New Design/Material Solution for Isolating Pipelines with Chemical and Permeation Issues

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ABSTRACT

Glass reinforced epoxy (GRE) gaskets were a significant improvement over prior isolation technologies, such as phenolic gaskets, which were in use since the early 1900's. GRE has now been used to isolate pipelines in a broad range of industries for close to 50 years. Advances in oil and gas extraction, changes in oil chemistry and changes in installation practices have exposed some potential weaknesses in common gaskets utilizing GRE as the primary form of isolation. The typical GRE gasket uses media permeating through the gasket to energize the seal. This "leak to seal" design is an indicator that GRE may not be the best choice as a gasketing material as media stream materials have become increasingly incompatible with the epoxy resin. Due to the continued efforts to design GRE gaskets with reduced permeation paths, it is believed that GRE's permeability is a well known issue, but GRE has other weaknesses that open this product up to potential failure in a pipeline. The GRE can be prone to delamination at high pressures due to the material's laminate construction, the operating temperature range of GRE is not as high as many oil and gas operators would desire and finally, the thickness and thickness tolerance of GRE can cause installation challenges and potential failure by media leakage.

This paper will graphically and technically display these performance weaknesses with output from both laboratory testing and field evaluation. An in-depth review of failure modes and causation will be executed on a mode-by-mode basis. A solution will be presented with data and imagery defining a newly developed technological solution for pipelines requiring isolation.

Key words: Isolation gasket, insulating gasket, GRE, glass reinforced epoxy, electrical isolation, permeation, blowout, delamination, pressure, temperature, Tg, hydrotest, resistance, chemical attack, steam, H2S, CO2, CO, NEMA,G10, G11, sour gas, API, ASME, volt, helium, nitrogen, coating, coated, encapsulated.

INTRODUCTION

Phenolics were one of the first materials used to combat corrosion by disrupting the electrochemical reaction between anodes and cathodes particularly in flanges. Isolating phenolic gaskets were first used in 1934. First patent #US2021571 A – 1934(1). Glass reinforced epoxy (GRE) has been in existence since before 1942 and has been used as an electrically isolating material from 1942(2) through today. The first use of GRE as a gasketing material was around 1968.In comparison to phenolics, GRE has tremendously greater mechanical and electrical capabilities.

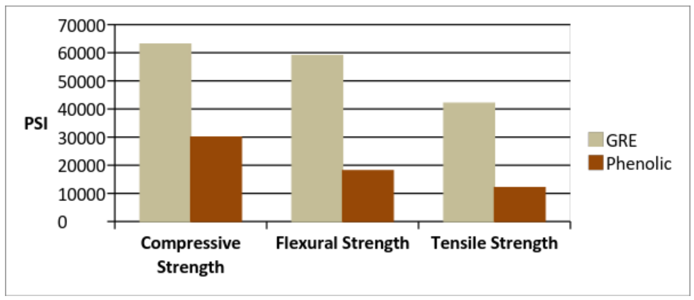


Figure 1: Comparison of GRE and Phenolic Materials (Dry State) (3)

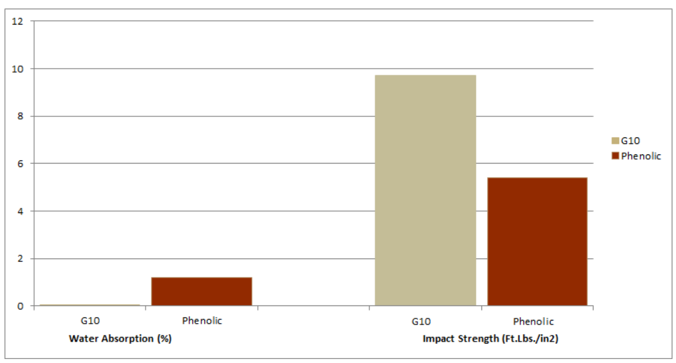


Figure 2: Water Absorption and Impact Strength(4)

Although GRE has excellent electrical and mechanical properties even when exposed to moisture, it can be prone to permeation through the body. The construction of GRE is typically woven glass fibers in an epoxy matrix. The glass fibers and epoxy are pressed together under heat and pressure. As can be seen in Fig. 3 ,Microscopically, the glass fibers look almost like “straws” in the matrix of epoxy resin. It is possible that media can find its way along these straws and create a significant amount of permeation. This potential permeation issue can be propagated by the many different available glass mesh sizes, types, and glass to epoxy ratios.

