TECHNICAL BULLETIN 0314
PHENOLIC vs. CELLULAR GLASS INSULATION
IN COLD PIPING APPLICATIONS
(WHEN 25/50 RATINGS ARE REQUIRED)

PURPOSE

There are many applications with service temperatures at *chilled water* temperatures that require 25 Flame Spread and 50 Smoke Development ratings as tested in accordance with ASTM E84 or its equivalent. On rare occasion, specifiers/engineers may require such at refrigeration temperatures - - below those in chilled water applications.

It is common knowledge that cellular glass products have been used for decades across a wide range of applications, including cold service. There is less common knowledge, and more stakeholders are uninformed, about modern phenolic insulation and its excellent track record in cold applications.

The purpose of this Technical Bulletin is to evaluate and comment on client, engineer, and/or specifier options for insulation at these conditions.

JUMP TO THE SUMMARY

WHAT IS COLD?

Definitions are imprecise, yet we will suggest the following:

- Chilled water: Ambient Temperatures to 32°F
- Refrigeration: 32°F to -60°F
- Low temperature refrigeration: -60°F to -148°F
- High temperature Cryogenic: -148°F to -238°F
- Cryogenic: -238°F to -469°F

For the purposes of this memo, we will focus on chilled water and the higher-temperature refrigeration applications.

WHAT IS “25/50” AND ASTM E84?

ASTM E84 characterizes the relative rate at which flame will spread and smoke is developed as the subject material burns. This test method is often referred to as the “Tunnel Test” because the test chamber is a nominal 25-foot-long by 20-inch wide chamber. A gas burner is lit at one end of the chamber and a draft is applied to facilitate flame propagation along the specimen. A photometer and light source is placed at the exhaust end of the chamber to measure the relative amount of smoke that is developed during the test. The test is run for 10 minutes and the distance that the flame propagates during that time is measured and used to compare to a standard. A photometer and light source is placed at the exhaust end of the chamber to measure the relative amount of smoke that is developed during the test.

The Flame Spread Index calculated is a relative indication of the flammability of the test material with respect to a *red oak* standard. Both the distance of flame spread and the time-rate of flame spread are considered as part of calculating a flame spread index. Overly simplified, a reported flame spread index of 25 indicates that a material has approximately 25 percent of the standard material's flame spread characteristics. Note this requires an experienced observer who uses his/her own judgment, and can thus be quite subjective. The "smoke developed index" is calculated similarly.

In accordance with Section 602.2.1 of the International Mechanical Code, materials (including insulation) within *indoor air plenums* shall have a flame spread index of not more than 25 and a smoke-developed index of not more than 50 when tested in accordance with ASTM E 84. Interpretations by other code authorities have allowed compliance with NFPA 255 or UL 723 as substitutes for ASTM E84. In applications with service temperatures below those of chilled water, installation within *air plenums* is rare yet this requirement may imposed elsewhere - - where there is a concern of fire within an enclosed space.

It is important to note that if the 25/50 rating is required, <u>all</u> materials must meet the rating, including vapor barriers, adhesives, mastics, jackets, pipe coatings, and so forth. It is also interesting to note that the flame spread and smoke development of an installed *insulation system* will be quite different than each of the components. Typically, a metal jacket over the vapor barrier and insulation offers an additional layer of protection that will delay the onset and likely reduce the impact of flame spread and smoke development.

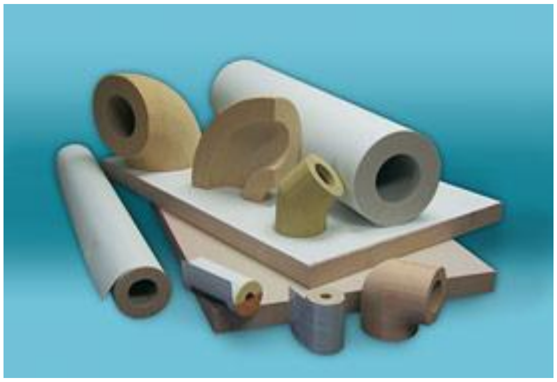
PHENOLIC AND CELLULAR GLASS

There are several *advertised* alternative insulants that are represented as acceptable in chilled water (and possibly higher-temperature refrigeration applications), <u>and</u> are rated as 25/50 per ASTM E84. In this Bulletin we choose not to address fiberglass or other alternatives since we believe their shortcomings make them a distant third compared to phenolic and cellular glass which are both closed cell foams.

