# TECHNICAL BULLETIN 1215
# COMPARISONS BETWEEN AEROGEL AND POLYISO IN LOW TEMPERATURE MECHANICAL INSULATION

**PURPOSE**

The purpose of this Technical Bulletin is two-fold: 1) to examine aerogel insulation (specifically Aspen Aerogels® Cryogel®Z) in some detail, and 2) to compare Cryogel Z with polyisocyanurate insulation (specifically Dyplast's ISO-C1®/2.5).

The approach in this document is to make objective and factual statements. If the reader concludes this document strays from that premise, this document will be revised and re-released to incorporate credible information.

**BACKGROUND ON "GENERIC" AEROGEL**

Aerogels have been in existence for more than 80 years. [Note Cryogel Z is a new branded product with quite different properties]. The general description of aerogel on the Federal website www.energy.gov is that aerogel is a lightweight silica solid derived from gel in which the liquid component of the gel has been replaced with gas. Some excerpts from the energy.gov website referencing aerogel (Note: again not Cryogel Z) include:

- "*When the liquid is removed, what remains is "puffed-up sand", with up to 99% porosity. The result is an extremely low density solid with several remarkable properties, most notably its effectiveness as a thermal insulator*."
- "*The silica solids, which are poor conductors, consist of very small, three-dimensional, intertwined clusters that comprise only 3% of the volume*."
- "*The remaining 97% of the volume is composed of air in extremely small nanopores*."
- "*These characteristics make aerogel the world's lowest density solid and most effective thermal insulator*."

**BACKGROUND ON ASPEN AEROGELS**

Aspen Aerogel was founded in 2001. From 2006 into 2011 Aspen Aerogels was helped by the Department of Energy (DOE) in the development of Cryogel® blanket insulation. The Cryogel Z product is quite different from the generic product described above. A paragraph on Aspen Aerogels' website adds important perspective to the above points: "*The outstanding thermal properties of aerogels have been studied for decades, but Aspen Aerogels has developed a technically and economically viable form of aerogel for industrial insulation uses. Our unique process integrates aerogel into a fiber-batting reinforcement to create flexible, resilient, durable aerogel blankets with superior insulating properties*." Thus Aspen Aerogel affirms that Cryogel Z is different from the aerogel described on energy.gov - - and indeed it is.

Thus to avoid any confusion, Cryogel Z product is quite different from the *conventional wisdom* version of aerogel described in energy.gov. The Cryogel Z Product Data Sheet[1] as well as other sources indicate the density of the Cryogel Z is <u>10 lb/ft$^3$</u> - - dramatically heavier than generic aerogel referenced on energy.gov and elsewhere; in fact it is the heaviest insulant alternative when evaluating the product *as shipped*. Note that cellular glass used in LNG applications is less at a

[1] http://www.aerogel.com/_resources/common/userfiles/file/Data%20Sheets/Cryogel_Z_DS.pdf

nominal 7.5 lb/ft[3], and polyiso a much less at a nominal 2.5-3.0 lb/ft[3]. [More on the weight in an *installed system* later.]

**CONTEXT**

Aspen Aerogels' Cryogel Z is aggressively marketed for use as an insulant on pipe and equipment in cold applications, including cryogenic (e.g. liquid natural gas, or "LNG"). Cryogel Z is a relatively new insulant when compared with both polyisocyanurate and cellular glass - - the most commonly-used insulants on LNG applications.

Review of publically available information on the physical properties of Cryogel Z leads to the conclusion that Aspen Aerogel has evolved Cryogel Z literature to correct some of the earlier statements/assertions - - some of which are unfortunately still available on other websites[2] presumably not controlled by Aspen Aerogels. Additionally, there are at least a few engineering companies that continue to have databases with physical properties (particularly thermal conductivities) of Cryogel Z that are not representative of the actual product delivered. Engineers/specifiers are thus cautioned to request current, validated information directly from Aspen Aerogels since there continues to be confusion in the marketplace on physical properties/performance.

