# TECHNICAL BULLETIN 0714
# Elastomeric Insulation versus Polyisocyanurate in Low Temperature Applications

## PURPOSE

Several of Dyplast's prior Technical Bulletins have provided in-depth comparisons of various insulants, including polyisocyanurate (polyiso or PIR), polyurethane (PUR), phenolic, polystyrene (expanded EPS and extruded XPS), cellular glass, and fiberglass - - as well as *less-than-comprehensive* comparisons with elastomeric and aerogel. Now with somewhat more information becoming available from elastomeric manufacturers and the aggressive marketing from elastomeric suppliers for colder applications it is appropriate to dedicate a Technical Bulletin to elastomeric insulants as compared to polyisocyanurate - - and to a much lesser extent phenolic, and cellular glass.

## QUICK PERSPECTIVES

The most basic perspective is that the overall cost of elastomeric insulation is materially higher than polyisocyanurate, and polyiso also has significantly better thermal insulation properties - - thus raising the question of "why use elastomeric":

### 25/50

The most immediate unambiguous answer is that elastomeric insulation meets a Flame/Smoke index of ≤ 25/50[1], and polyisocyanurate as yet does not[2]. When 25/50 is required, elastomeric does not compete against polyiso, but rather competes with phenolic, cell glass, and even polyethylene insulation on small diameter pipe. We will address competitiveness of elastomeric versus these insulants in this environment in a subsequent bulletin. When 25/50 is <u>not</u> required, polyisocyanurate would at first glance appear to be the obvious choice due to cost and long term thermal performance; but we'll examine this further in subsequent paragraphs.

### Thermal Resistance "R"/Conductivity "K"

In reference to thermal resistance, polyiso's R-value[3] is 6.7 (k-factor = 0.17) measured at 75°F, approaching twice the insulating value of elastomeric with "R" at nominally 3.7[4]. Virtually all insulants have improved thermal

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[1] Spread Index (FSI) ≤ 25 and Smoke Developed Indexes (SDIs) ≤ 50 (in other words meets a 25/50 rating per ASTM E84). A 25/50 rating is required when local codes invoke the International Mechanical Code or its equivalent for *indoor air plenum* requirements.

[2] Dyplast's ISO-C1 is currently at 25/160, and progress is being made.

[3] R-value = thermal resistance (hr.ft$^2$.F/BTU); k-factor = thermal conductivity (BTU.in/hr.ft$^2$.F), the inverse of R-value.

performance at lower temperatures; for instance at -265°F Dyplast's ISO-C1® has a k-factor of 0.11 (R-value of 9.1). The thermal conductivity for elastomeric insulation at -265°F could not be found in available information, yet some sample temperatures are listed in Table 1. Properties of both insulants are such that the k-factor of polyiso will always be better than elastomeric within each insulant's temperature range. Thus an equivalent thickness of polyisocyanurate would offer more energy savings per inch. Alternatively, a higher R-value (lower k-factor) would allow a lower thickness of insulation, which would further lower capital cost.

### Water Vapor Transmission

The other somewhat more ambiguous advertised advantage of elastomeric insulant is its Water Vapor Transmission which is indeed superior at nominally <0.1 perm-inch (with some product brands lower), while polyiso's WVT is 2.0. Yet polyisocyanurate is installed with a vapor barrier in refrigeration and LNG applications, consequently bringing the total insulation system to a water vapor permeance comparable to that of elastomeric; and while some elastomeric insulant suppliers indicate their product can be installed without a vapor barrier on small pipe in mild environmental conditions, the majority of suppliers and conventional wisdom note that "additional vapor barrier protection may be necessary when installed on low temperature surfaces or where exposed to high humidity conditions". So in cold applications, and in particular refrigeration and LNG, both polyiso and elastomeric require vapor barriers to ensure integrity against moisture.

### Pipe Jacketing

Since both elastomeric and polyiso insulants are cosmetically affected ultraviolet radiation, and of course potentially susceptible to severe weather (hail, hurricane, tornado) and mechanical abuse by employees and contractors, pipe jacketing in refrigeration and LNG applications is a requisite in almost all circumstances.

### Installation: Elastomeric

Another perspective is that the *ease of installation* advertised by some elastomeric suppliers refers primarily to the "tubes", with or without slits, made generally for small diameter pipe and often used by plumbers on hot and cold water applications.

**Figure 2: Elastomeric tube with adhesive on seam**

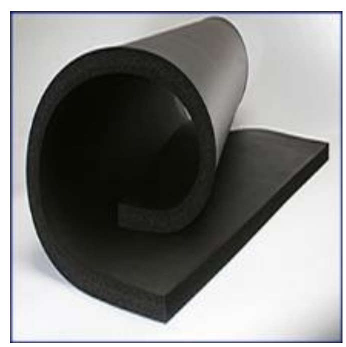

**Figure 1: Elastomeric sheet**

[4] Each R-value (i.e. k-factor) is measured per ASTM C177.