While this Technical Bulletin intends to generally address generic phenolic versus generic cellular glass, when specific comparisons are required we selected Dyplast's DyTherm® Phenolic as *best-in-class.*

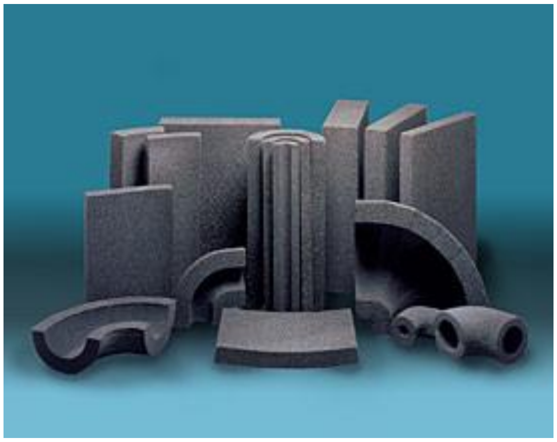
WHAT IS PHENOLIC INSULATION?[1]

[1] Description taken from Mechanical Insulation Design Guide - Materials and Systems; http://www.wbdg.org/design/midg_materials.php



Phenolic insulation is rigid foam insulation with a closed-cell structure. It is manufactured as large rectangular buns typically 3 feet wide x 3-12 feet long x 2 feet tall at densities ranging from 2.5 to 7.5 lbs/ft^3. Prior to actual installation, buns are fabricated into preformed pipe half-shells 3 feet long designed to fit over pipe or tubing. More complex shapes can also be fabricated to fit around fittings, elbows, and other equipment. ASTM material specification C1126, Type III covers this type of insulation at service temperatures from -292°F to +248°F. The specification defines requirements for density, compressive resistance, closed cell content, thermal conductivity, water absorption, water vapor permeability, dimensional stability, and ASTM E84 performance. While this ASTM spec lists three types, only the Type III is appropriate for use in pipe insulation. For comparison purposes, the maximum thermal conductivity at 75°F for the Type III phenolic insulation is 0.18 Btu-in/hr-ft^2-°F. Key applications for this phenolic insulation are on pipe, equipment, tanks, and ducts, especially those operating at temperatures below ambient.

WHAT IS CELLULAR GLASS?[1]



Cellular Glass is defined by ASTM as insulation composed of glass processed to form a rigid foam having a predominantly closed-cell structure. Cellular glass is covered by ASTM C552, "Standard Specification for Cellular Glass Thermal Insulation" and is intended for use on surfaces operating at temperatures between -450°F and 800°F.Cellular glass is produced in block form (Type I) in seven grades ranging in density from 6.12 to 10.6 lb/ft^3. Blocks of Type I product are typically shipped to fabricators who produce fabricated shapes (Types II, III, and IV) that are supplied to distributors and/or insulation contractors. Type I blocks are available in lengths up to 36 inches, widths up to 18 inches and thicknesses from 1.5 to 7 inches. Type II cell glass is used for Pipe and Tubing insulation.

Cellular glass insulation is a rigid inorganic non-combustible, chemically resistant form of glass. Because of the wide temperature range, different fabrication techniques are sometimes used at various operating temperature ranges. Typically, fabrication of cellular glass insulation involves gluing multiple blocks together to form a "billet" which is then used to produce pipe insulation or special shapes. The glue or adhesives used vary with the intended end use and design operating temperatures. For below-ambient applications, hot melt adhesives such as ASTM D312 Type III asphalt are usually used. Other adhesives may be recommended for specific applications.

