TECHNICAL BULLETIN 0620
Elastomeric vs. Polyisocyanurate Insulation In Food, Beverage, and Process Applications

PURPOSE

Elastomeric and polyisocyanurate insulation is commonly used in Process Applications such as food, beverage, and pharmaceutical, as well as refrigeration, HVAC, and chilled water. Dyplast recently issued a Technical Bulletin 0520 focused generally on refrigeration, and this TB 0620 now addresses the "Industrial Process" segment which is different from refrigeration applications as follows:

- Federal Regulations, such as those from the Food & Drug Administration, may make stainless steel piping an optimal choice given cleanliness, chemical resistance, and corrosion,
- Regardless of regulations, the use of stainless steel may be higher in Process Applications due to the process liquid/gas chemistry, sanitation, or washdown protocols,
- Temperature ranges in Process Applications may range beyond those encountered in refrigeration;

While the essence of this Technical Bulletin is focused on Process Applications, the content and conclusions are generally applicable to adjacent industries.

BACKGROUND

Dyplast's® Technical Bulletins are intended to provide in-depth and objective information and comparisons of various insulants, including polyisocyanurate versus polyurethane, polystyrene, cellular glass, fiberglass, elastomeric, and others. Our Qwik Guides typically offer abbreviated (one-page) technical perspectives, sometimes referencing Technical Bulletins.

The primary, demonstrable conclusion when we do comparisons has always been that polyisocyanurate (ISO-C1®) has better thermal insulation properties (combined with other physical properties that make thermal performance sustainable over the long term) than any other common pipe insulant[1], and typically at a lower installed cost. Yet we indeed acknowledge each alternative insulant may have a particular advantage in a particular application; for instance, if a compressive strength >150 psi is required in a pipe saddle, or if code requirements might demand 25/50 Flame/Smoke per ASTM E84.

As always, if any reader credibly argues that Dyplast has materially *misstated* or *misinterpreted* facts, we will revise this and related documents!

EXECUTIVE HIGHLIGHTS

The primary demonstrable conclusion is that polyisocyanurate (ISO-C1) has better thermal insulation properties than any elastomeric on the market - - and at a lower installed cost!

We herein comprehensively explain that the often-advertised *advantages* of elastomeric are in fact not material advantages, and possibly disadvantages, when compared to polyiso:

[1] Aspen Aerogel's Cryogel® brand advertises better k-factors, yet cost and other disadvantages often apply (addressed in a separate Technical Bulletin).

- Although certain beverage processing facilities (beer, wine, liquor, milk, soda, etc.) *may* exceed 212°F, the vast majority do not exceed 300°F
- Additionally, the majority of food and pharma processing occurs at temperatures under 350°F
- Elastomeric suppliers limit their maximum service temperatures to either 220°F or 300°F depending on the formulation; polyiso (specifically Dyplast's ISO brands) are suitable up to 350°F
- Elastomeric insulation has 30 to 47% poorer thermal conductivity when compared to polyiso (measured per ASTM C177 and C518); and when elastomeric insulation is commonly more expensive, the essential question is "***why use it***?"
- Some elastomeric insulant suppliers argue a debatable advantage that elastomeric is preferable on the small portion of process pipe that is Austenitic Stainless Steel (ASS) since it is less susceptible to Stress Corrosion Cracking (SCC)[2]; YET the facts are:
  - SCC generally occurs within temperatures from 140°F to 250°F (a temperature range at the higher end of the beverage industry, yet encountered in *food* and *pharma*).
  - SCC is not applicable to cold piping
  - Note: neither non-austenitic stainless steel nor carbon steel nor copper exhibit SCC!
  - SCC is a concern only in a narrow set of circumstances, where there is a presence of chlorides or similar *halogens*, plus the presence of water and stress (above thresholds) - - and over time
  - Polyiso has Leachable Chloride Content comparable to some elastomerics, and in some cases less
  - Given the chloride content of some elastomeric insulants, they may not be the appropriate solution to address SCC.
- At least two elastomeric insulant manufacturers publish *adjusted* R-value tables[3]; adjusted to create an illusion of superior performance when in fact the tables have nothing to do with the actual performance of the insulant and rather on the geometry (e.g. cylindrical pipe vs. flat) - - which would apply to any insulant.
  - ASTM standard conventions measure thermal heat flux using flat specimens to facilitate apples-to-apples comparisons of insulation
  - Publishing R-values for cylindrical geometries is not necessarily a deceptive practice, yet those R-values cannot be compared to other insulants unless the same geometric adjustments are made; polyiso always has superior thermal performance! (see more on this later, including indicative tables)
- Elastomeric insulants vary in their chemistries, and thus physical properties (e.g. NBR/PVC, EPDM, etc.); products may be sheets or tubes - - each with different characteristics [read more below].
- Polyisocyanurate (polyiso or PIR) insulants have many decades of demonstrably successful performance in food, beverage, pharma, and other process applications (from -297°F to +350°F), across a spectrum of metallurgies and industries.