1Patent # US2021571 A - “ Laminated composition gasket” - 21st February 1934

[2] 1942 GRE Use information - https://en.wikipedia.org/wiki/Fiberglass
[3] Material Comparison - G-10/Phenolic/Mylar Report, “Material Comparison”, (GPT, Denver, CO: Ben Kramer)
[4] Material Comparison - G-10/Phenolic/Mylar Report, “Material Comparison”, (GPT, Denver, CO: Ben Kramer)

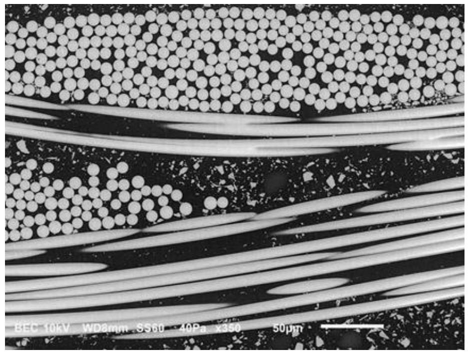


Figure 3: Ion Milled GRE Cross-Section

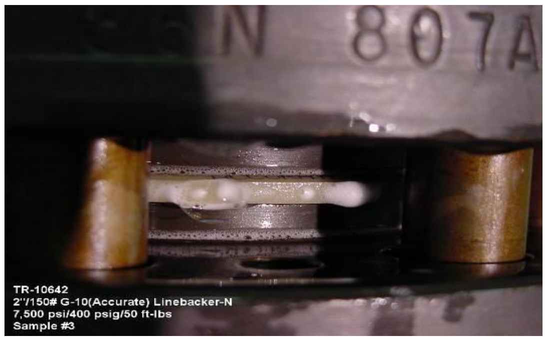
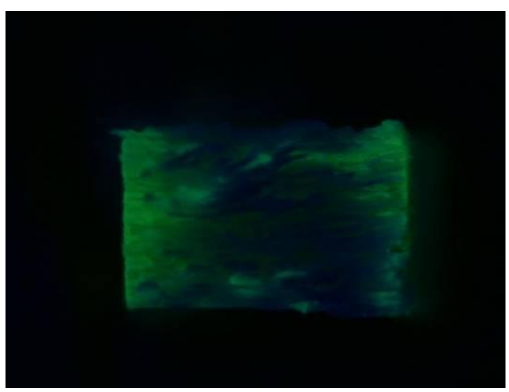


Figure 4: GRE Permeation[5]

Fig. 4[5] shows these very issues. To determine if the leakage in Figure 5 was from the surface of the gasket or from true permeation through the body of the gasket, a fluorescent dye was added to the internal media. From Ultraviolet (UV) light observation, seen in Figure 5[6], it is clear that the leakage was indeed through the body of the gasket and not between the flange and gasket face.



. **Figure 5: UV Permeation Evaluation** [6]

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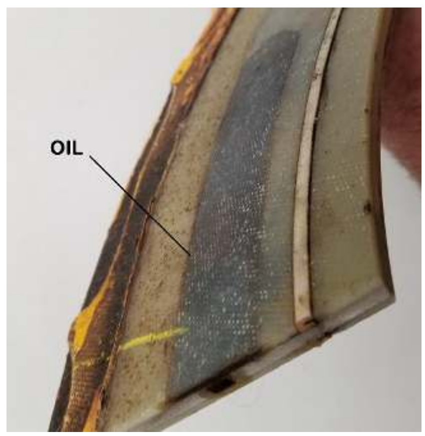
[5] Permeation Test - GRE Permeation Test Report (Palmyra, NY: Scott Tanner/Jim Drago)
[6] UV Permeation test - GRE Ultraviolet Permeation Test Report (Palmyra, NY: Scott Tanner)

The below images are quite amazing (figures 6&7) [7]. Although the GRE based product was in service for a period of over 20 years, it was noticed that a dark band of material resided under the surface of the GRE when the gasket was removed from service. The surface was pricked and oil leaked out of the interior of the GRE. There is no better representation of permeation of GRE than this image. As viscous as oil is, it is evident that over time and pressure even viscous oil can permeate through GRE.

. **Figure 6: GRE Crude Oil Permeation**



. **Figure 7: GRE Crude Oil Permeation**[7]

To help minimize the permeating effect seen in GRE gaskets, manufacturers sometimes created a "gauntlet" for the media to navigate prior to leaking through the gasket. This has lightly reduced the permeation effect, but eventually the media can find a way through the gasket.

A counter-intuitive, but brilliant concept was to put a stainless steel barrier in the path of the media. Although this product would be an electrically isolating gasket, the metal would be laminated on both sides with GRE and a groove machined through the GRE and into the stainless steel slightly. A seal would then be placed in the groove. Any media permeating through the GRE would come in contact with the seal and would attempt to go around the seal. Provided enough compressive load had been applied to the gasket, the media would be unable to compromise the intimate contact between the seal and the stainless steel core. The media would also attempt to go above the seal, but would encounter the flange and again if enough compressive load had been applied to the gasket, no leakage or permeation would occur. Prudent designs for the seal utilized a "C" shaped seal that could actually be energized by media permeating through the GRE. This "leak to seal" concept proved to perform well,

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[7] Failure Analysis Report - Isolation Gasket Failure Report Crude Oil Production (Denver, CO: Alex Morawski)

but intrinsically had deficiencies of its own. Firstly, this concept allows the media to enter into the GRE. This is acceptable if the media is chemically compatible with the GRE. The bulk of the material makeup by weight of GRE is epoxy. While, epoxy is traditionally somewhat chemically resistant it has a number of chemicals that have adverse effects on it (see appendix i).

