# TECHNICAL BULLETIN 0114[1]

# POLYISOCYANURATE VS. CELLULAR GLASS IN LOW TEMPERATURE MECHANICAL INSULATION

## PURPOSE

This Technical Bulletin is an update in our series of white papers aimed at providing our clients, engineers, specifiers, contractors, fabricators, and friends with objective information on our products and those of our competitors. This Bulletin focuses on a comparison of the physical properties of closed cell[2] polyisocyanurate[3] (polyiso or PIR) rigid foam insulation products with those of cellular glass insulation products for demanding below-ambient applications such as cryogenic, refrigerant, and chilled water where energy efficiency, moisture intrusion, and condensation are issues.

We strive to be *objective* and believe in *full-disclosure*. In that vein it should be said that cellular glass is a proven product made by several reputable manufacturers, and it may be the most appropriate insulant in some situations; for example in a chemically corrosive environment when 25/50 flame spread/smoke development[4] is required there is no better choice. Yet, as they say, the devil is in the details and insulation systems for low-temperature applications require engineering expertise that we do not purport to offer in this short Bulletin. Rather, we desire to raise issues that should be addressed by your engineer/specifier, and we will gladly provide any support or clarifying detail we may have.

Simply, we offer that polyiso insulation products are the preferable choice for a range of low temperature applications, particularly cryogenic, refrigeration, HVAC, and even domestic hot and cold water applications ranging from -297°F up to +350°F (-183°C to +177°C) and 375°F (190°F) intermittent service temperatures. Specifiers, engineers, and end-users should additionally note that while this Bulletin is focused on generic differences between cellular glass and PIR foams, yet there are indeed additional differences between the physical properties and performance characteristics of competing PIR insulations. We recommend end-users view other Technical Bulletins from Dyplast that address ISO-C1® and ISO-HT™ properties in comparison to alternative polyiso insulation products.

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[1] Update on Technical Bulletin 0213

[2] Determination of "closed celled" versus "open celled" is not as simple as it would first seem, since there are variations in the "%" of closed cells, as well as variation in cell structure and whether they can retain insulating gases. We could not find a statement from cell glass manufacturers re: % closed cells, but it is logical that it is very high. ISO-C1 has >95% closed cells in its 2 lb/ft$^3$ density, and >98% in higher density.

[3] Polyisocyanurate is a form of polyurethane (PUR), but the chemistry and properties are different to improve flame spread, smoke development, and dimensional stability - - among other properties.

[4] No U.S. manufactured polyiso currently meets the 25/50 criteria; however Dyplast's ISO-C1 and ISO-HT meet Class 1 per ASTM E84.

## SUMMARY

- K-factor: the aged thermal conductivity (k-factor) at 75°F of ISO-C1 polyiso is 0.176 Btu·in/hr·ft$^2$·°F whereas cellular glass is nominally 0.29; thus the thermal insulation performance of cellular glass is roughly 65% worse than polyiso, which results in cellular glass insulation systems being much thicker (important from a weight, volume, quantity of accessory products such as sealants, jackets, etc., and space aspects).
- Brittleness and Shipment/Handling: cellular glass is more susceptible than polyiso to vibration, thermal shock, and mechanical shock; thus cellular glass may have breakage during transportation to the job site and subsequent handling; polyiso is not of course immune to damage during shipment or handling but typically requires less mitigation efforts; thumbrules for cellular glass from insulation specifiers and contractors sometimes assume 5% breakage during shipment, 15% breakage from handling on job site.
- Brittleness and Operations: cellular glass may be less suitable for application in process environments with high vibration, movement, or thermal/mechanical shock; cellular glass breaks or cracks may create a path for heat and/or moisture to pass; polyiso is not brittle and is not as susceptible to vibration, movement, or thermal/mechanical shock; when polyiso is installed in areas where mechanical abuse is expected, such as workers stepping on the insulation, higher density polyiso with higher compressive strengths should be considered; even when abused, since polyiso is not brittle so it will not crack like cellular glass so such thermal/moisture leaks are less likely to form.
- Thermal Expansion/Contraction: since cellular glass has a thermal expansion coefficient less than polyiso, expansion joints are less of an issue; pipe metallurgy and the range/duration of temperature cycling are determining factors yet our experience is that the cost of additional expansion joints is not material when insulant selections are being made.
- Water Vapor Transmission and Joints/Cracks: (i.e. WVT, or permeability): both polyiso and cellular glass are "low perm" materials; cellular glass manufacturers generally advertise "zero" perm; polyiso insulation has low (but not zero[5]) water vapor permeability; for both materials the risk of moisture infiltration is less determined by the inherent property of polyiso or cell glass and more-so dependent on the quality of the vapor retarder/barrier, the number of joints between insulant segments[6], the performance of joint sealants, and the likelihood of cracks in the insulation; both cellular glass and polyiso manufacturers recommend vapor retarders in cold service, and vapor barriers at even lower temperatures.
- Vapor Barriers: although cell glass manufacturers sometimes advertise that vapor barriers

