FOAMGLAS® CELLULAR GLASS INSULATION VS COLD-SERVICE AEROGEL BLANKET INSULATION IN CRYOGENIC APPLICATIONS

INTRODUCTION

LNG and other cryogenic applications can be challenging to properly insulate, so choosing the appropriate insulation and properly designing the system is critical. This white paper compares FOAMGLAS® cellular glass insulation and cold-service aerogel blanket insulation in many important categories for cold/cryogenic applications.

Cellular glass insulation is a rigid, lightweight closed-cell insulating material composed of millions of completely sealed glass cells, each an insulating space. Cold-service aerogel blankets are flexible fibrous blankets with aerogel particulates embedded within them. The blankets are laminated to a vapor retarder to provide directional impermeability.

When comparing the two insulation types, a key difference is how thermal conductivity can change with environmental conditions and the effects on long-term performance, but there are additional important factors to consider which we will also discuss.

We are comparing the performance of the two insulation types in terms of initial and long-term thermal conductivity, permeability, fire performance and cost of installation. These are all concerns in cold/cryogenic applications. In addition to knowledge gained in the field over several decades, Owens Corning has reviewed published literature for aerogel blankets and has also conducted tests to compare its performance in various categories.

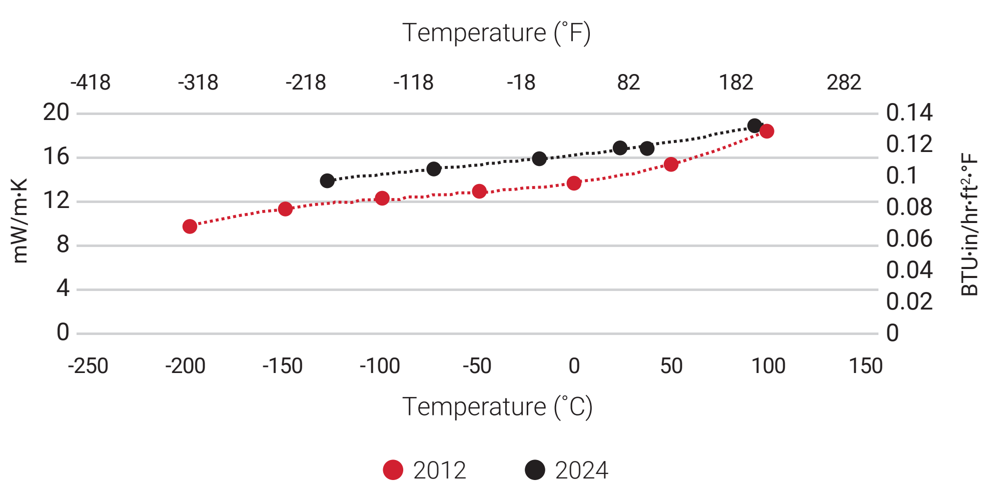
INSULATION SYSTEM PERFORMANCE—PRODUCT DATA SHEET REVIEW

When reviewing product data sheets (PDS) over the years, the claims for certain properties of aerogel have shifted.

Let us focus first on the properties of the aerogel insulation before the system is in service. Changes to cold-service aerogel blanket declarations could affect system performance if the correct design criteria are not considered. So, making sure you are designing based on the most up-to-date data sheet is critical.

The chart below shows how published values for thermal conductivity of Cryogel® Z blanket, an example of cold-service aerogel blanket insulation, have increased over time. We are comparing changes over the years using ASTM C177 (Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus). From published data in 2012[1] and 2024[2], thermal conductivity declarations increased at every temperature.

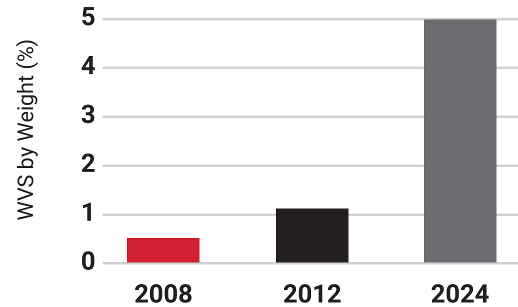
CHANGES IN CROYGEL® Z BLANKET THERMAL CONDUCTIVITY DECLARATIONS



In terms of water vapor sorption, Cryogel® Z blanket literature[3] stated in 2008 that water vapor sorption (WVS) was less than 0.5% by weight. For comparison, the number in their literature in 2012[1] more than doubled to 1.1% by weight. In 2024[2], the published number increased about five times to 5% by weight. Once again, when making decisions, it's important to ensure you are using the most recent literature and declarations during the design phase of cold/cryogenic systems.