Application of elastomeric on larger pipe and/or lower temperatures requires the larger and more expensive tubes with slits,

Figure 4: Link to video on making an elbow

or alternatively careful measurement of the sheets to wrap around straight pipe and elbows carefully crafted by skilled labor, and carefully seal all joints and seams[5].

Figure 3: Hand cut/glued elastomeric elbow

Given elastomeric's relatively poor k-factors, multiple layers are inevitably required for lower temperature refrigerant applications and for LNG in particular. For instance, for an LNG application at 80°F ambient and 80% humidity conditions (conditions easily possible in eastern and southern coastal regions) an elastomeric insulation system must be 6 inches thick requiring three layers of two-inch elastomeric insulant, as opposed to an option of 3.5 inches of polyiso. In fact, generally any application operating at less than -20°F would require more multiple layers of elastomeric, while a single layer of polyiso is possible.

Referencing the installation guide for LNG from one manufacturer[6] , the opening paragraph of that document offers insight into the process. We have paraphrased and added detail from later in their document:

1. LNG insulations are all multilayered
2. Cut each sheet to size by measuring the circumference of the prior layer
3. The first layer is never glued, and rather held together by applying aluminum tape circumferentially every 12 inches. Longitudinal seams are also sealed with aluminum tape
4. The joints of the first layer always have an expansion joint, filled with fiber insulation
5. The first layer is always covered with an aluminum/polyester vapor barrier
6. The first layer does not adhere perfectly to the pipe: an excess of 2-5% is necessary to allow for thermal contraction of the insulation during use
7. The subsequent layers are installed in the same way as those for traditional applications for cold (i.e. glue and anti-condensation tape on all joints and staggering of the joints between the various layers).

[5] Elastomeric installation examples on YouTube are many, but include https://www.youtube.com/watch?v=dWkWtKYKOfA and https://www.youtube.com/watch?v=imGhBXMs6ik.

[6] L'ISOLANTE K-FLEX: http://www.kflexusa.com/downloads/Installation%20Guides/K-FLEX%20LNG%20Applications%20Installation%20Manual.pdf

Given the information available the complexity and risk issues may be concluded as:

1. The labor and material involved in multi-layer applications can be assumed to be generally triple the amount for a single layer application;
2. The skill-sets required for field installation and the related costs, particularly in a labor union environment include:
   a. Field calculations for lengths of elastomeric sheets to cover extra layers;
   b. Experience in cutting and fabricating elbows and fittings, particularly in multi-layer applications - - with of course offset joints and seams;
3. Risk assessment for applications at less than -70°F where elastomeric becomes brittle
   a. Thermal shock?
4. Performance of specified adhesives and tape at cryogenic temperatures;
5. Elastomeric insulant behavior over multiple thermal cycles.

### Installation: Polyisocyanurate

We caution the installation of any insulation system that will operate at cryogenic temperatures is not "easy", since skilled labor is involve and attention to detail critical to the long-term success of the insulation system. Yet we offer that the installation of a polyisocyanurate insulation system is as *easy* or *easier* than other insulant systems. A polyiso insulation system over pipe primarily consists of insulant half-shells (generally three feet long yet can be made in custom lengths) that are placed over the pipe and secured with fiber tape, then wrapped with a vapor barrier secured with vapor barrier tape. The vapor barrier can be factory applied with self-seal overlapping tape if desired.

**Figure 5: Polyiso "clamshell" with factory-installed vapor barrier**

Elbows and fittings can be fabricated to precise shapes and measurement for simple field application. Expansion/contraction joints are added as necessary to accommodate expansion/contraction in long linear runs of pipe. Even though polyiso is rigid, with excellent compressive strength to withstand abuse, a metal protective jacket is almost always applied.

**Figure 6: Polyiso valve cover**

Note that when polyiso is installed in lower temperature systems, including LNG, multi-layer systems are normally specified by the engineer even though a single layer of polyiso could readily accommodate the thermal resistance requirements. The reason is simply to enable the off-setting of seams and joints, thus providing an extra layer of protection against moisture penetration in the unlikely event of the breach of the vapor barrier/jacket. In single-layer systems, polyiso half-shells (or quarter-shells[7] on very large pipe) can have ship-lapped seams and joints to provide additional moisture protection. Polyiso has decades of successful performance in very low temperature applications, including LNG temperatures and below. For the sake of brevity in this document, view the following Case Study on Elba Island LNG and Dyplast's Installation Guidelines.

Figure 7: LNG Piping (ISO-C1)

## PHYSICAL PROPERTIES

| Physical Property | Polyisocyanurate Insulation | Elastomeric Insulation | Units | ASTM Standard |
|---|---|---|---|---|
| k-factor @ 75°F | 0.17 | 0.249[8] to 0.270[9] | Btu-in/hr-°F-ft$^2$ | C177 |
| k-factor @ -20°F | 0.18 | 0.220 | Btu-in/hr-°F-ft$^2$ | C177 |
| k-factor @ 150°F | 0.20 | 0.284 | Btu-in/hr-°F-ft$^2$ | C177 |
| R-value @ 75°F | 5.88 | 3.77 | hr-°F-ft$^2$/Btu | C177 |
| R-value @ -20°F | 5.56 | 4.28 | hr-°F-ft$^2$/Btu | C177 |
| R-value @ 150°F | 5.0 | 3.31 | hr-°F-ft$^2$/Btu | C177 |
| Water Absorption | 0.6% | 0.2% | % by volume | C209 |
| Water Vapor Transmission | 2.0 | ≤ 0.006[10] to 0.03[11] | perm-in | E96 |

7 While half-shells can be fabricated, quarter-shells are sometimes more economical due to the number of shells that can be fabricated from a single "chunk" of polyiso insulation.