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[2] Chloride stress corrosion is a type of intergranular corrosion and occurs in austenitic stainless steel under tensile stress in the presence of oxygen, chloride ions, and 'high' temperature.

[3] http://www.armacell.us/fileadmin/user_upload/Reference_Sheets_INS/AP_ArmaFlex_Tolerances_and_R_Values.EN.US.2017.pdf; and http://www.kflexusa.com/downloads/Technical%20Data%20Sheets%20-%20Insulation/K-Flex%20Insul-Tube.pdf

CORROSION and METALLURGY

No metal pipe is immune from all corrosion threats, and a typical *process* plant has carbon steel, copper, and stainless steel piping - - with the latter a minority, and with ASS as a smaller segment. A competent insulation engineer should be engaged to assess all potential corrosion risks for each metal and in each given environment inside and outside the pipe. Dyplast addresses general corrosion in more detail in Technical Bulletin 0611.

Yet since elastomeric suppliers often focus on Austenitic Stainless Steel, let's discuss SCC since related advertising sometimes has often-unstated or under-stated caveats!

Stainless Steel

Stainless steel may be required to comply with Food Contact Substances (FCS) rules or approvals by the Food and Drug Administration (FDA), National Science Foundation (NSF), or the American National Standards Institute (ANSI).

Stainless steel may be additionally appropriate in food, beverage, and pharma due to:

- general corrosion, erosion, and stain resistance
- impermeable, bacterially resistant surfaces
- ability to withstand frequent washdowns with detergents, and
- temperature compatibilities

There are 150 varieties of stainless steel, yet only a few of which are traditionally used in food, beverage, and pharma. The vast majority are not subject to Stress Corrosion Cracking (SCC). In general, three Grades of stainless steel meet food, beverage, and pharma requirements; SAE 200 Series (chromium-nickel-manganese alloys), SAE 300 Series (chromium-nickel alloys) and SAE 400 Series (chromium alloys). SAE 300 Series is Austenitic Stainless Steel.

Of the Series 300 austenitic stainless steel varieties:

- Grades 304 and 316 stainless steel are the most typical
- Of the two, 304 is the most common yet it is not as resistant to specialized corrosion by chloride, fluoride, silicate, or sodium ions. Grade 304 is commonly used when processing dairy and beer
- Grade 316 is more frequently used in commercial food production, and pharma where higher "salt" content may exist.