[5] ISO-C1 polyiso has 1.65 perm-inch WVT; Trymer polyiso advertises 4.0

[6] Polyiso is manufactured as large continuous "bunstock" that can be fabricated into pipe insulation many times larger than is possible with cell glass, thus minimizing the number of joints and seams; ask your supplier for specific dimensions

are not required, polyiso manufacturers more often recognize that in low temperature applications engineers almost always specify that a vapor retarder or barrier be applied over the insulant - - not so much to compensate for the WVT of the insulant but rather as a second line of defense for the joints, seams, and cracks; vapor retarders are more often used at chilled water temperatures while vapor barriers are increasingly important as temperatures drop below refrigerant temperatures; thus given the facts in the prior paragraph, vapor retarders/barriers could arguably be more important in cell glass systems than polyiso systems.

- Water Absorption (WA): Although different ASTM standards govern the testing of WA in polyiso and cellular glass[7], each have excellent water absorption properties, and water absorption should not be a factor in a properly installed insulation system.
- Installation – the "insulation system": A particular insulation product can perform at its peak only when properly installed within a more complete "insulation system" with sealants, adhesives, vapor barriers, weather mastics, jacketing, and so forth; while some cellular glass manufacturers advertise that neither vapor barriers nor jackets are required, the fact is that the vast majority of engineer/specifiers require similar accessory components; in fact, cellular glass insulation systems may require more complexities than a comparable polyiso insulation system, and thus may be more time-consuming to install and thus may have more potential for errors during the installation process; for example, a cellular glass system for LNG pipe may require an abrasive-resistant coating, a latex mastic as a weather barrier mastic (3 - 4 gal./100 $ft^2$ ), then a layer of synthetic mesh fabric, and then a second coat of weather barrier coating, and possibly a metal jacket' whereas a polyiso system installation would require only a sealant on seams/joints/ butt-ends, and a vapor barrier sheeting over the insulation (and this could actually be shop applied, making field installation even easier) and protective metal jacketing; note of course that polyiso systems as well as cellular glass systems require mastics at vapor stops and potentially other discontinuities; thumbrules from insulation contractors indicate that cellular glass requires a minimum of 30% more labor to apply than polyiso.
- Installation – field fabrication: installation contractors may have varied opinions on whether cellular glass or polyiso is easier to field fabricate (change shape/dimensions at the jobsite); cellular glass can be shaped by abrading it against a rough surface (or even the pipe itself, although maybe not advisable) or by using a rasp; some installers have minor complaints relating to abrasion to a worker's hands, glass dust, and odor; and the density/weight of cellular makes it somewhat more difficult for workers to handle; on the other hand, polyiso is shaped or re-shaped in the field typically with a sharp knife also it can also be shaped with a rasp; the most common complaint from installers is dust.
- Installation – number of insulation segments: the maximum dimensions of cellular glass insulation blocks are less than those of polyiso bunstock, and therefore when larger pipe

[7] The percent by volume WA for ISO-C1 polyiso is 0.04%, and for Trymer <0.7%; and for cellular glass <0.2%

diameters are involved, the cellular glass blocks must be joined together with adhesives; for very large pipe, multiple (more than two) cellular glass segments are required, resulting in more joints and seams to seal, which means more labor, more consumption of materials, and more possibility of improper installation (e.g. a seam not sealed, or a cracked piece of insulation) - - which can lead to thermal and/or moisture leaks; polyiso bunstock on the other hand is large enough to be fabricated into two half-shells even for the largest of pipe diameters; due to cellular glass's poorer insulating properties, a cellular glass insulation system is also likely to have more layers than a comparable polyiso system thus requiring more steps in the process, more joints to seal, and resulting in more consumption of sealants, tapes, adhesives, etc.