Figure 8: G10/G11 After Sour Gas exposure - 14 days[8]

The glass is very chemically resistant, but the epoxy can be compromised by steam, hydrogen sulfide and other common oil and gas pipeline chemicals. Various chemicals are very common in oil and gas pipeline applications and have been on the rise as less and less sweet gas is transported through pipelines. Additionally, more steam use is seen today as wells are injected with steam[9]. The results of exposure to these chemicals can be seen here in figure 9. Notice the bubbling of both G10 and G10[10]materials when exposed to a sour gas composition. Also, note the density changes and force displacement changes of GRE when exposed to typical pipeline fluids (figures 22-29).

Figure 9: Gasket Exposure to Steam [10]

In regards to temperature exposure – GRE is traditionally not known as a "high temperature" material. The common temperature ratings for G10 and G11 products range from 266F/130C to 302F/150C for G10 and 356/180C to 392F/200C** for G11 .Temperatures in the oil and gas industry have continued to climb as technologies change and new methods of drilling, extraction and processing have evolved. Given that many GRE isolation gaskets are installed in high pressure applications, the high operating

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[8] G10/G11 Sour Gas Exposure - 14 Days - Isolation Gasket Material Screening Testing (Hertfordshire, UK: Element Materials Technology)
[9]M. Radakrishnan, "Future Trends and Economic Implication of Enhanced Oil Recovery in North America",Webinar, https://www.brighttalk.com/webcast/5564/148065/future-trends-and-economic-implication-of-enhanced-oil-recovery-in-north-america
[10] Steam exposure Test - ", (GPT, Denver, CO: Ben Kramer)

temperatures can compound potential pipeline issues by causing the laminate to begin to flow if the recommended operating temperature is surpassed even slightly as seen in Figure 10(11). Note the outer diameter of the gasket below has maintained its normal coloration, while the high temperature has discolored the gasket inboard of the seal and slightly outboard of the seal where the heat was highest.

Figure 10: High Temperature exposure of G10(11)

Hydrotesting – According to Process Industry Practices (PIP) (12), it is a common practice to hydrotest a pipeline prior to the actual operation of the pipeline***. Prior to transportation of oil or gas through the pipeline water is introduced in the system and is typically pressurized to 1.5X the maximum operating pressure. This assures that the line is leak free and will have sealing integrity when the hydrocarbon product is transported in the pipeline. With GRE with metal cored products, the exposure to water under high pressure can dramatically reduce and even eliminate isolation capabilities(13). With pressure, the "leak to seal" design of GRE faced, metal cored gaskets can absorb water reducing the isolating properties (see table 2 below). While the design of a metal cored gasket eliminates potential issues with permeation from ID to OD, it can in turn lower the isolation performance of the gasket by decreasing the length of electrolyte path as the water permeates to the sealing element. This can lead to electrical resistance of the isolation assembly being drastically reduced and the possibility of unnecessary current loss in a CP system. This can and has been overcome with the introduction of products completely encapsulated with a dielectric material or by introducing an inner diameter seal that eliminates the media contact with the ID of the gasket (or a combination of the two technologies). Below Figures 11 and 12 show how the G-10 VCS-T resistance post hydro test can drop from, as much as, 4 [GOhm] to less than 1 [MOhm]. However, the metal cored, GRE faced isolation gasket with a PTFE ID seal prevents water from permeating through the GRE at the outset and loses no isolating properties.

RESULTS

Test Samples:

- TR-10091: 2"/600# G-10 VCS (ID2) – Mylar sleeves & G-10/ZPS washers
- TR-10092: 2"/600# G-10 VCS-T – Mylar sleeves & G-10/ZPS washers

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[11] High temp exposure of G10 - Wellhead Gasket Failure Analysis Report (Denver, CO: David Wittekind)

[12] PIP PLE00012 Piping Examination and Leak Testing Guide - B31.8 Pipelines , April 2017***https://pip.org/docs/default-source/practices-documents/ple00012.pdf?sfvrsn=a9f2cb9e_0

[13] G-10/Phenolic/Mylar" (GPT, Denver, CO: Ben Kramer)Material Comparison - G-10/Phenolic/Mylar Report, "Material Comparison - G-10/Phenolic/Mylar" (GPT, Denver, CO: Ben Kramer)