8 NETZSCH Instruments North America, LLC Report # 621002395 on K-Flex.

9 KFDS-0001-0511_K-Flex ECO Tech Data Sheet_screen.pdf re: green K-FLEX ECO™.

10 R&D Services Report: RD13202-R1 on K-Flex.

11 Varies by elastomeric product brand.

| | | | | |
|---|---|---|---|---|
| FSI/SDI | 25/160 | 20/25[12] to 2 inch<br>25/50[13] to $^{3}/_{8}$ inch | | E84 |
| Closed Cell | Yes | Yes | | |
| Maximum Thickness | > 6 | ≤ 2[14] | inches | |
| High temp | +300°F[15] | 300°F[16] (200°F for some products) | | |
| Low temp | -297°F per ASTM C591 (and applications considerably below[17]) | -297°F (only -70°F with Seam-Seal) | | |
| Fiber, PVC, and CFC – free | Yes | Yes | | |
| Flexible | No (with caveat[18]) | Yes[19] | | |
| Color | Natural | Black, Green, or White[20] | | |

**Table 1: Physical Properties**

[12] 25/50 per ASTM E84 per Southwest Research Institute Report 01.15209.01.124[1]; 2 inch black K-Flex panels glued to 0.25 inch cement board.

[13] Note some elastomeric insulation products are 25/50 only to 3/8 inch thickness.

[14] Aeroflex advertises certain products up to 4 inches thick, yet not 25/50.

[15] Dyplast's ISO-HT™ (2.5 lb/ft$^3$ density) is suitable for 350°F down to -297°F.

[16] Varies by product, yet this is the highest temperature expressed in publicly available datasheets.

[17] Dyplast has successful installations on liquid helium systems.

[18] ISO-C1 sheets are quite flexible, and can be wrapped around large tanks.

[19] Elastomeric insulation may lose flexibility at low temperatures (e.g. <25°F).

[20] WVT and other physical properties can vary with the color with the color of the product, even within the same product line.

## BACKGROUND ON POLYISOCYANURATE

Polyisocyanurate is a form of polyurethane, produced as a 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.

**Figure 8: Polyiso exiting the *tunnel***

Polyiso bunstock for mechanical insulation is produced by pouring the 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. 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 higher thermal efficiency than competing polyiso, EPS, XPS, fiberglass, or cellular glass insulation, and its standard temperature range is from -297°F to +300°F. Polyiso densities typically range from 2.0 to 6.0 lb/ft$^3$, with 2.0 to 2.5 lb/ft$^3$ used for low temperature pipe and equipment, and 6.0 lb/ft$^3$ used for pipe hangars.

## BACKGROUND ON 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 through or around a small diameter pipe. Elastomeric insulation can also be supplied in flexible sheets that can be wrapped around larger diameter pipe or applied to a thin (e.g. ¼ inch) inflexible cement board substrate. The three main components used in the manufacturing of elastomeric closed cell foam insulation include the following:

**Figure 9: Elastomeric sheet**

- Synthetic rubber blend, typically nitrile butadiene rubber (NBR) and/or ethylene-propylene-diene monomer (EPDM)
- Polyvinyl chloride (PVC), and
- A chemical foaming agent

**Figure 10: Elastomeric "tee"**

These 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, thousands of tiny air pockets (cells) form. The profile is cooled while striving to ensure the cells remain unbroken and intact, thus maintaining the material's closed cell structure. 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.

## SUMMARY

The most scientific approach to insulation product decision-making is to look at the hard facts of physical properties as measured by independent laboratories.

Considering elastomeric's relatively poor thermal conductivity (k-factor) of approximately 0.25 to 0.27 Btu-in/hr-$ft^2$-°F (R-value of 4 to 3.7 respectively, and comparable to expanded polystyrene or cellular glass) elastomeric compares rather poorly with polyisocyanurate k-factor of nominally 0.17 at 75°F - - almost double the insulating ability.

Considering elastomeric's poorer thermal resistance properties, "*moisture resistance*" remains elastomeric foam suppliers' strongest selling point when compared to other insulating materials. Yet when considering the fact that virtually all very low temperature pipe insulation is installed with vapor barriers and jackets, the advantages of elastomeric diminish.

The disadvantages, on the other hand, include product cost, labor costs, and potential risks as mentioned above.

Polyiso, alternatively, has been used successfully for decades in refrigeration and cryogenic environments, and the cost of the insulant, the installation, and risks are lower - - while the thermal performance over the long term is superior.