- Insulation Thickness: The thickness of the insulation is primarily dependent on the k-factor (addressed in the first bullet); the materially better k-factor of polyiso will always lead to polyiso requiring less thickness that cell glass; for instance, a 4 inch thick layer of polyiso (at a 0.176 k-factor) is typically equivalent to almost 7 inches of cellular glass (at 0.29 k).

- Number of Layers: Multiple layers of insulant are generally specified not to add more thermal efficiency[8] (since polyiso and cell glass can be fabricated to virtually any thickness[9]) but rather to allow offsetting joints and seams - - thus mitigating risks of moisture infiltrations; there is no logical reason that cell glass manufactures should argue their insulant requires fewer layers; to the contrary small billets of cell glass must be glued together to make fir larger pipe segments, while in theory polyiso can be manufactured to accommodate virtually any pipe diameter and length to minimize the number of seams and thus the requirement for more layers.

- Weight: Cellular glass has a density of generally 7.5 lb/ft$^3$ versus 2.0 lb/ft$^3$ for the most commonly used polyiso[10]; the low thermal efficiency of cellular glass (65% worse than polyiso) compounds the problem since cellular glass installations may require closer to double the thickness to provide the same insulating performance; the result is a significant increase in weight and volume on a given pipe run [for example assume an 8 inch diameter run of piping requiring 2 inch of polyiso insulation at 2 lb/ft$^3$ density; every linear foot of insulation would weigh 0.87 lbs; since 3.5 inch thick[11] cellular glass must be applied to achieve the same R-value, a linear foot of cell glass would be 6.6 lbs - - 7.5 times more weight than polyiso]; the costs of additional pipe hangars, stress on joints that can lead to failure, and inability to run multiple pipes in a small space may make cellular

[8] Two 3-inch layers of polyiso have the same thermal resistivity as a single 6-inch layer, yet two layers allow staggered joints & seams to provide another line of defense against moisture intrusion.

[9] Note cell glass' high density can lead to very heavy segments at greater thicknesses.

[10] For some refrigeration and LNG applications, density of polyiso may be 2.5 lb/ft$^3$, and higher for pipe hangars.

[11] Using 3E-Plus software developed by North American Insulation Manufacturers Association, rounded to nearest ½ inch thickness.

glass a less suitable insulation.

- Combustibility: Cellular glass has a zero flame spread index (FSI) and a zero smoke developed index (SDI) per ASTM E84; polyiso insulation products for mechanical insulation made in the U.S. currently meet only Class 1, and cannot be installed when *air plenum* conditions are required; caution must be exercised when installing any insulant in *air plenum environments* since vapor retarders, weather barriers, sealants, mesh, or adhesives must each have compliant FSI/SDI characteristics; note also that cellular glass can shatter and lose its insulating integrity when severely thermally or mechanically shocked; when exposed to flame, polyiso insulation will char, but maintain its shape, providing precious minutes of thermal protection to pipe, equipment, and vessels to allow response.

  [Important Note: *Section 602.2.1 of the International Mechanical Code states that materials within return air plenums shall be either non-combustible or have less than or equal to a 25/50 fire spread index and developed smoke index when tested in accordance with ASTM E84. Interpretations by other code authorities allow compliance with NFPA 255 or UL 723 as substitutes for ASTM E84. Essentially this means that insulation systems (and all accessory components within, such as sealants, vapor barriers, etc.) installed in either air plenums or inhabited areas to be non-combustible or ≤ 25/50. Name-brand cellular glass such as FoamGlas meets this ≤25/50 requirement. ISO-C1 polyiso is 25/130, so it should not be installed in air plenums or in indoor inhabited areas. Caution should be observed when using cellular glass in such applications that all related sealants, barriers, and such are ≤ 25/50*.]