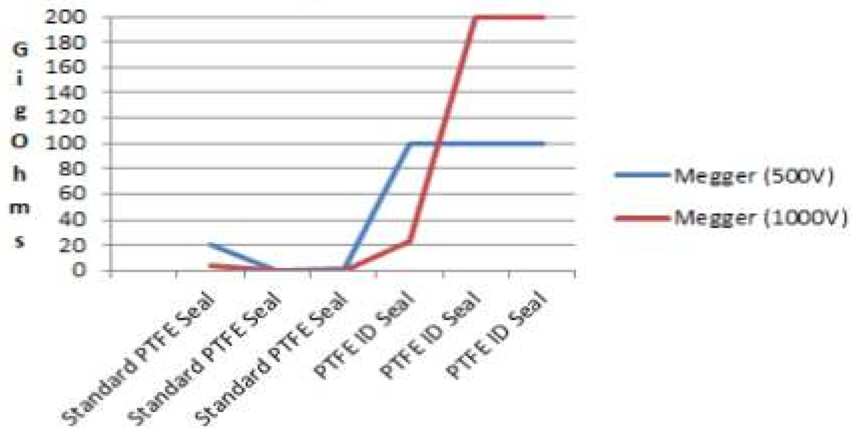

Figure 11: Isolation Results (Flange to Flange) – Per Hydro

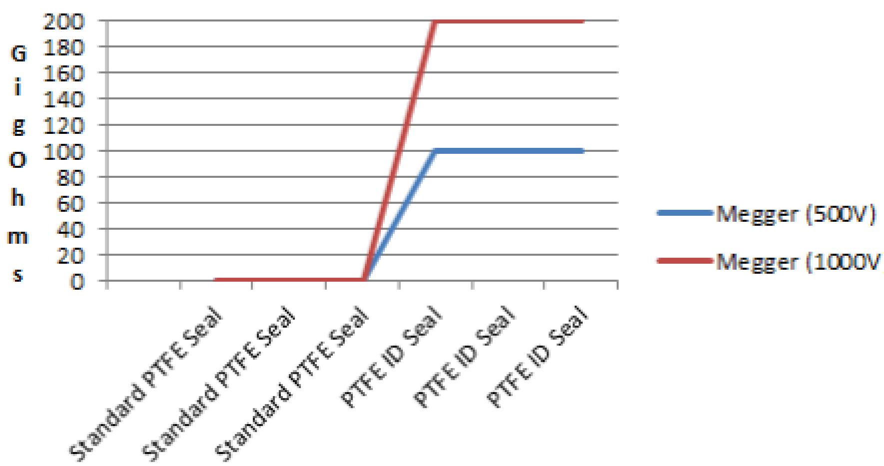

Figure 12: Isolation Results (Flange to Flange) – Post Hydrotest

The design of a high pressure, metal cored isolation gasket typically requires a thick gasket to accommodate seals on both sides of the structure that extend into the metallic core. This is to prevent permeation through the entire gasket. Unfortunately, this thicker gasket can also be difficult to install. Today's pipeline's are designed for 1/8th inch thick gaskets as a norm. The typical high pressure isolation gasket is between .260" and .308" (6.6mm and 7.8mm) making installation especially difficult if the flanges have any angular misalignment. Homogeneous GRE isolation gaskets are often produced in 1/8" thickness, but are not truly designed for high pressure oil and gas systems. Some customers have included in their isolation gasket specifications recommending isolation gaskets for new construction only or when there is enough of a space between flanges to properly insert.

The laminate construction of GRE isolation products opens itself up to potential delamination under high pressure. The product is produced by layering many sheets of woven fiberglass and impregnating with epoxy, then heating and pressing. In high pressure applications or high load applications, the epoxy can fracture allowing to the woven layers of fiberglass to separate. In sealing applications, this is obviously an issue.

Figure 13: Gasket samples of GRE at High Pressures

The majority of isolation gasket applications in oil and gas are in midstream transportation pipelines which are moving preprocessed or even pure hydrocarbon products at close to ambient temp from one location to another. GRE's have a high resistance to your common hydrocarbons; Y-grade, E-P mix, P/P mix, and LPG.(Chemical Resistance Guide for Plastics - Compass Publications) [(14)] and for the majority of applications thermally pose little risk as operating temps are typically below the material property ratings of common GRE. Where the problem arises is more on the upstream, exploration and production applications, where the hydrocarbons are much hotter, less pure containing higher contents of CO2 and H2S. The combination of chemicals and temperatures can play havoc on GRE based isolation gaskets. Thermally, it is common that GRE gasket manufacturers will rate their products at temperatures above the Tg(Glass transition temperature) of the material, which in many applications is perfectly suitable and has been justified through testing. he problem is the testing is usually conducted in an inert environment with Nitrogen or similar test media. With temperature ratings of GRE gaskets up to 150C(300F) for G-10 and 200C(392F) for G-11, the actual Tg of those materials is much lower than those ratings or at the very bottom of the range. The Tg can also vary from grade to grade and batch to batch of GRE materials and is allowable per the guidelines of NEMA LI1[(15)], which by the way is not meant for materials in gasketing applications. Below you will find Tg values of many different grades of GREs used in isolation gaskets (Figures 14-16) [(16)].

Procedure

DMA(Dynamic Mechanical Analysis) was used to compare the actual Tg of multiple samples of G-10 used in isolation gasket from various global manufactures. This can be seen in figures 14, 15, and 16.