Stress Corrosion Cracking

- Considering stainless steels, SCC only occurs on Austenitic variety
  - If the pipe is not ASS there is no SCC
  - Non-austenitic stainless steels, carbon steels, and copper are not susceptible to SCC
- SCC occurs at temperatures ranging from around 140°F to 250°F
- SCC requires a combination of four factors – 1) a susceptible material (in this case ASS), 2) a ***threshold*** of leachable chloride, fluoride, silicate, or sodium ions, 3) a presence of water above a ***threshold***, and 4) tensile stresses above a ***threshold***. If any one of these factors are eliminated, SCC initiation should not occur
  - No elastomeric suppliers list the content of all ions listed in the above bullet (to our knowledge)

- Some elastomeric insulant suppliers list chloride content; others do not
- Certain elastomeric suppliers state "<0.05% water-soluble chloride ions" in accordance with DIN 1988 (a relatively old code of practice for drinking water installations)
  - Without assessing the details behind this DIN standard it is challenging to conclude why it is used
  - Conventional terminology would indicate 0.05% is 500 ppm!
- Another elastomeric supplier lists leachable water-soluble chloride ions as ≤90 ppm per EN13468 and ASTM C871
- ISO-C1/2.0 has a maximum leachable chloride content of 88 ppm per ASTM C871, with higher density ISO-C1 foams having a value of <60 ppm
  - Pipe coatings can eliminate SCC
- For perspective, during installation of the pipe and the insulation system there is likely human 'hands-on' contact with the pipe that could leave behind chlorides exceeding what may leach from insulation; note that even then, SCC requires the presence of water
- Finally, *washdown* solutions may contain chlorides and fluorides; sea water spray and even humidity and rain can contain salts;
- Thus, proper installation must ensure WVT and WA are near zero.

PHYSICAL PROPERTIES

To quote from an elastomeric pipe insulation provider[4]: "Two commonly used synthetic rubber products, EPDM and NBR/PVC, are similar in appearance, but have very different performance properties that are not apparent just by looking at the two products…. [certain elastomeric] products may not deliver on what is claimed."

Elastomeric insulants come in tubes or sheets/rolls from several suppliers.

On the other hand, polyiso is a rigid thermoset foam that is manufactured as large, continuous rise bunstock in variable dimensions and densities. Higher densities have improved strengths, yet the chemistry is essentially the same and the thermal insulating properties very comparable. Buns are subsequently cut and fabricated into pipe and alternative shapes (e.g. for fittings) that fit tightly. [read more in Appendix 1]

The most important perspective is that polyisocyanurate has an inherent thermal conductivity (k-factor) 30% to 47% better than elastomeric insulants, dependent on the elastomeric product, and at a lower installed cost. So let's start with k-factor:

Thermal Conductivity "k-factor"

Thermal conductivity is the essential and inherent property of any insulant that determines how it performs as a thermal insulator. The k-factor is measured "per inch" of insulant thickness (per meter in metric); the k-factor of a 3-inch thick insulant, counter-intuitively, is the same as for a 1-inch specimen; it is not additive per inch. K-factor

[4] https://www.aeroflexusa.com/about/we-are-different-and-better/epdm/

is typically measured by either ASTM C177[5], C518, or comparable EN standards - - which each test insulant specimens in a 'flat' configuration (i.e. a sheet).

The k-factor is a measure of the heat flux of the insulant, and therefore determines the thickness of an insulant in a particular application (pipe, wall, or special shape) and within the particular environmental conditions such as temperature, wind, humidity, etc. It is critically important to emphasize that when engineers and specifiers calculate the thickness of insulant, their algorithms/calculations depend on inputting the insulant's inherent k-factors measured per ASTM across the spectrum of in-situ temperatures! They do not input R-values! In pipe thickness applications, algorithms/calculations subsequently incorporate how the thermal flux will vary across a cylindrical geometry. 3E-Plus[6] is a classic example of such an algorithm; note it has been criticized as overly-conservative in lower temperature environments. ASTM C680 offers a more comprehensive approach to evaluating the thermal performance in cylindrical geometries, yet most end-users would find the mathematical equations daunting. It's best to depend on a qualified engineer.

The aged[7] k-factor of ISO-C1/2.0 as measured by C177 is an excellent 0.19 BTU·in/hr·ft^2·F at 75°F, compared to 0.245 for elastomeric (NBR/PVC). The lower the thermal k-factor, the better the thermal performance.