INSULATION SYSTEM OBJECTIVES

An installed insulation system for a cold piping application consists of one or more layers of the core insulant, vapor retarders, tapes, jackets, bands, mastics, adhesives, and possibly pipe coatings. The ultimate objectives of an insulation system, while complying with regulations, can be multiple yet typically include:

1. Conserve energy by reducing heat loss or gain; lost energy costs money; typically the capital cost of an “excellent insulation system” as compared to a “good insulation system” is inconsequential when compared to the cost of energy that can be reduced over the life of the system.
2. Prevent vapor flow and water condensation on cold surfaces.
3. Control surface temperatures for personnel protection and comfort.
4. Facilitate temperature control of industrial processes: a poorly designed or installed system can lead to process failures due to an array of modes - - product quality, frozen valves, process liquid evaporation and pump cavitation, and so forth.
5. Increase operating efficiency of cooling, plumbing, and process systems found in commercial and governmental installations.
6. Prevent or reduce damage to equipment from exposure to fire or corrosive atmospheres.
7. Assist mechanical systems in meeting criteria in food and cosmetic plants.

GENERAL POINTS FIRST

Let’s make some general points first:

- <u>There is a good and bad case for any and every type of insulation product made</u>. Some insulants are heavier, dustier, have lower compressive strength, are harder to shape in the field, are more expensive, have longer lead times, are more sensitive to chemicals, etc. - - than other insulants. Yet for a particular application, the range of acceptable insulants narrows very quickly when environmental and process conditions are matched with the expectations of the client.
- Assuming a particular insulant has been vetted as acceptable for a particular application (i.e. temperatures, 25/50, etc.), and assuming it is installed properly within a well-designed *insulation system* (and not abused) - - *any insulant may* “*perform”*! The more important issue becomes “<u>*what are the short and long-term economics*</u>?” - - and the economics encompass capital costs, energy loss, process control, risk profile (e.g. to punctures, crushing, etc.), and so forth. In theory, fiberglass, mineral wool, or perlite could be used on a refrigeration pipe, but the thickness would be impractical and the slightest flaw in application or damage in use could lead to system failure. There would be *no second-line-of-defense* against a vapor barrier breach.
- <u>Chemical resistance is rarely of concern</u> since both phenolic and cellular glass insulants

are resistant or impervious to virtually all chemicals we could envision being used in *cold applications*. In the rare instances where an application has a material risk of, for example nitric acid leaks, phenolic insulation should not be used since it is indeed an organic compound that can be affected by certain chemicals. Note however, that phenolic's organic nature is at the root of its superior insulating qualities. On the other hand, cellular glass is susceptible to potassium and sodium hydroxide solutions. Nevertheless the overall point still applies - - cell glass and phenolic insulants are both suitable for installation in chilled water and refrigerant applications.

- Corrosion Under Insulation (CUI) refers to pipe wall material deterioration underneath the insulation material. CUI is a recognized problem that must be addressed by designers, specifiers, and end-users. CUI can occur under any type of thermal insulation, and is very complex given the assortment of metals (carbon steel, stainless/austenitic steel, copper, and all the variants). Yet the type of corrosion will depend not only on the metallurgy of the pipe but also the mix of corrosive elements - - understanding that corrosive elements can be introduced during pipe production, pipe shipping/storage, installation, insulation contact, process liquid contact, weather, joint compounds, adhesives, mastics, or other environmental influences. At the highest level, corrosion requires:
    - *High* temperature ("high" is generally defined as above 32°F)
    - Moisture
    - Oxygen
    - Concentration of corrosive ions (generally, *halogens*)

  Both cellular glass and modern phenolic insulation have *less than detectable* halogens, and in a properly designed and installed insulation system there should be neither moisture nor oxygen.