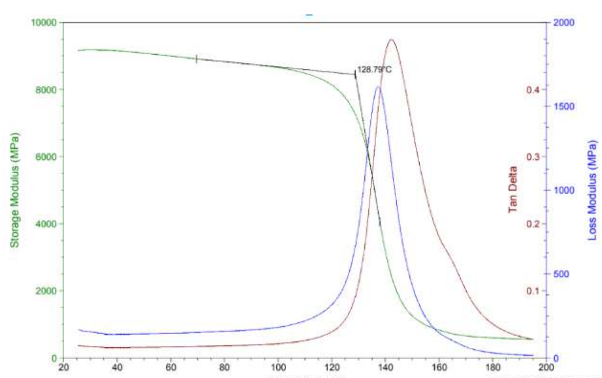

Figure 14: Chemistry & Materials Laboratory Job Number: 11644

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[14] Kenneth M. Pruett, Compass Publications, "Chemical Resistance Guide for Plastics", (La Jolla,CA:Compass Publications, 2000) Pg 2- 661
[15] NEMA Standards, Publication No. L1 1-1998," Industrial laminating Thermosetting Products", (Rosslyn, Virginia . National Electrical Manufacturers Association)
[16] Measurement of the Glass Transition Temperature Using Dynamic Mechanical Analysis - (Brooklyn, NY: TA Instruments)

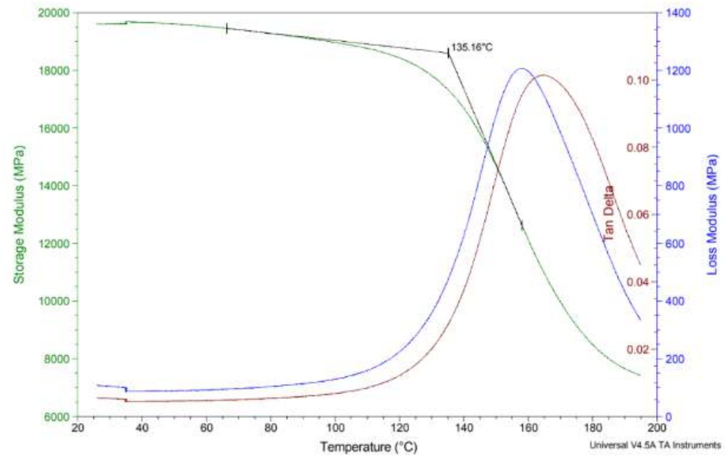

Figure 15: Chemistry & Materials Laboratory Job Number: 11637

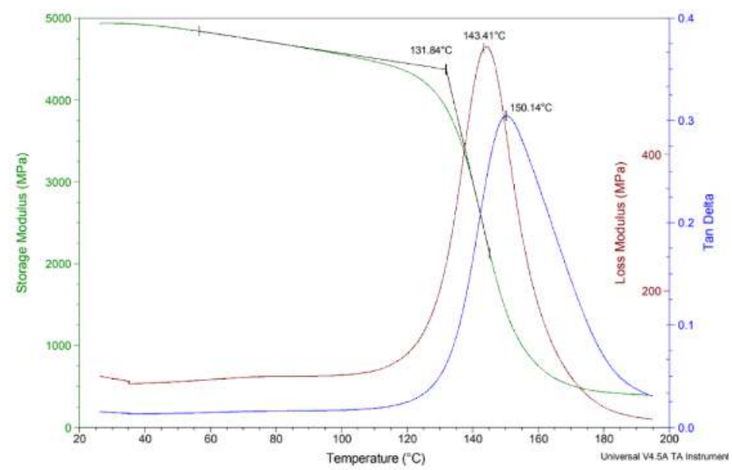

Figure 16: Chemistry & Materials Laboratory Job Number: 11643

Findings

These 3 graphs are from 3 separate Isolation gasket manufacturers, showing the Tg of G-10 based isolation gaskets using DMA (Dynamic Mechanical Analysis). The testing was conducted for by an internal Chemistry & Materials Laboratory in April 2017. As can be seen the Tg rating from different manufactures is between 128C and 135C depending on manufacturer. One thing to note is the temperature at which the material starts to transition is below the typical 150C G-10 rating from each of these manufactures.

To see the effects of chemicals in some upstream applications, such as H2S and CO2, testing was also conducted to measure changes in mechanical properties that chemical temperature exposures can have on GREs used in isolation gaskets. While there may be slightly better epoxies for some of the chemical/thermal combinations, below are the results and procedures from testing conducted using common GREs used in isolation gaskets. The below data is from immersion tests conducted with sweet and sour gas mixtures of 70/30 mol% CH4/CO2 and 18/71/11 mol% H2S/CH4/CO2 respectively for 14 days that have caused past failures of isolation gaskets. Non-sour exposure was considered acceptable.

Synopsis of Element Hitchin Test performed on G10, G11 and coated steel, Report Number C4236/1 Page 3 of 48, by Element[17]

Figure 17: G10 condition after sour fluid exposure at 150°C for 2 weeks

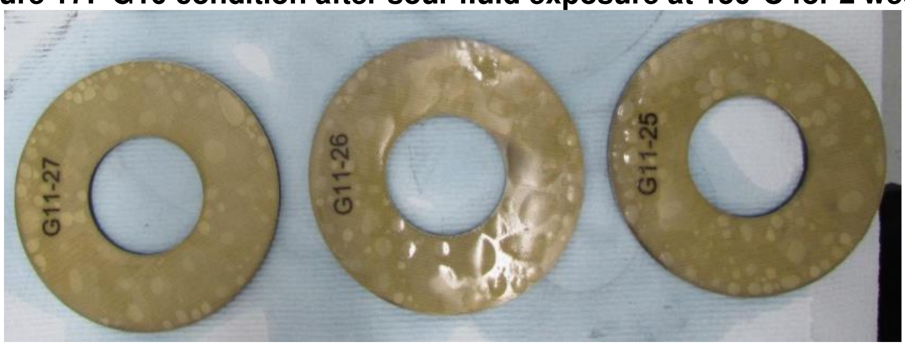

Figure 18: G11 condition after sour fluid exposure at 150°C for 2 weeks

Figure 19: Typical non sour exposed G10 & G11 sample conditions

[17] "Synopsis of Element Hitchin Test performed on G10, G11 and coated steel", Report Number C4236/1 Page 3 of 48, Element (Hitchin, UK)

