Flexitallic

PREVENTING FLANGE FACE CORROSION

In seawater and hydrocarbon services.

A CORRICULITE **SEALED.IN**sight.

CORRICULITE
Protection. Sealed in.

01.
CONTENTS

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01.
INTRODUCTION

Bolted flange joints in seawater and hydrocarbon services can be vulnerable to gasket degradation and flange face corrosion. In its document on corrosion management, the UK's Energy Institute ranks corrosion as the second most frequent cause in initiating loss of hydrocarbon containment in offshore platforms[1], and highlights corrosion as a major threat to asset integrity and plant efficiency

Moreover, flange face corrosion can be extremely difficult to detect prior to leakage leading to loss of valuable resources.
The impact on the environment can also be a major concern as can the immediate safety of plant personnel. Replacement or remedial works often means unscheduled downtime, additional costs and reduced plant efficiency.

Over the last twenty years, several studies have looked into the corrosion of flanged joints. The main area of investigation has involved flange materials, while little work has been carried out into gasket styles and materials.

Despite its widely recognised importance to reduce the conditions for crevice and galvanic corrosion, the selection of gasket materials has been historically overlooked in the market.

This paper considers the anti-corrosion characteristics of spiral wound gasket materials traditionally used in seawater and hydrocarbon service and compares them to a new gasket material - **Corriculite**.

1. Guidance for corrosion management in oil and gas processing, Energy Institute, London, May 2008.

02.

CORROSION MECHANISMS

To mitigate gasket and flange face corrosion, a basic understanding of corrosion mechanisms is required. The corrosion process at the flange-gasket interface is described as an electrochemical reaction.

In a flanged joint there are different components, and this can almost always lead to a difference in potential between different parts of the flanged joint. In the presence of an electrolyte or polar solvent, electrical current flowing between these areas of differing electrical potential can cause corrosion. Different types of corrosion are defined by the way these different areas of electrical potential are created, however, in practice these mechanisms rarely occur in isolation and flange face corrosion is usually attributable to a combination of factors.

Media commonly found in upstream oil and gas operations such as sea water, combined with temperature, microorganisms, contact between dissimilar metals and the presence of electrolytes can have a direct bearing on the onset and subsequent propagation of the corrosion process.

Two main types of corrosion are of particular interest at the flange gasket interface namely, crevice and galvanic corrosion.

Galvanic corrosion occurs when different materials that have the capability of inducing differing electrode potentials come into contact via a conductive medium (electrolyte). This capability is usually associated with metals, however graphite is one important non-metallic material which in flanged joints tends to act as the cathode therefore causing corrosion of the flange. Having knowledge of the corrosion potential of different materials can prove useful in choosing gaskets that will reduce the risk of corrosion in and around the flange gasket interface.

A commonly used gasket style in the upstream oil and gas industry is the spiral wound gasket (SWG). The SWG has been around for many years and is a trusted and proven design with regard to effecting a high integrity seal.

However, an appreciation of the fundamentals of the corrosion process highlights some of the limitations of the SWG if due consideration is not given to appropriate gasket material selection. The requirement for both a high integrity joint and fire safety can make gasket material selection more difficult than expected. SWG consist of both metallic and non-metallic materials.

The metallic components constrain the non-metallic sealing material, confer resilience and blow-out resistance, ensure correct gasket location and prevent over compression. The non-metallic component, when compressed conforms to flange contact faces and forms an impermeable barrier. By careful consideration of metallic components within the SWG, such as the selection of the same or similar metals to the flanges, galvanic corrosion arising from dissimilar metals can be mitigated.

03.

CURRENT MARKET LANDSCAPE

With regard to non-metallic materials the traditional options available have been flexible graphite or mica. Flexible graphite is commonly used due to its wide range of chemical resistance, temperature capability, low cost and good sealing performance. Another important consideration when in SWG form is its capacity for being fire safe.

The primary concern when using graphite in SWG gaskets relates to its ability to conduct an electrical current, as such it can play an important role in corrosion initiation and propagation depending on service conditions[2].

Studies show that when graphite is in contact with process chemicals that form electrolytic solutions, including acids and seawater, corrosion is significantly more aggressive compared to non-conductive materials.