For instance:

| Old literature Claims still on the internet | Current Statements on aerogel.com |
|---|---|
| "Lowest k-value of any cryogenic insulation material" | "Extremely low thermal conductivity (k-value) |
| "Cryogel® Z and Pyrogel® XT are lighter than other insulation materials" | "Maximum thermal protection with minimal weight and thickness" [note Cryogel Z is nominally 10 lb/ft$^3$ while ISO-C1/2.5 is 2.5 lb/ft$^3$; see sample pipe insulation weight calculation below] |
| "Hydrophobic with excellent resistance to moisture. (Its nanopores form a tortuous network of "dead end" clusters that resist vapor penetration, condensation, and ice.)" | "Factory-laminated vapor retarder provides moisture protection,--- " |
| "Remains totally flexible" [in cryogenic applications] | "Resilient Flexible" per ASTM C1101 [at cryogenic temperatures; exact measurement temperature not specified] |
| "Aerogels pose no chemical threat to the environment" | "See SDS for complete health and safety information" |
| "No respirable fibers" | Not referenced |

**Table 1: Cryogel Z: Evolution of Claims**

So! Is Cryogel Z a revolutionary insulant that will eventually dominate "cold" mechanical insulation applications? Or at the other extreme does Cryogel Z have fatal flaws? If the product is still evolving, is it ready for *prime-time*? The viewpoints of self-described "informed" stakeholders continue to be radically different; and internet research uncovers conflicting opinions regarding performance[3]. This Technical Bulletin may sway opinions one way or the other, yet at a minimum it is intended to assist stakeholders as they select the optimal insulant, and engineers as they design the optimal insulation system.

[2] While Aspen Aerogel cannot be held accountable for information posted by other companies, all companies should exert efforts to protect their brand by insisting misleading information is removed.

[3] Kaefer (www.kaefer.com), a leader in LNG installations since 1971, conducted laboratory testing of a LNG pipe insulated with Cryogel Z in tropical environment and in full cryogenic operational conditions, and concluded open cell/fibrous materials contain the risk of vapor which results in a degradation of the thermal properties as expected. Contact Dyplast for a copy.

**PERSPECTIVE ON INSULANTS (IN GENERAL)**

While the performance of stainless steel pipe can be predicted based largely on its verifiable content of chromium, molybdenum, manganese, etc., the performance of insulants can be predicted neither by elemental nor molecular analysis. Thus the release by manufacturers of an insulant's *physical properties* is an ***essential step*** in the selection of the *optimal* insulant. Of course, however, the physical properties must be:

1. the result of tests validated (and ideally, audited) by independent third party laboratories
2. recently tested to ensure they are in conformance with the most recent version of standards such as ASTM[4], CINI[5], etc.
3. offered with *full-disclosure*, rather than selectively releasing only favorable data, and
4. representative of the product being currently sold.

Bullet #1, above, will be echoed throughout this document since there are insulant suppliers that continue to perform only selective "in-house" testing to purportedly "achieve compliance", and then deliver a product with physical properties that may not meet requisite standards (e.g. ASTM or CINI). Expanding bullet #2, above: engineer/specifiers increasingly must hold insulant manufacturers accountable for absolute compliance with standards; and the major standards change frequently and are increasingly requiring measurements at cryogenic temperatures[6]. Additionally, several leading insulant manufacturers are performing tests that are not required by *standards* yet are deemed important for stakeholders to differentiate products as well as manufacturers of the "same" product. Bullets 3 and 4 should be self-explanatory.

**CRYOGEL Z THERMAL CONDUCTIVITY**

Thermal conductivity (k-factor[7] or *lambda*[8]) is of course the inverse of thermal resistance (R-value), and is inherently why end-users insulate. The lower the k-factor, the better; reciprocally the higher the R-value the better. Thermal conductivities indicated on insulant datasheets have been historically measured (with a few exceptions) at or near ambient temperatures. As mentioned, to remain compliant with relevant Standards Organizations thermal conductivities and other selected properties increasingly must be measured at cryogenic temperatures (e.g. ASTM C591-15 governs polyiso and CINI-2014 LNG applications). This is pertinent since:

Point 1. Thermal conductivities improve as temperatures decrease, although not necessarily linearly and different insulants begin their improvements at different levels (see chart below),

Point 2. Thermal conductivities can degrade with water absorption or water vapor transmission (plus resultant ice formation), and potentially with mechanical compression, and

[4] ASTM International is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services

[5] CINI (Committee INdustrial Insulation) is the dominant international standard for LNG facilities.