- Unfortunately, too often a client delegates the choice of insulation to another party, or is given insufficient objective information from which to make an informed decision. Clients should ensure their contractors and engineers execute *due diligence* and conduct a fresh and objective evaluation of capital versus long term costs for the given application - - rather than simply adopt old specifications that are their "*easy*" option.

- Installation: In our experience, virtually all insulation failures are due to either (1) improper installation of product or (2) misapplication (i.e. poor specification) of a product - - not the insulation product itself. More on this later in the Insulation Failures section.

- ASTM: The American Society for Testing and Materials is the best objective and globally accepted authority to establish standards and testing protocols for materials in order to compare "apples-to-apples". Yet this is a complex challenge when the range of chemistries and applications is so broad, and comparisons are too often not "*apples-to-apples*". For instance, some Water Absorption (WA) tests are 2 hours, some 24, sometimes 96 hours. Phenolic insulation is tested for WA under ASTM C209 Standard Test Methods for Cellulosic Fiber Insulating Board. Cellular glass has its own C240 Standard Test Methods for Testing Cellular Glass Block Insulation for testing WA.

ASTM C1126 strives to establish the basic standards for phenolic insulation use in various applications. ASTM C552 (Standard Specification for Cellular Glass Thermal Insulation) does the same for cellular glass. ASTM C1126 allows a maximum k-factor of 0.18 Btu-in/hr-ft²-°F at 50°F; ASTM C552 allows a maximum of 0.33.

- ASTM versus REALITY: Insulation systems exist within their own process and environmental conditions - - each with varied durations, temperatures, humidities, etc. It is impossible for ASTM to predict insulation performance under actual ("*in situ"*) conditions. For instance, a water absorption test by ASTM may have little applicability to long-term (e.g. 5-year) exposure of an insulant to warm moisture in an underground installation.

INSULATION FAILURES

As we have offered, virtually any insulation system can fail if: 1) specified for an inappropriate application, 2) improperly installed, or 3) abused. There have been a handful of past reported phenolic insulation failures that are still presented as *warnings* to prospective buyers that are presented out of context. Yet there are also cellular glass failures. The following selection is intended to make the point:

- Canadian Roof Decking: The earliest may have been *roof decking* in Canada in the 1990's. Of the lessons learned, the most significant was that at the time, Canadian phenolic manufacturers used higher concentrations of inorganic mineral acids than offshore counterparts. Today's technology is very different, utilizing modified catalyst systems. Phenolic roof insulation is being successfully applied in countless projects today, and indeed across Canada.
- Miami High-Rise: The chilled-water system failed at the Espirito Bank insulated with Kingspan's Kooltherm® phenolic product[2]. An investigation by a third-party expert[3] points to the keys to the pipe-insulation failure as: 1) the use of an All-Service-Jacket (ASJ) (a purported combination vapor barrier and protective jacket when it is in fact neither), 2) plus the insulation was 1 inch and it should have been 3 inches, and 3) after installation other workers stepped on and otherwise abused the insulation. The expert also listed excessive water absorption of the KoolTherm product. We were unable to locate documentation of the Water Absorption characteristic of the old KoolTherm product, but the WA of DyTherm Phenolic is <0.9% per ASTM C209, and that of cellular glass is as low as <0.2% per on-line datasheets. We point out the difference of maybe 0.7 % should not be sufficient to lead to failure of one insulation and lack of failure in the other.

  We quote from Mr. Lotz's article in HPAC Engineering magazine, posted in several

[2] Different chemical formulation than DyTherm Phenolic.

[3] William A. Lotz, PE is an American Society of Heating, Refrigerating and Air-Conditioning Engineers Life Member, Fellow, and Distinguished Lecturer. BSME in mechanical engineering from the University of Miami and a registered professional engineer in eight states.

locations on-line[4]:

- "The coating on the phenolic-foam fittings was not a vapor barrier, while some fittings had no vapor barrier at all"
- "The specified foam was too thin, which resulted in condensation on the ASJ facer, which hastened the demise of the thin foil vapor barrier in the ASJ laminate"
- "The workmanship on the entire pipe-insulation system was quite poor, while damage to the ASJ caused by other trades severely compromised the vapor barrier"
- "The insulation[5] had little or no resistance to vapor in a high-humidity climate".