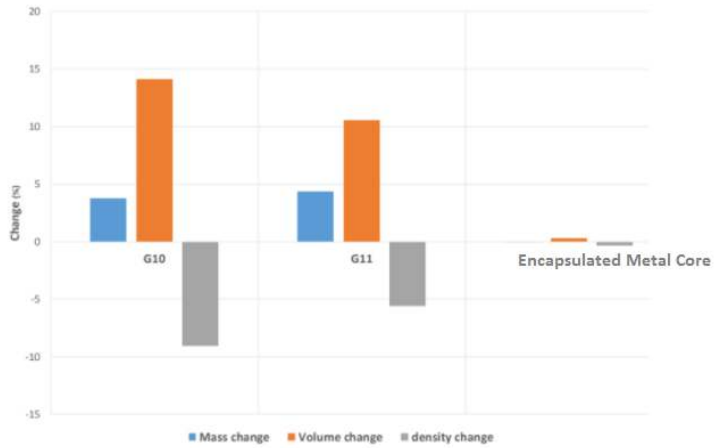

Figure 20: Mass/Volume/Density Change After Exposure

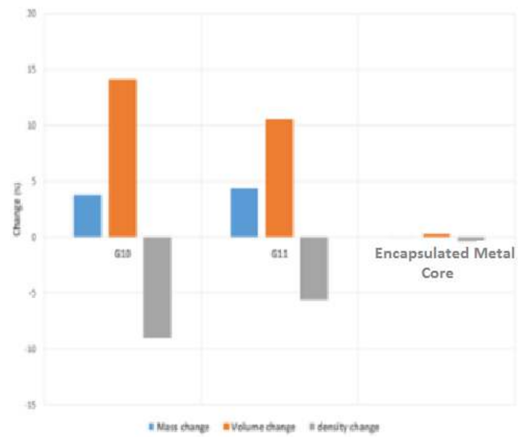

Figure 21: Mass, volume, and density change after sour fluid exposure

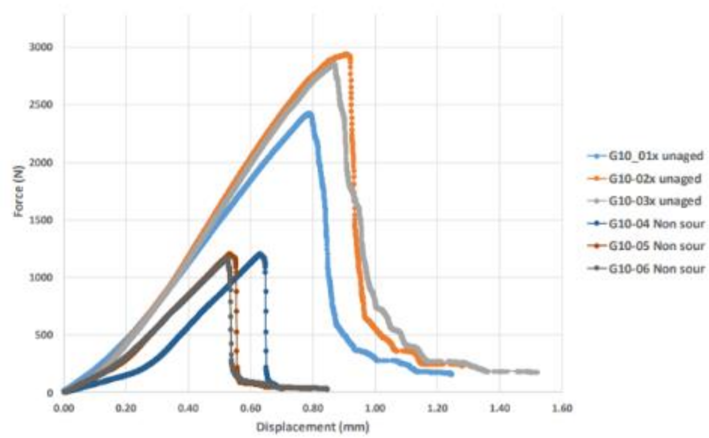

Figure 22: Force- displacement curves for G11 control specimens, and samples exposed in sour fluid at 150°C

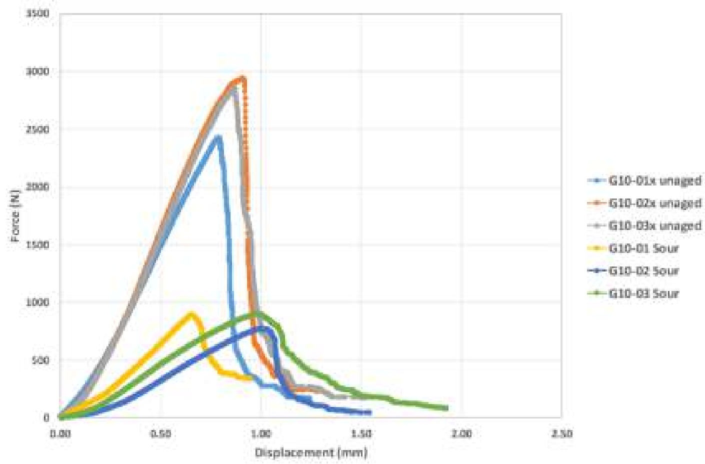

Figure 23: Force- displacement curves for G11 control specimens, and samples exposed in sour fluid at 150°C

A Leap in Isolation Technology

A new, patent pending design for flange isolation has been developed. This design is a departure from over 100 years of isolation technology for gasketing products. Virtually all have been laminated structures that are laminated either of layers of plastics and fiber or laminates of plastic and fiber with a metallic core. This development is a metallic core with a proprietary, highly electrically isolating coating encapsulating the metal core (see Figure 24).

