

# Tech Solutions 538.0

## Understanding Mean Temperature Phenomenon for Polyisocyanurate Insulations

### Introduction

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.

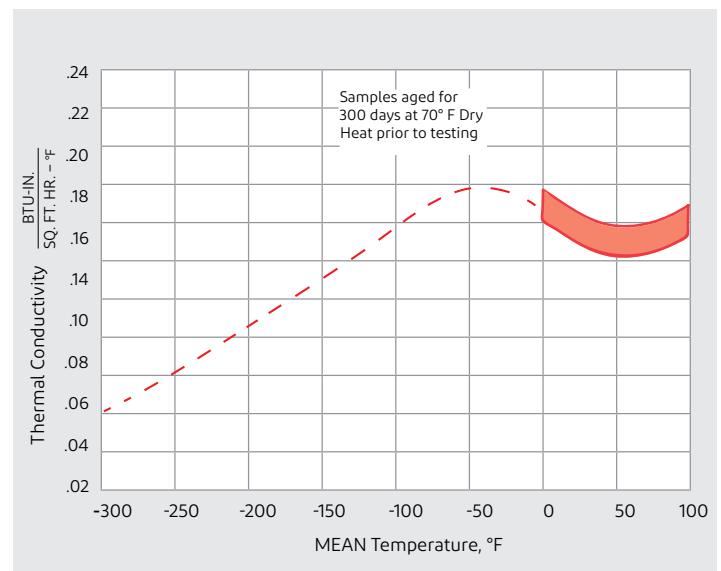


Figure 1 – Thermal Conductivity vs. Mean Temperature of Thurane

\* 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 21st 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.