In comparison, performance declarations in FOAMGLAS® insulation product data sheets[4] have remained constant for those same analyzed characteristics over that same time period.

CHANGES IN CRYOGEL® Z BLANKET WATER VAPOR SORPTION DECLARATIONS



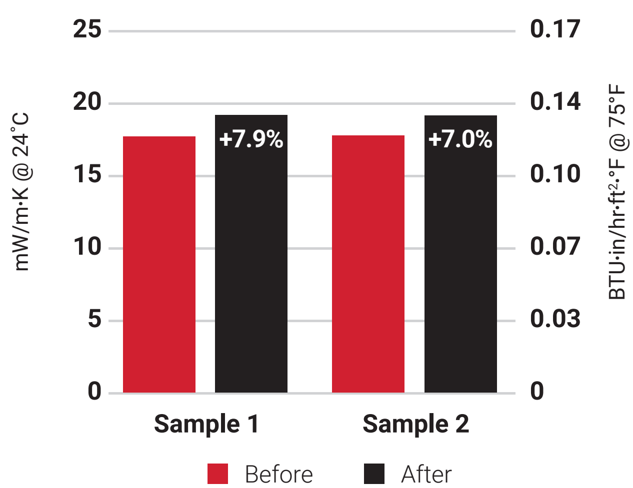
ISSUES ON THE JOB SITE PRIOR TO INSTALLATION

Aerogel blankets can exhibit degraded thermal conductivity performance due to loss of particles during shipping, handling and installation. The dust released is also a hazard during blanket installation and may require additional Personal Protective Equipment (PPE), including a respirator. Prior to and during application, properties of aerogel blankets can naturally degrade due to normal environmental conditions.

The Effects of Shipping and Handling
The chart on the right shows an increase in thermal conductivity between 7-8% after being handled, when measured by ASTM C518 (Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus)[5]. This can negatively impact the performance of systems that were designed around out-of-package thermal conductivity values.

In comparison, FOAMGLAS® insulation does not exhibit degradation of thermal properties due to handling.

THERMAL CONDUCTIVITY AFTER HANDLING COLD-SERVICE AEROGEL BLANKETS



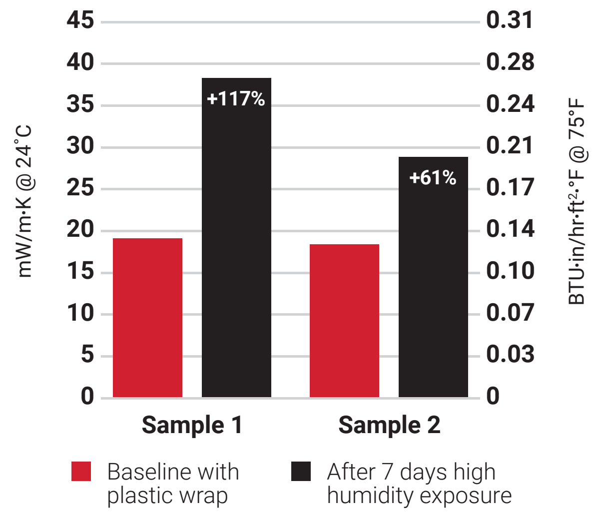
Cold-service aerogel blanket samples underwent simulated field handling to determine the effect on the thermal conductivity.

The Effects of Moisture and Humidity

Aerogel blankets can be affected by rain and humidity on the job site, especially in humid environments. As is noted on the chart to the right, this can significantly affect thermal conductivity before the product even gets installed. In some cases, thermal conductivity doubles when exposed to high humidity environments before testing, as measured by ASTM C518 (Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus)[5]. This large increase in thermal conductivity can drastically affect the performance and longevity of the system.

In comparison, FOAMGLAS® insulation is 100% closed-cell glass and is impermeable to water and water vapor, and thus does not experience the same types of aging behavior that were observed with cold-service aerogel blankets.

EFFECTS OF HIGH HUMIDITY ON THERMAL CONDUCTIVITY OF COLD-SERVICE AEROGEL BLANKETS



Samples exposed to 100% humidity for 7 days and rested at 25% humidity for 24 hours before testing. Simulation of material stored on site in humid climate before install. Note thermal conductivity degradation.

LONG-TERM PERFORMANCE AFTER INSTALLATION

FOAMGLAS® insulation is made of cellular glass, a 100% nonabsorbent material, while aerogel blankets are absorbent fibrous materials that rely on a vapor retarder jacketing to protect piping and equipment from moisture.