Standmyr and Hagerup have reported corrosion problems with graphite containing gaskets on 6% Mo stainless steel flanges on several North Sea platforms[3] and Turnbull pointed out that, at the electrode potentials achieved in chlorinated seawater, graphite will stimulate acidification and exacerbate corrosion[4].

Mica has been used as an alternative to graphite in corrosion sensitive applications. It offers a high degree of flexibility, thermal stability, good chemical resistance, importantly is a poor electrical conductor, thus mitigating the onset and propagation of galvanic corrosion. The issue with mica relates to its ability to form a tight seal.

In recent years joint tightness has become a hot topic, emission limits from flanged connections are becoming increasingly stringent and under standard test conditions mica fails to effect what have become acceptable levels of flange tightness. This is due to the inherent, immutable lamina structure of mica.

The need for new material combinations has opened up new market opportunities for gasket manufacturers. Although both materials have characteristics that can be very useful to flange applications, they do not have the characteristics to offer optimum performance.

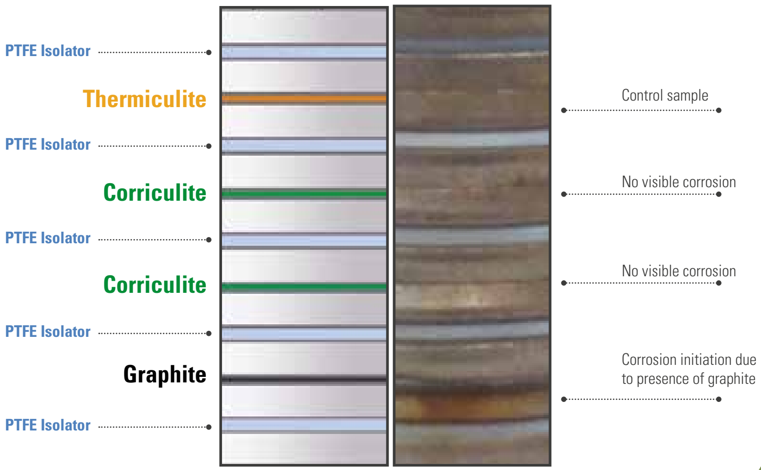
Corriculite – the new industry standard responding to the latest consumer demand for gaskets with strong anti-corrosion characteristics, Flexitallic has further developed its proprietary Thermiculite® based sealing technology. **Corriculite** has been formulated using a special blend of thermally and chemically exfoliated vermiculite and polymers for use in upstream corrosion sensitive sealing applications.

Unlike graphite, **Corriculite** is an effective insulator and as such will not induce galvanic action within the connection. Unlike mica the use of exfoliated vermiculite results in a gas tight structure capable of meeting and exceeding stringent emission requirements. **Corriculite** is fire safe complying with the industry recognised fire test standard API 6FB. The operational temperature range comfortably encompasses that found in the upstream oil and gas industry.

The unique composition of **Corriculite** gasket material ensures the resulting SWG's provide a cost effective solution when used as part of a corrosion management system compared to the use of industry standard graphite based gaskets, increasing plant run-time, safety, joint reliability while reducing cost.

2. A. Turnbull, Impact of graphite gasket/duplex stainless steel couples on crevice chemistry and likelihood of crevice attack in seawater, proceedings of NACE Corrosion 1998, Paper No 682.
3. O. Standmyr and O. Hagerup. Field experience with stainless steel materials in seawater systems. Paper No. 707, Corrosion 98, San Diego. USA. NACE International, 1998.
4. A. Turnbull, Impact of graphite gasket/duplex stainless steel couples on crevice chemistry and likelihood of crevice attack in seawater, proceedings of NACE Corrosion 1998, Paper No 682.

04. TESTING



A number of bench mark tests have been carried out to validate the performance of Corriculite SWG filler material compared with graphite and mica.

CORROSION TESTING:

Salt water exposure: This test methodology has been designed to qualitatively assess the field service corrosion performance of different materials. The test involves clamping a number of annular material samples through a fixed head bolt.