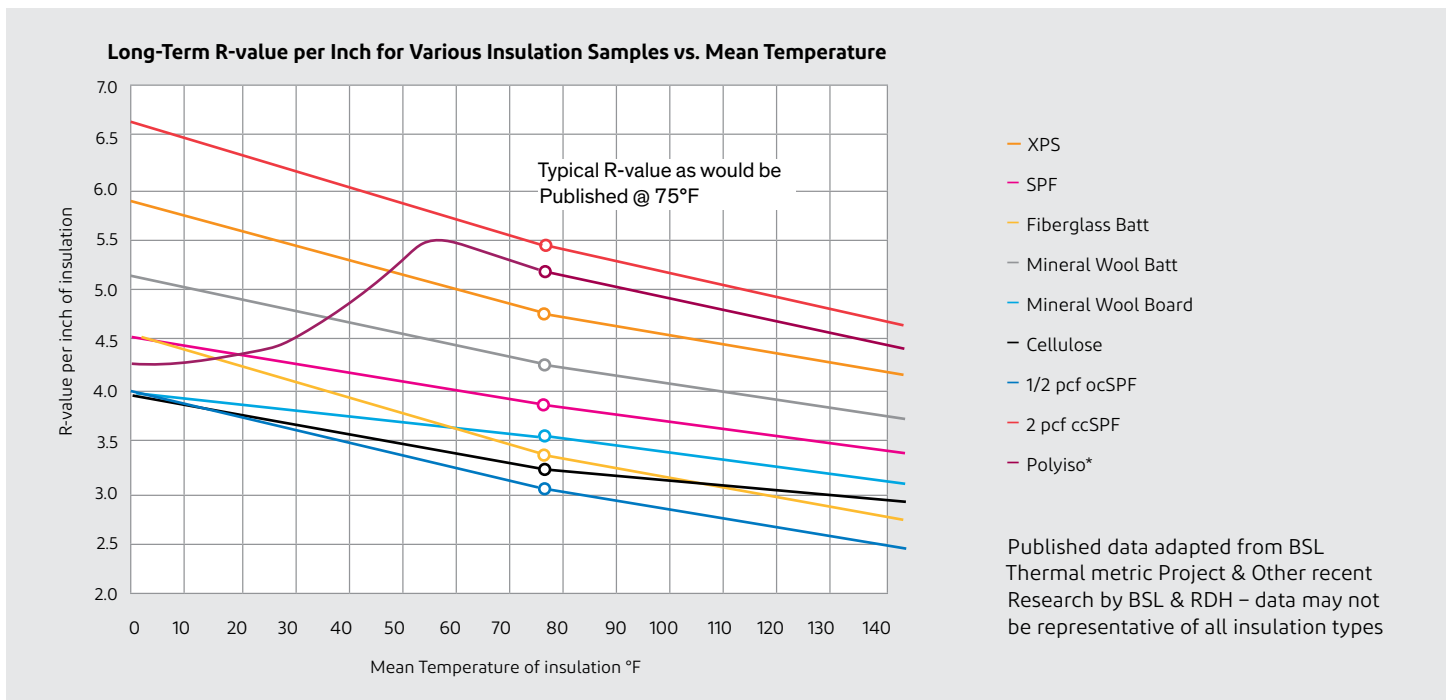
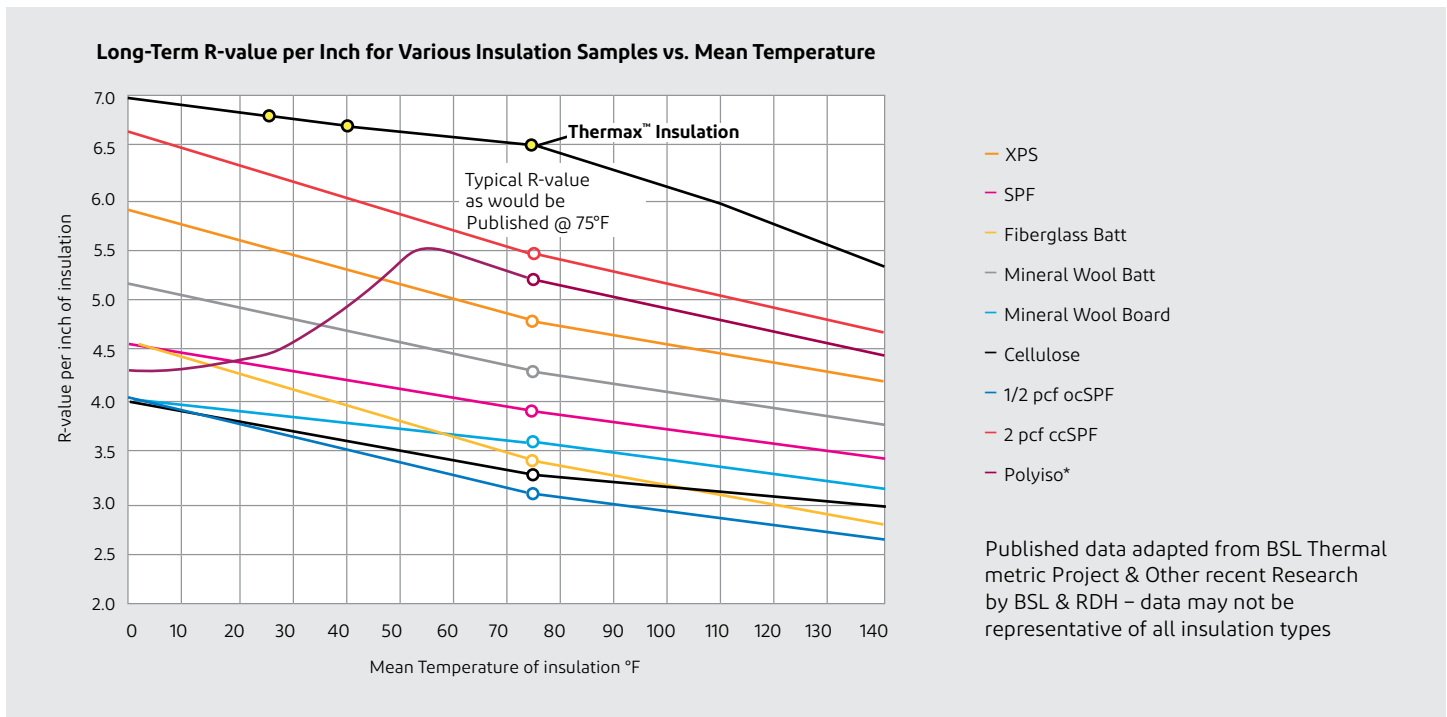


Figure 2: Common representation of selected insulation R-Values as a function of Mean Temperature



**Figure 3:** Common Representation of Selected Insulation R-Values as a function of Mean Temperature with Thermax™ Brand Insulation properties

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.

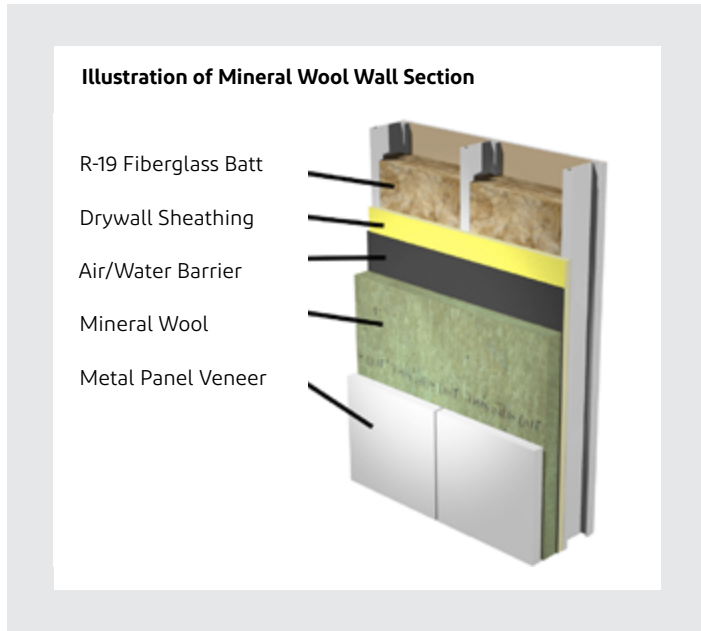
As part of an effort to investigate a wide range of Building Science phenomena, The Dow Chemical Company built a long term field testing facility in Midland, Michigan, the Dow Building Solution's Wall Assembly Research Center.