Water Absorption and Permeability

One of the benefits of aerogel blanket insulation is its "hydrophobic" properties. This means that the material is demonstrated to be non-attractive to water molecules in liquid form. In a water molecule, the end that contains the hydrogen atoms is more positively charged than the end with the oxygen atom. This gives water a natural attraction to other molecules that possess a similar disparity in charge from one end of their molecules to another. Hydrophobic materials are those that do not have a preferred charge at one end of their molecules, which means they are not inherently attracted to water molecules.

However, it should be noted this lack of attraction plays no role in preventing the ingress of water in vapor form when a vapor drive is present. This means that, while the product may shed liquid water that accumulates after it enters the system, the product is reliant on the presence of the external vapor retarder jacketing to resist water vapor from entering the insulation and subsequently condensing into liquid form.

For aerogel blankets, the published water vapor transmission value[2] of 0.00 perm is based on the thin vapor retarder film that is pre-applied. The vapor transmission rate of the aerogel blanket insulation material itself is similar to other fibrous insulation materials, such as fibrous glass and mineral wool. Therefore, any defect in the laminated vapor retarder or taped seams can lead to moisture intrusion and decreased thermal performance.

In comparison, FOAMGLAS® insulation is an impermeable material and does not rely on the presence of a vapor retarder jacketing. Individual sections of FOAMGLAS® insulation will not absorb moisture in liquid or vapor forms.

Effects of Moisture on Long-Term Thermal Performance

For permeable materials, the presence of vapor drive is an ever-present risk to long-term thermal performance.

Aerogel blankets can exhibit a high potential for moisture ingress into the insulation system that will decrease the thermal performance. As a result, an increased thickness is required to offset this degradation. This can also have an impact on cost because more materials can be necessary.

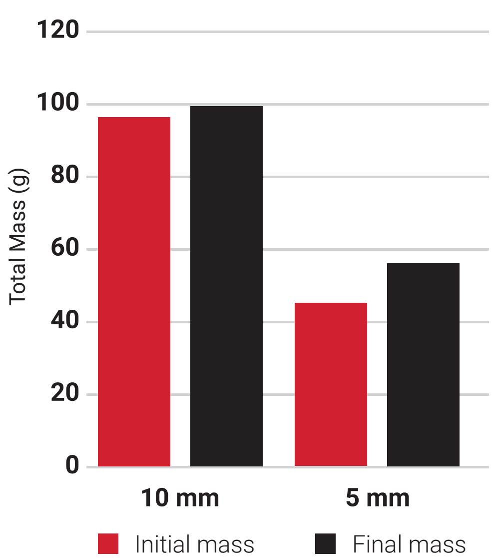
When aerogel blankets are exposed to environments with a high vapor drive, either on the job site or when in service, the material can become saturated with moisture, leading to a measurable decrease in thermal performance.

The charts below show how cold-service aerogel blankets exhibit water retention and thermal conductivity degradation after exposure to water and vapor drive conditions. Despite the presence of a hydrophobe, water ingress into this system is an issue. While water in large volumes drains from the mat, moisture in smaller volumes and not coalesced into droplets remain in the mat, significantly affecting thermal conductivity. When the system is in service at cryogenic temperatures, this water can become ice, further degrading the thermal conductivity.

As previously stated, because of the presence of a hydrophobe, many aerogel blankets demonstrate an ability to shed liquid water in large quantities when exposed to it, as depicted in **Chart A**. However, aerogel blankets can be prone to retaining water that has been exposed to the material via vapor drive and subsequent condensation, which brings a demonstrable reduction in thermal performance as depicted by **Chart B**.

CHART A

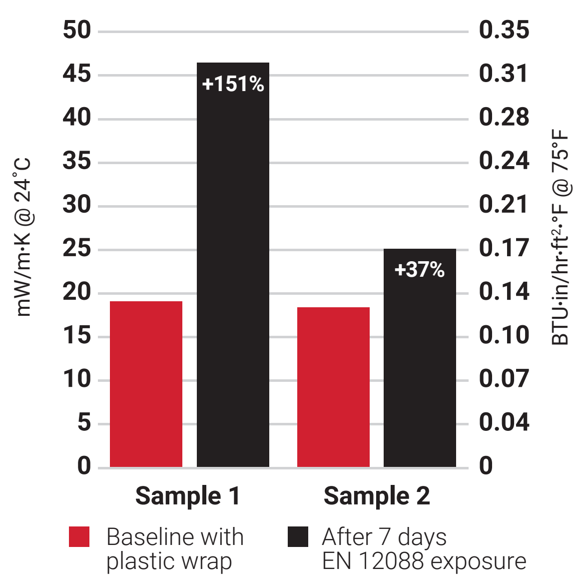
WATER RETENTION CHARACTERISTICS OF AEROGEL BLANKETS



ASTM C1511—Standard Method for Determining the Water Retention (Repellency) Characteristics of Fibrous Glass Insulation. Note minimal water retention after submerging 10 mm and 5 mm mats.