Additionally Kingspan's attorney's convinced the plaintiff that the damage was not due to Kingspan's product, but to the fault of others. Claims were dropped and Kingspan was released from liability.

- Minute Maid Stadium Houston: There are parties (some uninformed and others "*artful*") that refer to this as a *phenolic failure*. In fact it was a design/installation failure of an insulation system of which the vast majority was fiberglass. Engineers and construction companies were sued, but not insulation suppliers. Engineers reportedly erred by used design data from the Houston Airport that was mostly an indoor installation with much lower humidity and environmental stresses than the stadium. Apparently there were thus insulation thickness issues, and again, an ASJ wrapper was used - - subjecting the insulation to the high humidity, and fiberglass water absorption is so high it is not listed.
- NAVFAC FoamGlas® Failures: Many years ago, a Technical Report published by the Naval Facility Engineering Command (NavFac) elaborated on their investigations of 58 FoamGlas underground applications and concluded that within the 26 installations 0-5 years old there were 4 failures. Within the 32 installations 5-10 years old there were 17 failures. They offered that failures were due to, and we quote
    - "the vapor barrier or the Foamglas was frequently broken, allowing moisture to penetrate the Foamglas insulation",
    - "Foamglas absorbs more water (as much as 7.9% by volume) than had been reported", and
    - "failure of vapor barrier and insulating material to prevent water intrusion permitted pipe corrosion, heat loss, and sometimes disintegration of the Foamglas".

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[4] http://www.foamglas.com/__/frontend/handler/document.php?id=1274&type=42

[5] We interpret that the "insulation system" had little or no resistance to water vapor; also that the Kooltherm formulation was the "old formulation"; and also that if *abused* no insulant can perform to design expectations.

On the basis of these investigations NavFac concluded that Foamglas was not suitable for insulating pipes below the water table or in wet soils[6].

Insulant Failure Summary

The point made in this Section is that every insulant likely has a particular installation that a competitor can rightly or wrongly argue as a failure. The questions that must be asked include:

1. "to what extent was the insulant the root cause of the failure"?
2. "does a failure of an insulation system 18 or 47 years ago disqualify an insulant that may actually be the best option today", and
3. "why do competing insulation suppliers often not discuss physical properties, economic performance, and credible experience in an objective manner?"

Phenolic insulation has been successfully installed in hundreds of applications over the past years, and Dyplast's DyTherm Phenolic in particular has an enviable record of successes.

From another perspective, a client or engineer that chooses an insulant based on claims by the seller that "*the other insulant fails*" may not be well-served.

CAPITAL AND INSTALLATION COSTS

Again, let's start with a few facts:

- Capital Cost per Board Foot: The cost of cellular glass compared to DyTherm Phenolic per board foot can be assumed to be 50% higher; yet expense of fabrication into pipe half-shells can be additionally expensive for cellular glass since the sizes of cell glass "blocks" are smaller and must therefore be glued together prior to fabrication; and the types of required adhesives varies with the ultimate *process temperatures*, leaving more room for error. For larger pipe sizes, there will be inevitably more "pieces" of cell glass to be fabricated, since half-shells become *third-shells* and smaller. It is difficult to estimate a related increased cost, yet in a bid comparison it is not immaterial.
- Thermal Conductivity vs. Thickness: The thermal conductivity (k-factor) of the most commonly available cellular glass versus phenolic is generally 67% worse at 50°F (0.3 versus 0.18 BTU·in/hr·°F·ft^2. Utilizing the industry-standard software 3E Plus, this means the thickness of insulation on a cellular glass system must be 4.5 inches on a 12 inch pipe operating at 50°F in sample conditions[7]. DyTherm Phenolic on the other hand requires only 2.5 inches.
- Thermal Conductivity vs. Board Feet: In the above example, the additional thickness

[6] Dyplast comment: We would be surprised if the root cause of these reported failures of FoamGlas have not been rectified and that this ban by NavFac has not been reversed.