Within this test facility, various wall configurations can be built, and their long term thermal and moisture properties can be measured with state-of-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.

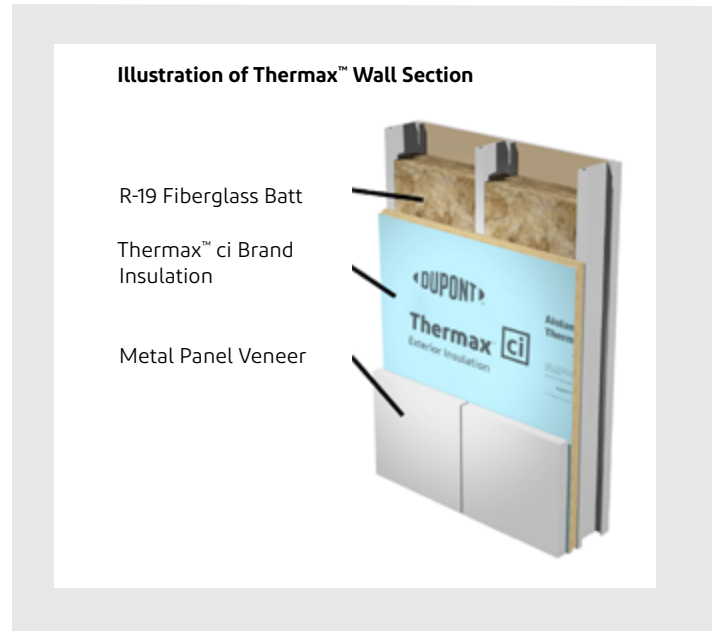


**Wall Assembly Research Center:** A laboratory built by The Dow Chemical Company in Midland, Michigan to test the performance of several different wall assemblies in real world conditions.

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

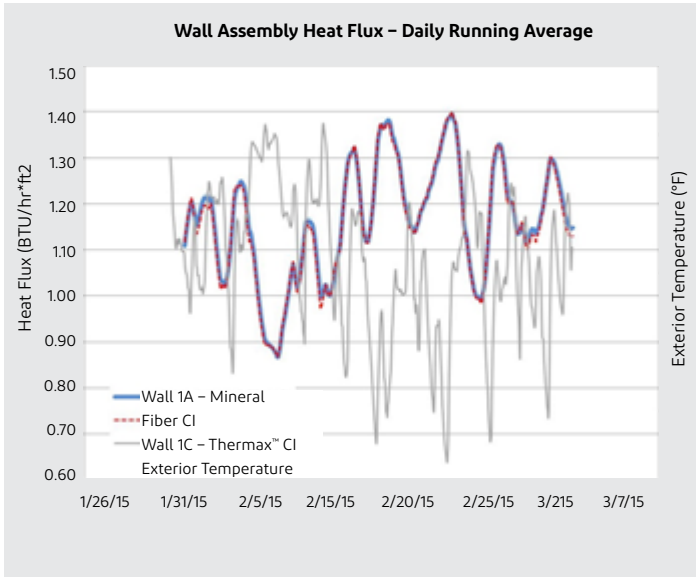


Thermax™ Insulation Wall Section – R10 CI (1.55”) + R19 Cavity

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.