[6] ASTM-C591-15 requires thermal conductivity measurements across a temperature range from +200°F to -200°F; CINI has similar k-factor requirements and also additional measurements at -265°F.

[7] K-factor (thermal conductivity) is measured in Btu·in/ h·ft$^2$ ·°F.

[8] *Lambda* is the metric unit representing thermal conductivity, generally expressed as W/m·K.

Point 3. Thermal conductivities of some insulants, such as polyiso "*age*"[9], although *aging* materially slows as temperatures decrease, and essentially ceases at LNG temperatures (discussed later).

The following chart displays the behaviors of the thermal conductivities of four common insulants as temperatures decrease:

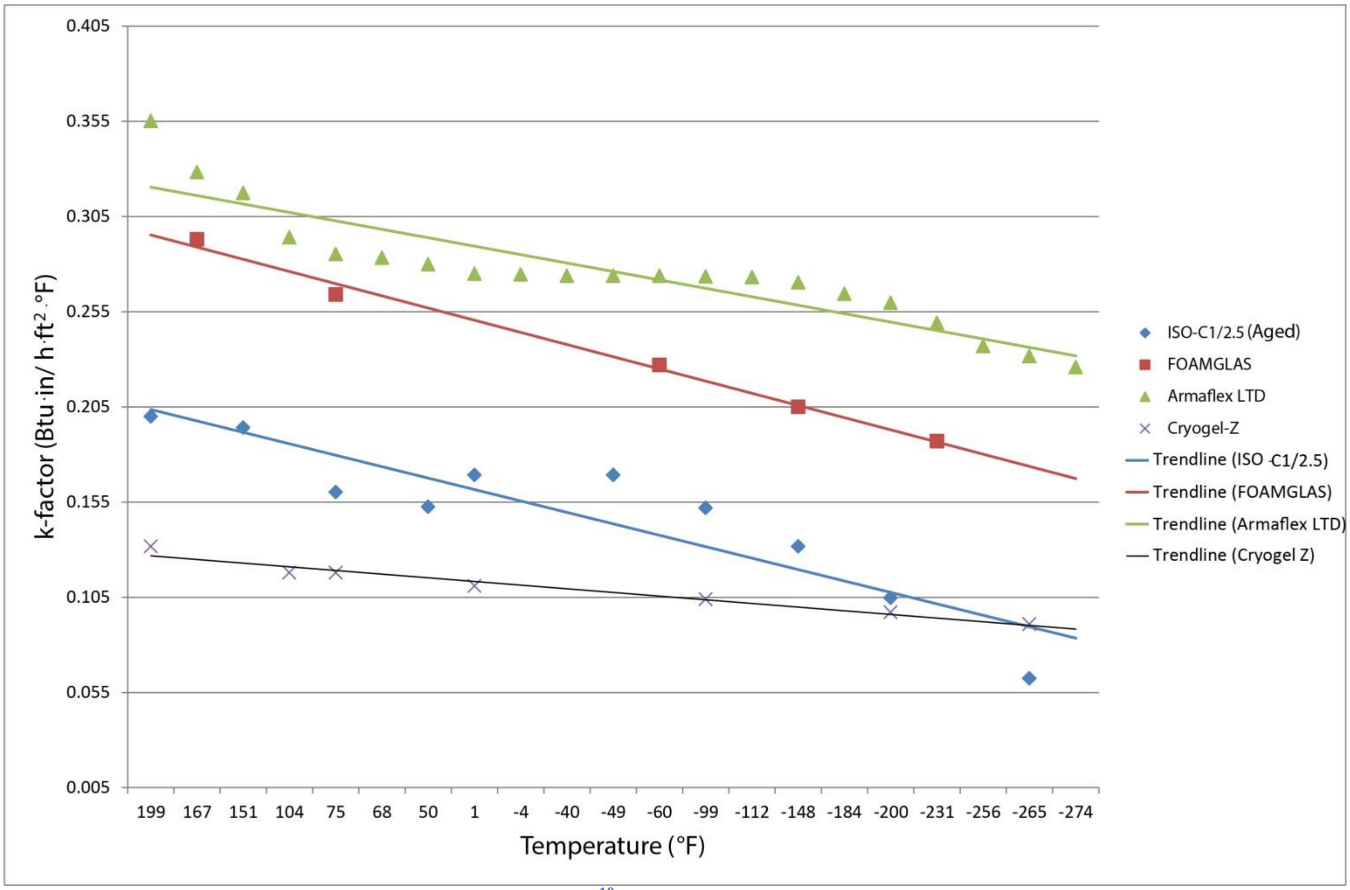


**Chart 1: Thermal Conductivity versus Temperature**[10]

*Chart notes:*

1) *This chart includes k-factors for cellular glass and elastomeric insulants for comparison purposes.*
2) *Readers are cautioned to request demonstrable/verifiable information from manufacturers, and should not depend on this chart.*
3) *Thermal conductivities may vary between manufacturers of "the same" product.*
4) *Trend-lines are linear representations of potentially non-linear functions; for actual lambdas between points, the manufacturer should be contacted.*
5) *ISO-C1/2.5 polyiso's points are "180-day Aged at +/-75°F" (discussed later).*
6) *Thermal conductivities of Cryogel Z are typically measured at a compressive load of 2 psi, implying they may be worse are higher compressive loads.*

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[9] To allow apples-to-apples comparisons, polyiso insulants are tested after an aging process; again discussed later.

[10] Data in chart taken from publicly available information for sample "best in class" insulants: respectively Dyplast polyiso, Pittsburgh Corning's cell glass, Armaflex elastomeric, and Aspen Aerogel.

Addressing in more detail the first three points above the chart:

**POINT #1: K-FACTOR VERSUS TEMPERATURE**

Chart #1 represents the thermal conductivity across the potential temperature range of LNG piping, considering cycling and shut-downs. The thermal conductivities of each insulant improve as temperature decreases, yet the slopes are different and they are each begin their downward slope from quite different starting points at +200°F (93°C). Note that ISO-C1/2.5 polyiso's points are particularly non-linear primarily due to the behavior of cellular gases as temperature decreases. Also note that as temperatures approach that of LNG, the actual *independent-laboratory-validated* datapoints for ISO-C1/2.5 are materially better than those of Cryogel Z.