[7] Sample conditions are 80°F ambient, indoors, at 75% humidity.

equates to significantly higher board feet of insulant (which is generally how insulant is priced). 2.5 inches of phenolic on a 12 inch pipe requires roughly 9.5 board feet of insulant per board foot. 4.5 inches of cellular glass on a 12 inch pipe requires almost 19.4 board feet per board foot, more than double. Combined with a 50% premium cost per board foot for cellular glass over phenolic per board foot, this leads to a capital cost (before fabrication or installation) for cellular glass three times that of phenolic.

- Thermal Conductivity vs. Extra Vapor Barrier & Jacket: The above scenario leads to cellular glass requiring approximately 24% more vapor barrier, jacketing, and other materials than DyTherm Phenolic. It's difficult to estimate the increased cost, yet it is not insignificant. The increased size also reduces ability to run multiple pipes with cell glass insulation in a small space. Note that thermal conductivity generally improves as temperatures decrease so insulants must be compared at the same temperature, and we submit that the difference is even more profound at lower temperatures.

- Density/Weight: Although DyTherm Phenolic is available in higher densities, 2.5 lb/ft^3 is standard for cold applications[8], whereas the typical cellular glass insulant is 7.5 lb/ft^3. For example again assume again a 12" diameter run of piping requiring 2.5" of phenolic insulation at 2.5 lb/ft^3 density; every linear foot of insulation would weigh 2 lbs; since 2.5" thick cellular glass must be applied to achieve the same insulating value, a linear foot of cell glass would approach 12 lbs - - 6 times more weight than phenolic; the costs of additional pipe hangars, and stress on joints that can lead to failure.

- Installation – the *insulation system*: A particular insulation product can perform at its peak only when properly installed within the "insulation system" with sealants, adhesives, vapor barriers, weather mastics, jacketing, and so forth. A cellular glass insulation system is generally more complex than a comparable phenolic insulation system. Since the lengths and diameters of cellular glass insulation segments are smaller than those of phenolic, for larger pipe there will typically be more segments (pieces) of cellular glass to install as compared to a phenolic system; more pieces/parts means more seams and joints 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; a cellular glass insulation system is also likely to have more layers than a comparable phenolic system thus requiring more steps in the process,

[8] Higher densities are available for use in pipe hangars and where the insulation may be subject to mechanical abuse, such as where an operator or maintenance technician may step on the pipe.

more joints to seal, and resulting in more consumption of sealants, tapes, adhesives, etc.

- Brittleness: Cellular glass is susceptible to vibration, movement, thermal shock, and mechanical shock; thus cellular glass may have high breakage (10% - 20%) during to transportation to job site and may be unsuitable for application in process environments with high vibration, movement, or thermal/mechanical shock. If cellular glass breaks the cracks may create a path for heat and/or moisture to pass; phenolic is not brittle and is not as susceptible to vibration, movement, or thermal/mechanical shock. When phenolic is installed in areas where mechanical abuse is expected, such as workers stepping on the insulation, higher density phenolic with higher compressive strengths should be considered. Even when abused, since phenolic is not brittle it will not crack like cellular glass so such thermal/moisture leaks will not form. Thumbrules from insulation specifiers and contractors assume 5% breakage during shipment, 15% breakage from handling on job site.
- WVT: (water vapor transmission, or permeability): Both phenolic and cellular glass are "low perm" materials, and DyTherm Phenolic meets the requirements of ASTM C1126. Yet cellular glass advertises "zero" perm. Phenolic insulation has low (but not zero) water vapor permeability. For both materials, zero-perm joint treatments and proper sealing are critical to support vapor drive resistance. If the joints in a cellular glass system are left unsealed, cellular glass will crack or shatter. Both materials require vapor retarders in cold service. Phenolic installed within a zero-perm vapor barrier system has a WVT comparable to cellular glass.
- Water Absorption: Both DyTherm phenolic and cellular glass have excellent water absorption properties, and DyTherm Phenolic meets the requirements of ASTM C1126. Water absorption should not be a factor in a properly installed insulation system; the percent by volume for phenolic is <0.9% and for cellular glass <0.2%.