CHART B

EFFECTS OF DIRECTIONAL WATER VAPOR DRIVE ON COLD-SERVICE AEROGEL BLANKETS



Samples exposed to EN12088 conditions for 7 days. Samples placed between 90˚C (122˚F) water bath and 1˚C (34˚F) cooling plate to create vapor drive.

Fire Safety
In hydrocarbon processing facilities, the absorption and retention of liquid hydrocarbons within insulation systems can pose a fire safety concern.

As was discussed in the moisture section, many aerogel blankets promote their hydrophobic properties, referring to the tendency of the material to not be attracted to the polarity of water molecules. Hydrocarbon molecules are different from water in that they are considered nonpolar, meaning the molecules do not contain a significant difference in electronegativity from one end to the other.

What this means is that a hydrophobicity of material is not an applicable countermeasure to exposure to liquid hydrocarbons. Permeable materials that are considered hydrophobic may still tend to collect and retain hydrocarbons to which they become exposed. If fibrous insulation, such as an aerogel blanket, were to become saturated with liquid hydrocarbons in this manner, it would present a risk to fire safety should it become inadvertently ignited at some point.

In comparison, FOAMGLAS® insulation is a 100% closed-cell glass insulation that will not absorb or wick flammable hydrocarbons in liquid or gaseous forms. It will not burn or contribute to fire or smoke, as it has both a flame spread and smoke generation of zero.

This mitigates the potential for an insulation system to become saturated with flammable process materials and pose a fire hazard down the road. FOAMGLAS® insulation is widely specified in areas of high risk for process leaks, such as valves and flanges for this very reason.

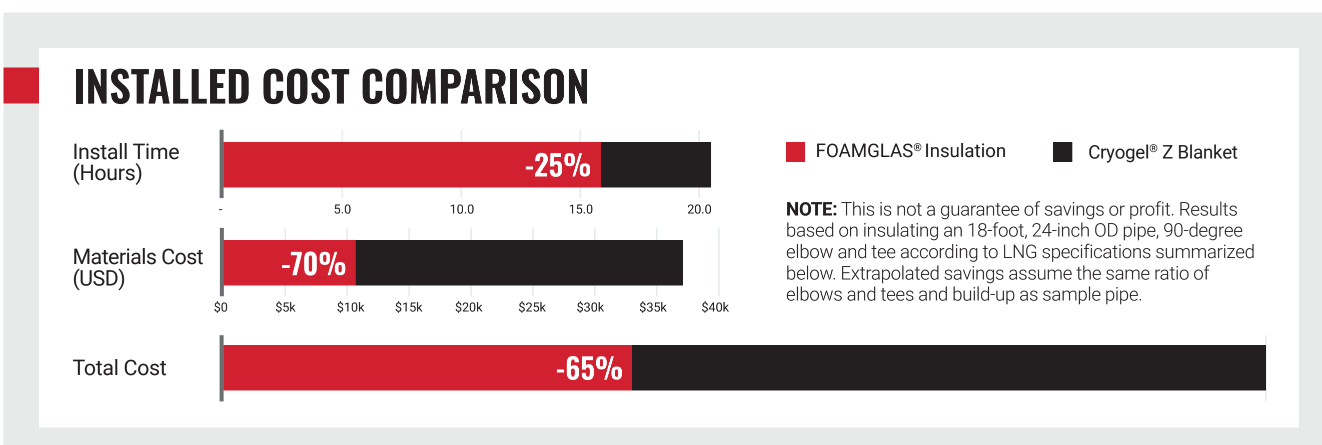
INSTALLATION TIME AND COST

Owens Corning commissioned a third-party study aimed at providing a comprehensive analysis of material costs, labor expenses, total system cost and install time for both insulation types.

The parameters of the study were based on insulating an LNG pipe utilizing thickness calculations based on published thermal conductivity curves and installation methods as recommended by manufacturers and with consultations with local engineering companies.

Installation Study Findings
According to the market installation study conducted by an independent third-party insulation contractor, commissioned by Owens Corning Insulating Systems, LLC, in August 2024, FOAMGLAS® insulation can save approximately 70% in material costs and 25% in labor costs compared to cold-service aerogel blankets. Overall, on a project basis, use of **FOAMGLAS® insulation can save approximately 65%** in materials and labor costs compared to the use of cold-service aerogel blanket insulation.