ISO-C1/2.0 has improved k-factors at lower temperatures: 0.16 at -100°F, 0.18 at -50°F … and is 0.23 at +150°F. K-factors of virtually all insulants improve at lower temperatures, yet at different gradients.

Elastomeric (NBR/PVC) k-factors are nominally 0.245 and 0.235 at temperatures between 32 to 50°F Elastomeric (EPDM-based) k-factors are poorer at 0.28 and 0.278 at the same respective temperatures. In any event, end users should verify with the supplier.

Elastomeric k-factors are materially poorer when compared to polyiso, and thus elastomeric insulation over the pipe must be thicker than a polyiso alternative; or from another perspective, a given thickness of polyisocyanurate will always provide more energy savings than elastomeric, regardless of temperature - - further lowering costs.

Thermal Resistance "R-value"

As stated above, the k-factor is a measure of the inherent property of an insulant *to insulate*. In a flat geometry (e.g. a wall) as measured by ASTM C177 and C518, the *thermal resistance* (R-value) is simply the inverse of *thermal conductivity* (k-factor) at 1-inch thickness. Yet R-values are *additive* across insulants greater than 1 inch thick, such that an R-value of "4" in a 1-inch thick sheet is generally accepted as "8" in a 2-inch thick sheet.

In a *cylindrical* pipe geometry the heat flux would be different if it could be measured in-situ, since the heat flow is radial from a smaller pipe surface area to the larger outer surface of the insulant.

The *adjusted R-value tables*[8] offered by some elastomeric suppliers are not necessarily deceptive since they represent the realities of heat-flux across insulation over a cylindrical pipe - - yet these *adjusted R-value tables* are rarely presented with the proper context or caveats. For instance, certain elastomeric suppliers list their k-factors on datasheets at 1 inch, say 0.245, and do not list their R-value at 1 inch which would be 4.08. Yet a sample *adjusted R-value table* indicates R-values as high 20.4 for two inches of elastomeric insulation on a 3/8 inch pipe

[5] ASTM C177 is an absolute method and is the referee method designated by C591 for thermal conductivity measurements.

[6] 3E Plus® is a software program by the North American Insulation Manufacturers Association; while sometimes maligned, they offer a generally conservative approach.

[7] "Thermal Aging" of insulants is discussed in Dyplast' Technical Bulletin 1115.

[8] This document does not address the accuracy of such equations, yet accepts the concept.

- - implying 10.2 R-value per inch - - when in fact an ASTM measured k-factor of 0.245 yields an R-value of 4.08 per inch.

Again, the industry-standard is to calculate R-values on flat specimens to facilitate comparisons with other insulants. Calculations based on cylindrical geometry may be interesting to astute observers, yet potentially deceptive to others. In Appendix 2, we demonstrate that using the same cylindrical geometric calculations as used by at least one elastomeric supplier[9], the "adjusted R-value" of polyiso is in all cases better than that of elastomeric.

Indeed, Armacell offers some context for their R-value tables: "*These specifications are based on the measurement methods employed by Armacell. Other methods may not result in the same values and cannot be used to determine if the product is within the given tolerance."

And another context provided by K-Flex is that their tables are not "R-value" but rather "R-value per square foot" - - which K-Flex must define since the units are problematic. To be credible, this approach must be substantiated with *units-of-measure* and/or test methods that can be verified and compared to ASTM methodologies.

Thus, the tables from some elastomeric suppliers that *adjusted R-values per geometry* should not be used for either thickness calculations or insulant comparisons. Since polyiso has a better thermal conductivity than elastomeric insulants, under all circumstances it will always result in either thinner insulation walls, or greater thermal performance at a given thickness.