COMPARISON OF INSULANTS

The following table displays key physical properties of phenolic (DyTherm) and cellular glass Note that these are "product" values, and not "insulation system" values.

QUALITY	DYTHERM PHENOLIC[9]	CELLULAR GLASS
Density	2.5 lb/ft^3 standard[10]	7.5 lb/ft^3 standard
Thermal conductivity (aged[11])	Excellent	Fair

[9] Based on 2.5 lb/ft^3 standard density

[10] Higher densities available up 7.5 lb/ft^3

WVT without vapor barriers	Very good	Excellent, yet dependent on joint & seam treatments
WVT with vapor barriers	Excellent	Excellent
ASTM E84 FSI/SDI	< 25/50 (quoted as 0/10[12])	< 25/50 (often quoted as 0/0)
Available with factory-applied vapor barrier	Yes	Possibly, for smaller sizes
Compressive Strength (parallel)	27 psi (150 psi at 7.5 lb/ft^3 comparable density)	116 psi
Closed cell structure	Yes	Yes
Resistant to vibration/movement	Yes	No
Requires a metal jacket	Yes	Usually
Thicknesses available	Virtually unlimited, from 1/8" upwards	Limited, 1" minimum

[11] "Aged" thermal conductivities measure the k-factors after the insulant has reached an *equilibrium* with its environment, and *blowing agents such as hydrocarbons* have been displaced by "air".

[12] Independently verified by Southwest Research Institute.

SUMMARY

Assuming a particular insulation and manufacturer have been vetted as acceptable for a given application (i.e. temperatures, humidities, wind, emissivity, etc.), and assuming the insulant is installed properly within a properly designed *insulation system* (and not abused) - - it will *perform*! The more important issue becomes "*what are the economics*?" - - and the economics encompass capital costs, energy loss, process control, risk profile (e.g. punctures, crushing, etc.), and so forth.

As demonstrated above, DyTherm Phenolic is the clear choice when compared to cellular glass.

DyTherm Phenolic and cellular glass insulation each are 25/50 per ASTM E84, but DyTherm Phenolic has clear advantages over cellular glass in every other important category:

1. 60% better insulating value
    - 0.18 versus 0.30[13] at 50°F
    - 2.5 inches versus 4.5 inches thickness in the above example
    - More volume means more surface area to cover with vapor barriers, mastics, jackets, etc.
2. 67% lower cost per board foot
    - Plus lower fabrication costs
    - Plus generally lower installation costs
        - Less volume to handle
        - Fewer, smaller pipe segments to handle
3. #1 and 2 above when taken together puts DyTherm Phenolic capital cost at one-third that cellular glass - - and that's ignoring *fabrication and installation*
4. 33% the weight
    - 6 times more weight per linear foot (in the above example)
    - More weight means more stress on pipe, more pipe hangars and supports
5. Excellent Water Vapor Transmission and Water Absorption, particularly considering zero-perm vapor barriers, and less insulation surface to cover means fewer installation errors and smaller risk profiles.

In summary, both phenolic and cellular glass have been demonstrated as viable choices as insulation for cold applications when 25/50 is required. However, when comparing both side by side, the overall advantages clearly belong to phenolic - - -**DyTherm® Phenolic**.

[13] Per 3E-Plus Insulation Thickness Calculator (http://www.pipeinsulation.org/)