**POINT #2: K-FACTOR DEGRADATION**

As noted above, thermal conductivities can degrade with increased water absorption and water vapor transmission, and ice can form. K-factors may also potentially degrade with mechanical compression of a batting such as Cryogel Z. The impacts of High Water Absorption (WA) and Water Vapor Transmission (WVT) on insulant performance are often confused, so are further explained:

***Water absorption*** is the amount of water (not water vapor[11]) present in an insulant, measured either by volume or weight. There have been numerous failures of *cold* pipe systems when insulants (particularly fiber-based) absorbed water, resulting in loss of thermal resistance. Cryogel Z is a "modified" aerogel with *fiber-batting* reinforcement; its water retention per ASTM C1511 is stated as ≤5% by weight[14].

Although not addressed on aerogel.com, a 2010 study available on the internet titled "*The Influence of Insulation Materials on Corrosion Under Insulation" by two Aspen Aerogel representatives state "Pyrogel XT*[12], *and two brands of expanded perlite achieve their water-repellency with chemical additives that make them resistant – though not impervious – to water's natural capillary action*"; and later in the paper state "*the Pyrogel XT shows very little hydrophobe loss over the 200 days studied. Again, this performance is tied to hydrophobe chemistry which, in the case of Pyrogel XT, is based on a highly crosslinked methylsiloxane resin*."

Thus, based on the assumption that Pyrogel XT and Cryogel Z are similar, one could conclude that the water-repellency of Cryogel Z's fiber-batting depends on a comparable chemical additive. Engineers and specifiers may wish to execute their own due diligence to ensure the chemical additives remain effective under all relevant conditions and durations.
The reported Water Absorption/Retention values for ISO-C1/2.5 and Cryogel Z are as follow:

| **Product** | **Test Method[13]** | **Water Absorption (or "Retention" in the case of C1511)** | **Int'l Governing Standard** |
|---|---|---|---|
| ISO-C1/2.5 | ASTM D2842 | 0% (by volume) | ≤5% (CINI) |
| ISO-C1/2.5 | ASTM C272 | 0.6% (by volume) | ≤1% (ASTM) |
| Cryogel Z | ASTM C1511[14] | ≤5% (by weight) | ≤5% (ASTM) |

[11] Since the definition of "moisture" can be debated, it is not used herein. Rather, water "vapor" is used.

