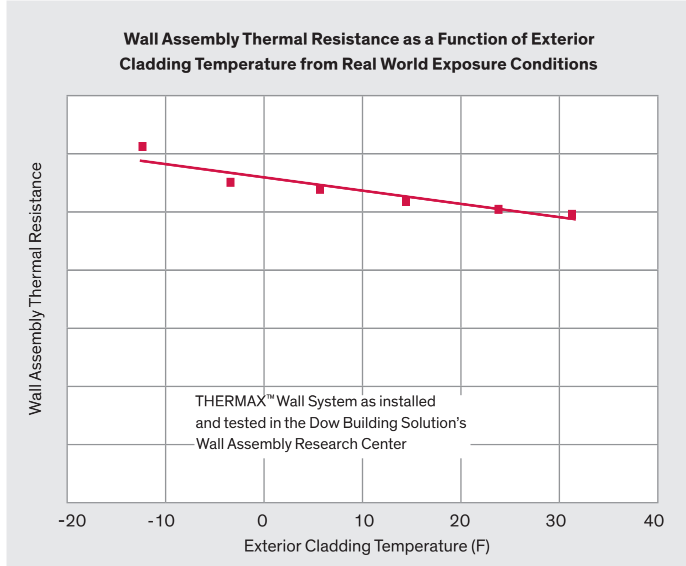


Figure 5: Real World calculated R-Value as a function of exterior temperature during February, 2015.

There are three lines on this graph of the thermal performance of these wall systems, but it is hard to tell since it looks like there are only two. The gray line indicated the exterior air temperature measured every hour during the month. We would expect to see the amount of heat driven through the wall to increase when the outside air temperature decreases due to the greater temperature difference across the wall assembly, and that is exactly what we see.

What we also see is that the measured thermal performance of the two wall systems is nearly identical across a wide span of exterior air temperatures when installed to the same target CI R-value. The heat flux through the mineral wool wall is represented by a solid blue line and the heat flux through the THERMAX Insulated wall is represented by the dotted red line. The heat flux is a measure of the actual, real world insulating performance of each wall section and the associated insulation. The two lines are so identical that it is hard to tell that there are two separate lines describing the thermal performance for the two distinct types of continuous insulation.

This data can be looked at in another way to make a more direct investigation of the mean temperature phenomena of this wall configuration. We can combine the Heat Flux with the temperature difference across the system to get an assembly thermal resistance. We can then compare this calculated R-Value to the exterior temperature to see if there is any change in the thermal resistance with temperature. When this is done with the THERMAX Insulated wall system, we get the data shown in Figure 5.

Note: This study does not include effects of water intrusion into insulation products that can occur during temperatures above freezing. Insulations susceptible to water absorption will experience deteriorated thermal performance during wetting periods.

The Conclusion: THERMAX™ Brand Insulation maintains its R-Value at lower temperatures both in the labortatory, and in the real world.

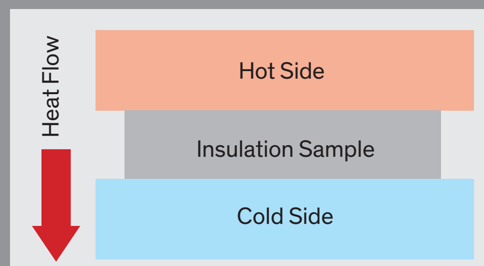
1. In the laboratory, THERMAX Brand Insulation gains R-Value at lower mean temperatures, unlike other types of polyisocyanurate insulations that have been reported to lose signifi cant R-Value in third party studies. This is because THERMAX Brand Insulation is different from other polyisocyanurate foam insulations in both the core properties and the facers. Since 1975, there have been 16 patents granted for THERMAX™ insulation, validating its unique performance and innovation amongst other insulation materials.

2. THERMAX Brand Insulation does not change R-Value any differently than mineral wool in real world assemblies when the exterior temperature gets very low. Even at a tempera ture as low as -15°F. This data shows that the alleged poor low temperature performance of polyisocyanurates shown in other studies (refer to Figure 1) simply does not apply to THERMAX Brand Insulation. 1.55" of THERMAX Brand Insulation installed direct to the steel studs performed thermally equal to a system comprised of 2.4" Mineral Wool, WRB and Exterior Sheathing (3" total thickness).

To measure a material's R-value, it must be exposed to a temperature difference causing heat to flow from the warmer side to the colder side of the insulation (Figure 6). Measuring the resulting heat flow allows the R-value to then be determined. The average of this temperature difference is referred to as the "mean temperature."

A product's R-value can vary significantly depending on the mean temperature used. For this reason, the R-value of different insulation materials should be compared at the same mean temperature. The Federal Trade Commission (FTC) has established the mean temperature for which insulation R-values should be measured and reported as 75°F.

Even though the FTC has established 75°F as the standard mean temperature at which to measure and report R-Value, this doesn't mean we cannot also compare insulations at other mean temperatures. However, it is important to look at the same mean temperature when comparing insulations.



$$\text{Mean Temperature} = \frac{T_{hot} + T_{cold}}{2}$$

Figure 6: Basic set up for measuring heat flow and the resulting R-Value for and insulation material.

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