Water Vapor Transmission

The Water Vapor Transmission (Permeance) of elastomeric insulation is typically advertised as low, and nominally <0.1 perm-inch (with some product brands higher). Thus, some elastomeric insulant suppliers indicate their product can be installed without a vapor barrier on small pipe in mild environmental conditions; this indeed may be correct if "small" and "mild" are defined and validated by a qualified engineer. Yet the majority of suppliers note that "additional vapor barrier protection may be necessary when installed on lower temperature surfaces or where exposed to high humidity conditions". [Again, it's important to define the adjectives]

The majority of *process applications* require a protective covering for weather/UV protection in exterior piping -- and indeed in many interior applications where cleanliness standards necessitate frequent washdowns, often accommodated by using PVC jacketing with weld adhesives or self-sealing lap tape. Thus, both elastomeric and polyisocyanurate insulants will often have a jackets and vapor barriers. And in such applications where the elastomeric suppliers argue that no additional external protection is required, an alternative polyiso application with a vapor barrier yielding a zero WVT will have substantially better WVT and still be more cost-effective.

Flame/Smoke and ASTM E84

Elastomeric insulants are typically advertised with an excellent Flame Spread Index (FSI) as ≤ 25 and Smoke Developed Index (SDI) ≤ 50 (in other words meeting a 25/50 rating per ASTM E84). Yet 25/50 is required in only a minority of *process* applications. [Note: A 25/50 rating is required only when local codes invoke *indoor air plenum* requirements]. On the other hand, many process applications require only Class 1 per ASTM E84, with which polyiso readily complies.

[9] http://www.armacell.us/fileadmin/user_upload/Technical_Bulletins_-_Insulation/TB01_CalculateR-Value.US.EN.2018.pdf

Pipe Jacketing

Since both most elastomeric and polyiso insulants are cosmetically affected by ultraviolet radiation, and of course potentially susceptible to severe weather (hail, rain, etc.) and mechanical abuse by employees and contractors, pipe jacketing in process applications is appropriate in many circumstances. Since polyiso has compressive and other strengths in excess of elastomeric, polyiso may in fact require less jacketing.

Appendix 1: Product Descriptions

WHAT IS POLYISOCYANURATE?

Figure 1: Polyiso exiting the *tunnel*

Polyisocyanurate (a modified polyurethane with improved physical properties) is produced as the result of a chemical reaction between polyol and isocyanate. Polyiso has a higher percentage of isocyanate to improve k-factor, dimensional stability, and flame/smoke properties.

Polyiso bunstock for mechanical insulation is produced by pouring a multi-component liquid onto a moving belt. As the liquid travels through the "tunnel" it undergoes a chemical reaction and rises into a "bun" constrained on three sides but not on top; nominally 48 inches wide by 30 inches high; dimensions on higher density bunstock may vary. The foam is cured and subsequently cut into sheets or blocks that can be fabricated into virtually any shape and size for small to very large pipe insulation. Dyplast's ISO-C1 has a standard temperature range from -297°F to +300°F; ISO-HT is effective up to 350°F. Polyiso densities typically range from 2.0 to 6.0 lb/ft^3, with 2.0 to 2.5 lb/ft^3 typically used for low temperature pipe and equipment, and 6.0 lb/ft^3 used for pipe hangars and applications where higher strengths are appropriate.

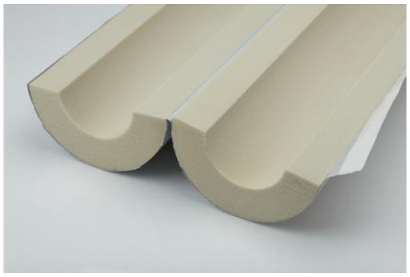

Figure 2: Polyiso "clamshell" with factory-installed vapor barrier

WHAT IS ELASTOMERIC?