[12] Aspen Aerogel's Pyrogel XT is the higher-temperature version of Cryogel-Z; there appears to be sufficient similarities to warrant that stakeholders question any differences.

[13] Test Methods per ASTM vary by preparation, durations, temperatures, immersion depths, post-immersion processing, and/or measurement per volume versus weight.

**Table 2: Water Absorption Properties**

Again, engineers and specifiers should execute due diligence when comparing WA's of alternative insulants, as well as when evaluating the likelihood and ultimate effect of higher WA at cryogenic temperature. This Technical Bulletin has insufficient space to address related factors such as:

- The performance and reliability of a vapor barrier (versus *retarder*) on WA
- The risks associated with a high WA insulant covered by a single vapor barrier that could be compromised
    - Note, Aspen Aerogel could argue multiple vapor barriers result from multiple wraps of Cryogel Z; Dyplast would offer a polyiso with inherently low WA as a *second-line-of-defense*, particularly when supported by an inner and outer vapor barriers in multiple layer cryogenic systems.
- The physics behind the actual WA (measured at ambient) at *cryogenic temperatures*!
- The practicality of water being absorbed into the insulant at ambient (e.g. *startup* temperatures) and then dropped to LNG temperatures.
- And on!

***The good news*** is that *empirical evidence* plays a large role in bypassing the complexities. For instance, polyiso insulants have been utilized in LNG applications for decades - - making the above concerns moot.

***Water vapor transmission*** represents the tendency of an insulant to allow water vapor to move from "warm to cold" and "more to less". Imagine, hypothetically, using dense *steel wool* as an insulant wrapped around a cold pipe. Vapor drive would move water vapor (humidity) in the atmosphere toward the pipe; the *steel wool* would never "absorb water". There would be no *water-logged* insulant, yet there would be formation of ice on the pipe - - incrementally thickening until ambient temperatures may melt it. The net effect is a decrease in the thermal conductivity of the *insulation system* - - not the insulant itself. A bit esoteric, but envision "before the ice" there were two inches of steel wool around the pipe; "after the ice" there was one inch of ice and one inch of steel wool! Yes, we could indeed debate the thermal conductivity of cryogenic ice versus the conductivity of steel wool, yet that would miss the point. Alternatively, we would again offer that we should revert to empirical evidence of lack of WVT failures in polyiso and cellular glass.

The issue of a zero-perm vapor barrier, as in the WA discussion, is again critical *vis-à-vis* WVT. The Cryogel Z argument is that an integral vapor barrier mitigates risks, and indeed it does, since without it the WVT would be exceedingly and unacceptably high. Seasoned readers recognize however that mitigation is not elimination. Polyiso proponents would argue that if all insulants declared a WVT with vapor barrier, all could claim "zero" WVT.
Wisdom advises that the optimal risk mitigation strategy must assume there will be a weak-point in the vapor barrier whether the result of installation errors, or a fail-point such as at a *step-over* part of the pipe where workers inevitably step on the pipe to get to the other side (a design consideration more complicated than first thought). Cryogel Z proponents may offer that the zero-perm vapor barrier on each layer in a multiple-layer system *sufficiently* mitigates this risk - - which raises issues that pertain to:

1) Installation: do the installation procedures and prescribed accessory materials ensure there is no possible water vapor infiltration at joints, seams, vapor stops, etc. when considering operational scenarios such as mechanical abuse, startup, outages, severely adverse weather, and so forth.
2) If all installation procedures, materials, etc. are met, is the *performance versus cost* ratio positive?
3) Have *cost-centric* and *consequential damage* type risks been optimally mitigated?

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[14] Cryogel Z Datasheet notes: "Water retention uses a modified C 1511, nominal values".

***Compression*** of polyiso is generally never an issue since even at lower densities it has a relatively high compressive strength, and higher densities used within pipe hangars have even higher compressive strengths that exceed those of cellular glass. ***Yet***, note that the thermal conductivities of Cryogel Z are measured at a compression of "2 psi", which raises the question "*what are the k-factors at higher compressions?*" - - such as on the inner layers of a multi-layer application?