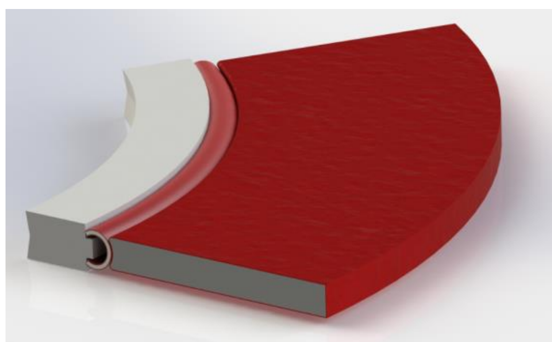

Figure 24: Encapsulated 316SS Core with PTFE/C-Ring Seals[18]

The coating is a modified version of a coating that been used in aerospace, medical, semiconductor and military use, but has not generally been used in industrial applications prior to this use. The coating is rated at a typical value of 1,000 volts per mil for isolation and can handle as much as 1540 cycle of a Taber linear abrasion test with a 1,000 gram load, 60 cpm, and a 1.5" length of stroke and an average scratch resistance of over 1500 passes with 1,000 and 140 passes with 2,000 grams per ISO 1518-2.

[18] Isolation Kit - Flange Assembly Isolation Kit New Design (Denver, CO: Ian Brown)

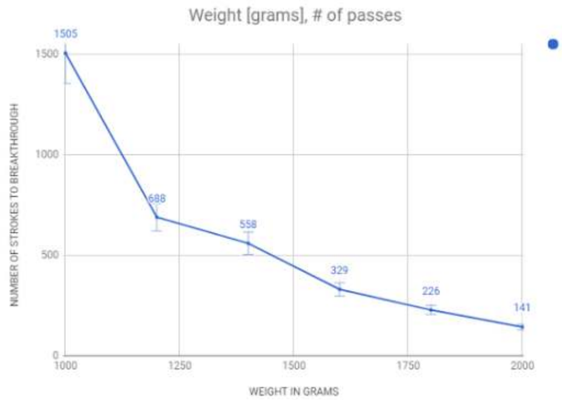

Figure 25: Taber Abrasion Test Results

The patent pending design includes a PTFE ID seal and an Inconel 718 C-ring as a secondary seal. The C-ring, combined with a sold metallic core enable this design to meet API 6FB Fire Test[(19)]requirements.

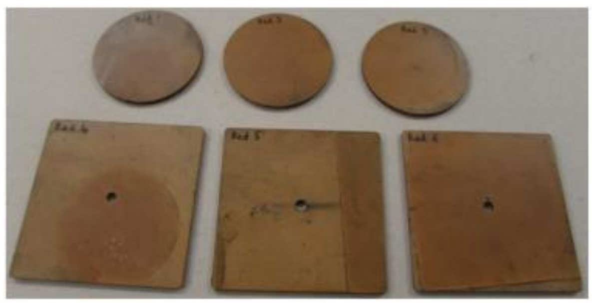

Figure 26: Encapsulated 316 sample after 2 week immersion in 18/71/11 mol% H2S/CH4/CO2 at 150C. No signs of blistering or disbondment from the substrate.

Because permeation has been virtually eliminated (see Figure 26) [(20)], sealability values have become extremely tight. The typical GRE laminate isolating gasket will average between 10-3 and 10-4 cc/second helium when tested at 2000 psi at both ambient and 392F. This new design averages between 10-7 and 10-8 cc/second helium leakage when tested in the same conditions. Below you can see the results of a leakage curve comparing the new design to the GRE laminated design. The red lines indicate the leakage values of the new design while the blue lines indicate the leakage value of the GRE laminated designs. The new design seals substantially tighter at both ambient and 200C. This improved seal tightness leads to very low emissions which can be seen figure 27.

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[19] American Petroleum Institute(latest), API 6FB Fire Test, performed by YARMOUTH RESEARCH AND TECHNOLOGY, LLC (North Yarmouth, ME)

[20] Encapsulated immersion test “H2S/CH4/CO2 at 150C” , (GPT, Denver, CO: Ben Kramer)