Elastomeric insulation is a "rubber" compound that is flexible and can be supplied as a tube, with or without a slit, that can be applied around pipe up to 8 or sometimes 10 inches in diameter (depending on supplier). Elastomeric insulation can also be supplied in flexible sheets that can be wrapped around larger diameter pipe, or over process pipe, fittings, and equipment. The three main components used in the manufacturing of elastomeric closed cell foam insulation predominantly include the following, yet end-users should request clarity on the product to be delivered:

- Synthetic rubber blends, which can vary considerably
- Nitrile butadiene rubber in combination with polyvinyl chloride (NBR/PVC)
- Ethylene-propylene-diene monomer (EPDM)

Figure 3: Elastomeric sheet

At least one supplier recommends NBR/PVC for insulation thickness under 1.5 inches, and EPDM synthetic rubber for insulation thicknesses above 1.5 inches. NBR/PVC and EPDM each have different chemistries and thus different thermal as well as physical properties such as water vapor permeability, water absorption, strength, maximum temperatures, and so on.

Figure 4: Elastomeric "tee"

In the manufacturing process components are combined in a large mixer, typically in batches of 500 pounds or more. The mixture is then put through extruding equipment to form a particular profile or shape, typically either a round tube or a flat sheet. The profile is heated in an oven to a specific temperature, a process that causes the chemical foaming agent to change from a solid to a gas. When this occurs, tiny air pockets (cells) form. It is then cut to size and packaged for shipment. Elastomeric foams can have a density ranging from 3 to 6 lb/ft^3, and are typically green, black, gray, or can be white in color.

There are numerous manufacturers of elastomeric insulation, with many branded products beneath each manufacturer, with physical properties varying considerable between products. End-users, engineers, and contractors are cautioned to be sure of the physical properties of the insulant to be purchased.

Appendix 2: Nominal R-Value Tables Adjusted to Cylindrical Geometry[10]

1" Thick Insulation Walls*

Pipe	Pipe ID (inches)	Calculated R-value** ISO-C1	R-value Elastomeric from ArmaFlex datasheets
copper	1	9.3	7.2
copper	1.25	9.3	7.2
copper	1.5	9.3	7.2
IPS	1.5	9.0	6.9
copper	2	8.7	6.8
IPS	2	8.4	7.1
copper	2.5	8.3	6.5
IPS	2.5	8.1	6.8
copper	3	8.1	6.3
IPS	3	7.9	6.6
copper	3.5	7.9	6.2
copper	4	7.7	6.1
IPS	4	7.6	6.4
IPS	5	7.3	6.2
IPS	6	7.2	6.1
IPS	8	7.0	5.9
IPS	10	6.9	5.8

2" Thick Insulation Walls

Pipe	Pipe ID (inches)	Calculated R-value ISO-C1	R-value Elastomeric from ArmaFlex datasheets
copper	1	19.8	14.5
copper	1.25	18.8	13.7
copper	1.5	17.9	13.1
IPS	1.5	17.3	12.4
copper	2	16.7	12.2
IPS	2	16.1	12.3
copper	2.5	15.9	11.6
IPS	2.5	15.4	11.7
copper	3	15.2	11.1
IPS	3	14.8	11.2
copper	3.5	14.8	10.7
copper	4	14.3	10.5
IPS	4	14.0	10.7
IPS	5	13.5	10.2
IPS	6	13.1	9.9
IPS	8	12.6	9.5
IPS	10	12.2	9.2

Notes:

* 1 inch and 2 inch thick insulation walls were selected as examples; other insulation thicknesses reflect the same trends since ISO-C1 has better k-factors

** R-values units are $ft^2 \cdot °F \cdot h/BTU$; calculated using logical application of Armacell's formula $R = [r_2 * (\ln(r2/r_1))] / k$, where r_2 is outer OD of insulant, r_1 is ID, and "ln" is the natural log[10]

*** K-Flex lists *comparable* R-values in their Insul-Tube datasheet

**** R-values can vary based on actual pipe/tube OD, insulant ID, tolerances in fabrication of insulation thickness, etc.

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[10] Dyplast does not intend that these R-values be used in any calculations involving thickness or performance requirements. Dyplast does not necessarily endorse this particular equation for *R-value calculations adjusted for cylinders*, yet uses them to offer an apples-to-apples comparison with certain elastomeric suppliers.