**POINT #3: THERMAL *AGING***

It is well known that thermal insulants using the *later-generation* blowing agents such as hydrocarbons and indeed *older* fluorocarbons lose a small amount of their insulating value over time since air can displace the insulating gases within the cells. ASTM has designed a testing protocol (C591) that "ages" the target insulant for 180-days at approximately 75F (24°C) prior to measuring k-factor. CINI specifies *aging* measurements per ASTM C591. As mentioned elsewhere, since polyiso has been successfully demonstrated in LNG application for several decades, the *aged* k-factors can be assumed to be representative of the average performance of the insulant over the life of the insulation system.

An important nuance is that k-factor values for polyiso listed at, for instance, **-**265°F were measured *at a mean temperature of -265*°F from samples *aged 180-days at ~75*°F. Thus engineering-minded folk may ask "to what extent does polyiso *age* at lower temperatures?" and/or "does a vapor barrier slow aging?" Good questions! Regarding vapor barriers and jackets, they will of course slow the aging process; and indeed thick insulant or multiple layers of insulant on an LNG pipe will slow the aging of the inner layers.

Regarding lower temperatures, the *aging* process slows dramatically and can be considered as virtually nil at cryogenic temperatures. In other words, in theory, if *initial* (i.e. prior to aging) polyiso is promptly installed on cryogenic pipe, the inner layers of the insulant nearer the pipe may not age; and layers operating at less than ambient temperatures will age more slowly than they would an ambient temperatures. Of course this cannot be measured or guaranteed since factors such as outages, cycling up to ambient temperatures, and so forth would result in the insulant being above cryogenic temperatures.

## INSTALLED INSULATION SYSTEM WEIGHTS

The weight of Cryogel Z is 4 times greater than ISO-C1/2.5, yet one could ponder that if Cryogel Z's higher thermal conductivity is sufficiently better than polyiso's in a given application, the actual installed insulant could be thinner and thus the installed weight could be less. To test this premise, two application temperatures were selected: 1) where the Cryogel Z's k-factor exceeded ISO-C1/2.5's by the largest amount, which happened to be at +199°F; and 2) at -265°F (i.e. LNG) where ISO-C1/2.5's k-factor actually exceeds that of Cryogel Z. The following table summarizes the results, with insulant thickness calculations based on 3E Plus®[15], assuming *credible*[16] environmental conditions[17].

> A technical note: Different insulant thickness calculation programs utilize different objectives [e.g. condensation control or heat loss (and indeed different heat loss standards), and different mathematical routines that "*integrate*" physical properties across the temperature spectrum from the pipe to the ambient. For the following 3E Plus calculations the selection of *heat loss* was pegged at 8 BTU/hr/ft$^2$ maximum.

[15] 3E Plus computer program calculates heat loss/gain on hot or cold piping and equipment, and determines economic thickness of industrial insulation, providing payback and savings data as well as $CO_2$ emission reduction data.

[16] The environmental conditions surrounding LNG plants varies considerably, often with higher than average temperature and humidity. The selected environmental conditions (see Footnote 16) are offered as *credible* and not as severe as some locations.

[17] 8-inch pipe, 75°F ambient, 80% humidity, 5 mph wind, stainless steel (dull) jacketing, condensation control.

| Temperature | Insulant | K-factor (Btu·in/hr·ft$^2$°F) | Insulant Thickness on 8-inch Pipe[18] | Weight of 100 feet of LNG pipe insulation (lbs) | Cryogel Z is Heavier than ISO-C1/2.5 by: |
|---|---|---|---|---|---|
| +199°F | ISO-C1/2.5 | 0.20 | 2.5 (1 layer) | 143 | |
| +199°F | Cryogel Z | 0.132 | 2.0 (5 layers) | 436 | 305% |
| -265°F | ISO-C1/2.5 | 0.062 | 4.5 (1 layer[19]) | 307 | |
| -265°F | Cryogel Z | 0.091 | 3.5 (8.75 layers[20]) | 878 | 287% |

**Table 3: Comparative Weights of Installed Insulants**

Thus a Cryogel Z insulant system in these examples weighs roughly 300% more than a polyiso system even though the thickness of the system may be somewhat less. The result negatively impacts shipping, handling, the number of pipe hangars, etc. This is likely not news for experienced design engineers/specifiers, yet there continues to be confusion among other stakeholders who continue to perceive "aerogels" as *extremely lightweight with thermal conductivities that are magnitudes better than other insulants*. One may also ask why an ISO-C1/2.5 system is slightly thicker when the k-factor of ISO-C1/2.5 is actually better than Cryogel Z at -265°F. The answer of course is that the temperatures across the insulant thickness vary from the pipe surface to the ambient environment, and at the *median* temperatures the aerogel still has a modestly better k-factor - - under the assumption of course there is no degradation from water absorption.