Based on the results of the study, the use of FOAMGLAS® insulation can save more than $1,500 per linear foot. These savings, extrapolated over 1,000 feet of pipe, could lead to an overall savings of $1.5 million.



FOAMGLAS® insulation total installed cost is less than half the cost of an installed Cryogel® Z blanket system on a 24" pipe operating at the LNG process temperature of -256˚F / -160˚C

INSTALLATION CHALLENGES

- Aerogel systems require significantly more pieces for fittings, increasing complexity and potential for error.
- Joint gaps in multi-layer systems can be failure points due to lack of joint sealant.
- Flexible aerogel blankets can be difficult to seal around protrusions (e.g., standoffs, valves).
- Dust from aerogel blankets can interfere with tape adhesion, compromising vapor barrier integrity.
- Uneven particle loss during handling can lead to hot/cold spots.

FOAMGLAS® insulation installation.

Cold-service aerogel blanket insulation installation.

FOAMGLAS® Insulation System Design
For FOAMGLAS® cellular glass insulation, the following materials were used:

- Double-layer system typical for LNG applications.
- Contraction joint, joint sealant, vapor retarder, metal bands and metal jacketing.

Aerogel Blanket Insulation System Design
For the aerogel blanket, the following materials and personal protection equipment were used:

- 10-layer system typical for LNG applications.
- Primary vapor retarder, secondary vapor retarder, metal bands and metal jacketing.

PERSONAL PROTECTIVE EQUIPMENT USED FOR EACH INSTALLATION

Personal protective equipment (PPE) is essential when installing insulation materials, particularly cold-service aerogel blankets, due to the potential health and safety risks associated with dust release and material handling. The installation of aerogel blankets requires comprehensive PPE—including a full Tyvek suit, N95 respirator or mask, gloves, safety glasses, bump caps and steel-toe shoes—as outlined in the product's Safety Data Sheet. This contrasts with FOAMGLAS® insulation, which requires less intensive PPE, such as a long-sleeved shirt, gloves and safety glasses.

FOAMGLAS® Insulation

Aerogel Blankets

SUMMARY

While cold-service aerogel blanket insulation has a better initial thermal conductivity value than FOAMGLAS® cellular glass insulation, there are deficiencies that start to show at the job site and once the system is in service that should be considered for long-term performance:

- For aerogel blankets, changes in thermal conductivity can be common even before it is installed due to loss of particles during shipping, handling and installation. Absorption of water and water vapor can worsen performance over time as well. With FOAMGLAS® insulation, thermal conductivity and impermeability remain constant at the job site and during its service life.
- For cold-service aerogel blankets, high permeability and the need to rely on a thin vapor retarder and jacketing can lead to moisture intrusion and poor thermal performance once in service. FOAMGLAS® insulation is impermeable, will not age over time and will not absorb moisture in liquid or vapor forms. It offers constant thermal performance throughout the entire life cycle of the insulation system.
- Aerogel blankets can absorb hydrocarbons, resulting in a risk of fire/smoke if ignited. FOAMGLAS® insulation is made of 100% closed-glass cells and will not absorb flammable liquids, burn or promote smoke. Its ratings for both flame spread and smoke are zero.
- FOAMGLAS® insulation is quicker and less expensive to install, saving approximately 65% in total material and labor costs compared to cold-service aerogel blankets.

Sources

1. Aspen Aerogels Cryogel® Z Product Data Sheet, 2012 Edition.

2. Aspen Aerogels Cryogel® Z Product Data Sheet, 2024 Edition.

3. Aspen Aerogels Cryogel® Z Product Data Sheet, 2008 Edition.

4. FOAMGLAS® Insulation Product Data Sheets, 2008, 2012, 2024 Editions.

5. RJLee Group report titled "Thermal, Combustibility, and Hydromechanical Properties Testing of Cryogel® Z Insulation Blanket," May 2020.

6. Aerogel Safety Data Sheet, January 2025 Edition.

OWENS CORNING® FOAMGLAS®

Industrial & Commercial Sales

Americas
+1 800 327 6126

Asia-Pacific
Singapore: +65 9635 9184
China: +86 (0) 21 6101 7179
Japan: +81 3 6365 4307

Europe, Middle East & Africa
+32 13 661 721

Technical Services

Americas & Asia-Pacific
+1 800 327 6126
foamglastechnical@owenscorning.com

Europe, Middle East & Africa
+32 13 611 468
industry.tech@owenscorning.com

PITTSBURGH CORNING, LLC
ONE OWENS CORNING PARKWAY
TOLEDO, OH 43659 USA

Toll Free + 1 800 327 6126
For web-based Sales and Technical Service inquiries, please visit **www.foamglas.com**

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