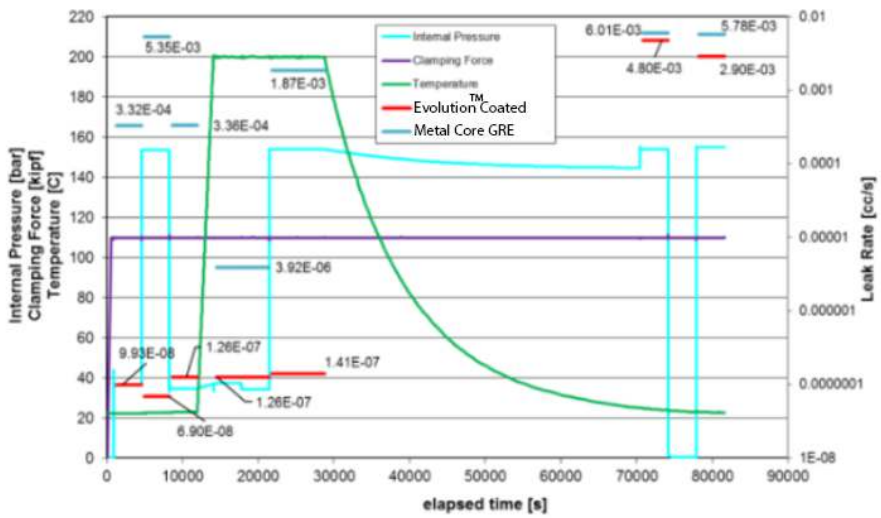

Figure 28: Course of leakage curve Model C&D 106. 94x63. 19x41.
Test Number: A17-021 & A17-023(21)

Thermal Cycle Number	Leakage Readings(PPMv)				Flange Temperatures	
	Ambient Temp.		500 def F Temp.		Heated	Other
	Avg.	Max.	Avg.	Max.	(deg F)	(deg F)
Start	0	1	17	23	404	505
1	1	1	6	12	344	504
2	0	1	59	69	389	505
3	1	1	32	42	391	505
4	13	16	45	56	394	505
5	0	1	End of Test- 5 Thermal Cycles Complete			
Averages->	3	3	32	40	384	505
Maximums->	13	16	59	69	404	505

Average Gasket thickness at end of test:	0.131	inches

Table 1: Fugitive Emission Gasket Test Report, Yarmouth Research and Technology, LLC Project Number: 217287(22)

In addition to the tighter seal capabilities the new design is also capable of sealing at higher pressure than previous designs. Once again, the majority of applications of isolation gaskets reside in the midstream transportation pipeline sector where pressures are typically of little concern or low risk however there are plenty of applications for isolation that are high pressures, API 10K or even 15K where hydrostatic testing can be done as high as 15 and 20 [ksi] respectively. In these areas high

21 AMTEC North America, Project Number A300 157, for Garlock Pipeline Technologies, Inc., April 27, 2017
22 Fugitive Emission Gasket Test Report, Yarmouth Research and Technology, LLC Project Number: 217287

pressure blow out of metal core GRE laminated isolation gaskets does happen as illustrated in table 1 above. The below data is from hydro testing that started at 5000 psig and was stepped up in ~5000 psi increments until blowout occured. A 10 minute dwell time was used between each increment to check for pressure decay and indication of leak. The new material and design advancements lead to greater than 25[ksi] pressure sealing capabilities without blowout. These new advancements give the possibility to use isolation gaskets at the upper end of API 10K and even 15K and possibly 20K rated flanges where isolation may be critical and have not historically been safe. These higher pressure capabilities also provide a high FOS (Factor of Safety) in the more common lower pressure applications.

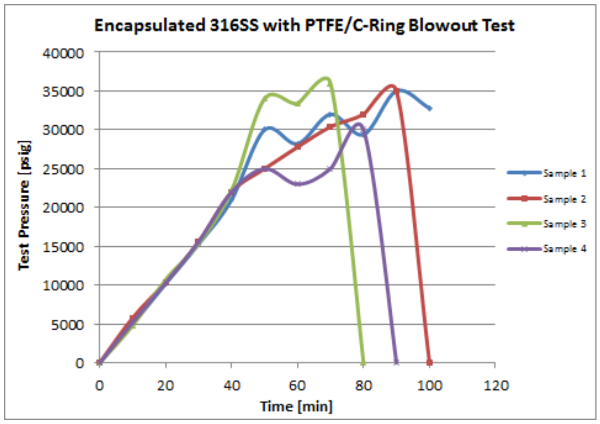

Figure 29: Blowout Data of an Encapsulate 316 with PTFE/C-ring seal. GPT C-604255 Product Comparison, Technetics Group

CONCLUSIONS

Glass Reinforced Epoxy (GRE) isolating gaskets have performed admirably for decades in oil and gas pipelines as well as pipelines in other industries. The product was far superior to prior art for isolating pipelines, but there indeed are limitations to the product. Those limitations are becoming more and more recognized as media combinations and percentages increase, as temperatures increase and as pressures increase. The fact that GRE is not inherently a fire safe material adds to the concern when reliability and safety are added to the equation, especially when these two topics continue to grow in importance in the oil and gas pipeline world. With the advent of a fully encapsulated flange isolating gasket, fire safe operation, higher operating temperature, tight sealing and high chemical resistance to virtually all oil and gas chemicals are all inherent in the product. Additionally, the thinner profile for a high pressure gasket is quite novel and will make installing the gasket a less arduous task for the installer thereby reducing installation damage of the gasket in flanges with less than ideal parallelism and gap openings.

ACKNOWLEDGEMENTS

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5. Permeation Test - GRE Permeation Test Report (Palmyra, NY: Scott Tanner/Jim Drago)
6. UV Permeation test - GRE Ultraviolet Permeation Test Report (Palmyra, NY: Scott Tanner)
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Appendix (i) - Chemical Compatibility Chart - GPT Material.
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