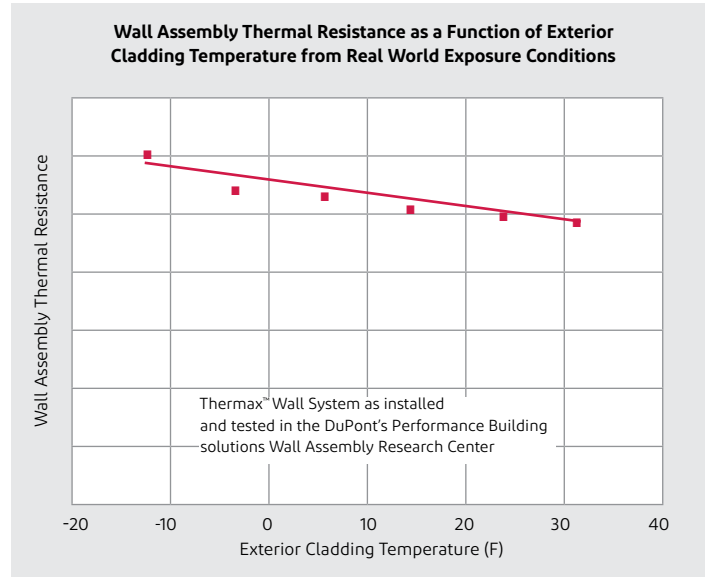
The measured data from these two wall systems was taken from the month of February, 2015. This was an excellent time for such a study as exterior temperatures were significantly lower than normal. See Figure 4 for these real world measured results.



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

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.



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

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 laboratory, 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 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. 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 temperature 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.

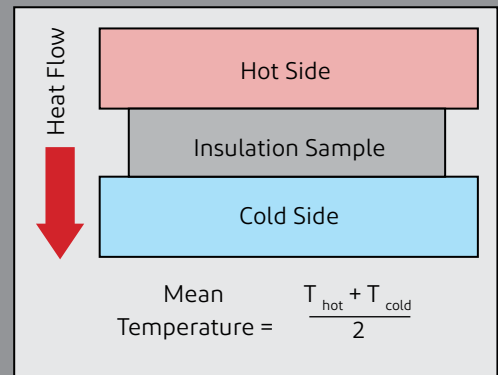


Figure 6: Basic set up for measuring heat flow and the resulting R-Value for an insulation material.



For more information visit us at  
[building.dupont.com](http://building.dupont.com)  
or call 1-866-583-2583

**NOTICE:** No freedom from any patent owned by DuPont or others is to be inferred. Because use conditions and applicable laws may differ from one location to another and may change with time, Customer is responsible for determining whether products and the information in this document are appropriate for Customer's use and for ensuring that Customer's workplace and disposal practices are in compliance with applicable laws and other government enactments. The product shown in this literature may not be available for sale and/or available in all geographies where DuPont is represented. The claims made may not have been approved for use in all countries or regions. DuPont assumes no obligation or liability for the information in this document. References to "DuPont" or the "Company" mean the DuPont legal entity selling the products to Customer unless otherwise expressly noted. NO EXPRESS WARRANTIES ARE GIVEN EXCEPT FOR ANY APPLICABLE WRITTEN WARRANTIES SPECIFICALLY PROVIDED BY DUPONT. ALL IMPLIED WARRANTIES INCLUDING THOSE OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY EXCLUDED. The buyer assumes all risks as to the use of the material. Buyer's exclusive remedy or any claim (including without limitations, negligence, strict liability, or tort) shall be limited to the refund of the purchase price of the material. Failure to strictly adhere to any recommended procedures shall release DuPont Specialty Products USA, LLC or its affiliates, of all liability with respect to the materials or the use thereof. The information herein is not intended for use by non-professional designers, applicators or other persons who do not purchase or utilize this product in the normal course of their business.

**CAUTION:** When cured, these products are combustible and will burn if exposed to open flame or sparks from high-energy sources. Do not expose to temperatures above 240°F (116°C). For more information, consult (Material) Safety Data Sheet ((M)SDS), call DuPont at 1-866-583-2583 or contact your local building inspector. In an emergency, call 1-989-636-4400 in the U.S. or 1-519-339-3711 in Canada. The blowing agent contained within this product can exhibit vapor flame limits under the right conditions. If specific operating conditions are such that concentrations of the blowing agent above the lower flammable limit can accumulate in areas with high relative humidity and in the presence of high-energy electrical discharges or other ignition sources, additional measures such as increased ventilation or coded electrical equipment (class one, division two) may be warranted. DO NOT SMOKE DURING USE. DO NOT USE NEAR ANY OPEN FLAME OR ELECTRICAL SOURCE. OUTDOOR USE ONLY. INDOOR USE INCREASES LIKELIHOOD OF IGNITABLE CONDITIONS. Insta Stik™ Quik Set Commercial Roofing Adhesive contains isocyanate and a blowing agent. Read the label and (Material) Safety Data Sheet ((M)SDS) carefully before use. Wear gloves, and goggles or safety glasses. Provide adequate ventilation or wear proper respiratory protection. Contents under pressure. For outside use only.

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

DuPont™, the DuPont Oval Logo, and all trademarks and service marks denoted with ™, SM or ® are owned by affiliates of DuPont de Nemours, Inc. unless otherwise noted. © 2020 DuPont.

43-D100866-enNA-0420