Note also that polyiso can be fabricated in pipe half-shells of virtually any thickness, and thus can be easily installed as a single layer. On the other hand, Cryogel Z is sold only in 0.2 and 0.4 inch thicknesses, so in the above example the application would require multiple wraps Cryogel Z requiring circumferential measurements for each layer, and subsequent application and sealing of seams.

Thus the selection of the *optimal* insulant boils down to:

1. capital/installation/life-cycle costs,
2. risks associated with validation of physical properties,
3. performance risks,
4. extenuating circumstances (this document too brief to address all, and engineers/specifiers must exercise due diligence)

**Cost vs. Performance**

With respect to bullet #1 (Cost), Cryogel Z documentation states it "*is both fast to install and durable, resulting in lower-cost, higher performing designs*". Obviously this statement cannot be refuted since it could be argued that Cryogel Z is lower cost than the most expensive insulant, and that it performs better than the worst insulant. Yet there is little publically-available, objective evidence that a Cryogel Z-based insulation system is lower cost or performs better than a comparable ISO-C1 based system. Proper *due diligence* executed by a competent insulation system engineer will best address the issues related to mechanical abuse (e.g. compressive strengths), use of Cryogel Z on elbows/fittings, pipe

[18] 3E Plus software calculates the thickness of insulants is in half-inch increments, so installations of Cryogel Z may need to have an additional wrap to achieve the required thickness.

[19] Although 1 layer of ISO-C1/2.5 may be acceptable in some conditions, conservative engineers may specify 2 offsetting layers to additionally mitigate risk of any moisture infiltration.

[20] 8.75 layers of Cryogel Z of course equates to 9 layers, making the installation actually heavier.

hangars, re-installation after maintenance, long term risk of moisture intrusion, and so forth.

**Cryogel Z Structure**
To return to the point that some stakeholders are still confused about the difference between "generic aerogels" and Cryogel Z, consider that the amount of air in Cryogel Z nanopores must be considerably less than 97% of the volume. The Cryogel Z Safety Data Sheet lists the Section 3 Composition as:

**3. COMPOSITION / INFORMATION ON INGREDIENTS**

| Chemical name | CAS No. | Percent |
|---|---|---|
| Synthetic Amorphous Silica | 7631-86-9 | 25-40% |
| Methylsilylated Silica | 68909-20-6 | 10-20% |
| Polyethylene terephthalate (PET or polyester) | 25038-59-9 | 10-20% |
| Fibrous Glass (textile grade) | Not Applicable | 10-20% |
| Magnesium Hydroxide | 1309-42-8 | 0-5% |
| Aluminum Foil | 7429-90-5 | 0-5% |

**The exact percentage (concentration) of composition has been withheld as a trade secret.**

**Table 4: Cryogel Z Composition per SDS**

## CONCLUSION
The intent within this Technical Bulletin has been to be objective, yet lacking some relevant data and empirical evidence regarding Cryogel Z, some subjectivity is inevitable - - yet based on applied logical conclusions.

A summary of conclusions includes:

- The much-advertised, and indeed excellent, thermal conductivities of Cryogel Z do not result in appreciably less insulant thickness at cryogenic temperatures; thus installed/lifecycle costs and operating risks become paramount;
- The high density of Cryogel Z inevitably results in an *insulation system* weighing dramatically more than a polyiso insulation system, requiring materially more structural support;
- A single layer of vapor retarder over a Cryogel blanket (with an inherently high WVT) may not sufficiently mitigate icing risks around LNG pipes;
- The total capital cost and life-cycle cost of a Cryogel-Z insulation system compared to alternative insulants with comparable or better performance must be assessed only after comprehensive due diligence by competent engineers.