- Cost: The cost of cellular glass per linear foot generally exceeds that of polyiso by a significant margin; the installation cost of cellular glass can also be much more expensive than polyiso; life-cycle costs relating to energy loss and maintenance also will favor polyiso over cellular glass.
- Chemical resistance: Cellular glass is arguably impervious to the majority of chemicals and is indeed resistant to organic solvents and nearly all acids; yet in the vast majority of cryogenic, refrigerant, and chilled water applications such chemical resistance is not required; it is appropriate to caution that a chemical resistance concern must include accessory products such as sealants, mastics, and vapor retarders.
- Compressive Strength: Cellular glass, at 7.5 $lb/ft^3$ density indeed has high compressive strength up to typically 90 $lb/in^2$, yet it should be noted that the compressive strength of 6 $lb/ft^3$ density ISO-C1 is typically greater than 135 $lb/in^2$ (parallel to rise); higher compressive strengths are most commonly required only in pipe saddle applications and in areas of high mechanical abuse, and in these applications polyiso insulation can offer high strength while enabling higher thermal efficiencies than cell glass - - and with fewer problems associated with cracking and weight management.
- Coefficient of Linear Thermal Expansion (CLTE): Cellular glass has a CLTE close to that of metal, and thus requires fewer contraction/expansion joints than a polyiso insulation system; polyiso, however, is much easier to work in the field and polyiso

contraction/expansion joints are relatively easy to install.

- Dimensional Stability: Dimensional stability is a combination of both reversible and irreversible changes in linear and volumetric units; cellular glass product data sheets typically advertise excellent to extraordinary dimensional stability, yet polyiso insulants have very good to excellent characteristics; the bottom line is that with properly installed contractions/expansion joints the issue is mute since any temporary or permanent changes in dimension can be accommodated by insulation system design; note that some cellular glass manufacturers make comparisons against polyurethane insulation without noting that polyisocyanurate is a different chemical formulation with much improved dimensional stability; note also that ISO-C1 has the best dimensional stability when compared with competitive polyiso products.
- Independent Testing and Auditing of Physical Properties: Although physical properties of insulants reported by manufacturers are generally credible, it is always prudent to demand validation of results by an independent third-party laboratory; even better, expect that the manufacturing and quality control protocols be periodically audited by an accredited agency.

The following table displays key physical properties of polyiso (ISO-C1) and cellular glass (FoamGlas). Note that these are "product" values, and not "insulation system" values.

| **Insulation Material** | **Units** | **Polyiso** | **FoamGlas** |
|---|---|---|---|
| Aged k-factor (at 75°F) | Btu·in/hr·$ft^2$·°F | 0.176 | 0.29 |
| WVT | Perm-in | 1.65 | <0.01 |
| Flammability ASTM E84 rating (insulation only) | FSI/SDI | 25/130 per FM | <25/50 |
| Density | lb/$ft^3$ | 2.0 | 7.5 |
| Water Absorption[12] | % by volume | <0.04 | <0.2 |

## Qualitative Comparison Chart:

| **Quality** | **Polyiso** | **Cellular Glass** |
|---|---|---|
| Thermal Performance | Excellent | Fair |
| WVT without vapor barriers | Very good | Excellent |
| WVT with vapor barriers | Excellent | Excellent |

[12] Measured by different ASTM standards; cellular glass manufacturers frequently note that the water is retained on the surface only.

| | | |
|---|---|---|
| ASTM E84 FSI/SDI | Very Good (Class 1) | Excellent (< 25/50; sometimes advertised as 0/0) |
| Available with factory-applied vapor barrier | Yes | Yes |
| Closed cell structure | Yes | Yes |
| Fiber free | Yes | Yes |
| Non-porous | Yes | Yes |
| Mold resistant | Yes | Yes |
| Resistant to vibration/movement | Yes | Less so |
| Requires a metal jacket | Generally | Generally |
| Thicknesses available | Virtually unlimited, from 1/8" upwards | Limited, 1" minimum |
| Lengths | Virtually any | Sold in 3 foot maximum |
| In-field fabrication | Easy | Less easy |