Test samples are placed between metal steel washers of the same dimension to form a three component test cell; each cell is then electrically isolated by the use of virgin PTFE washers to replicate the isolation of the joint's environment. Two material combinations were tested, one using zinc coated carbon steel components, and a second with 316 stainless steel parts.

A control assembly, made up as previously described but using only virgin PTFE washers, was also evaluated.

As per industry standard, the test assemblies were then exposed to an artificial sea water solution (ASTM D1141) for a minimum of two 90-minute immersion cycles separated by a 90-minute room temperature air exposure in a twenty-four-hour period over a series of three weeks.

Results indicated a clear difference in the corrosion behaviour of graphite compared with **Corriculite** and Thermiculite under the described test protocol. Corrosion was visible with both carbon steel and stainless steel test cells with graphite.

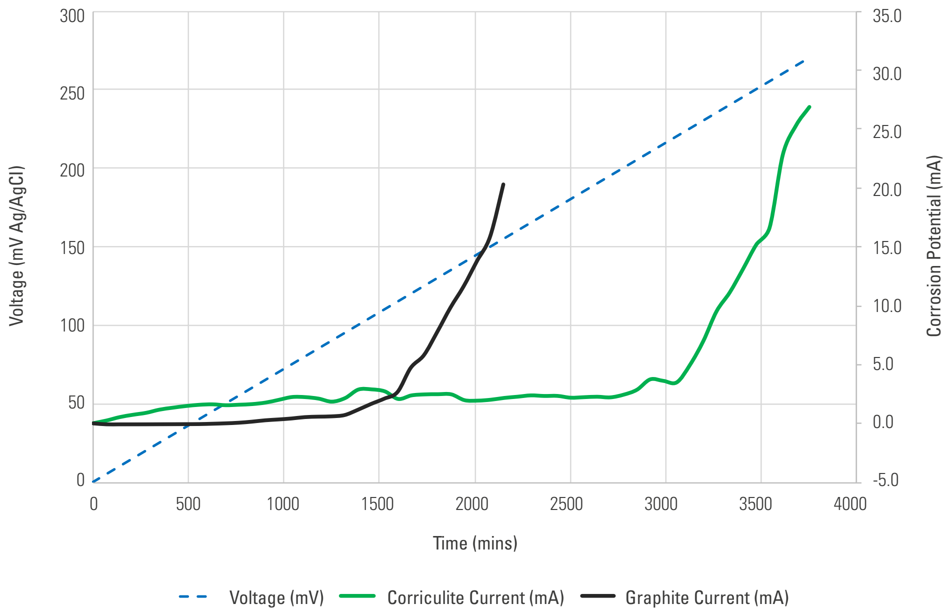
Corrosion was not seen in any of the Thermiculite or **Corriculite** test cells, clearly demonstrating **Corriculite's** corrosion resistance over graphite in corrosive sea water environments.

04.
TESTING contd.

Electrochemical analysis: In addition to the salt water exposure testing an electrochemical evaluation of gaskets in a flanged connection containing seawater was conducted.

A flange assembly containing a graphite filled spiral wound gasket was compared to an identical system with a **Corriculite** filled spiral wound gasket. The system was filled with artificial seawater and an electrochemical cell formed by the external application of a steadily increasing voltage.

The corrosion potential was recorded and this allowed a comparison between the two gaskets under accelerated conditions. The graphite gasket initiated corrosion at a level around half that of the **Corriculite** gasket further highlighting a clear difference and benefit of **Corriculite** over graphite.



Graph 1: Plot comparing graphite and **Corriculite** gaskets with increasing applied voltage.

SEALING TESTS:

EN13555 sealing test: The Amtec Temes test machine is a multifunctional gasket test rig that allows the measurement of leakage rates as a function of other variables such as gasket stress, internal pressure and temperature. The test machine was used to evaluate the sealing performance of **Corriculite**, graphite and mica filled style CGI spiral wound gaskets, under ambient temperature test conditions using helium at 40 bar internal pressure.

In each case the SWG was stressed over a 20 to 160 MPa range, at specific points during the application of the assembly stress the gasket is unloaded back to the initial 20 MPa start stress. Hence the test reveals the leakage behaviour of the gasket under assembly and off loading conditions.

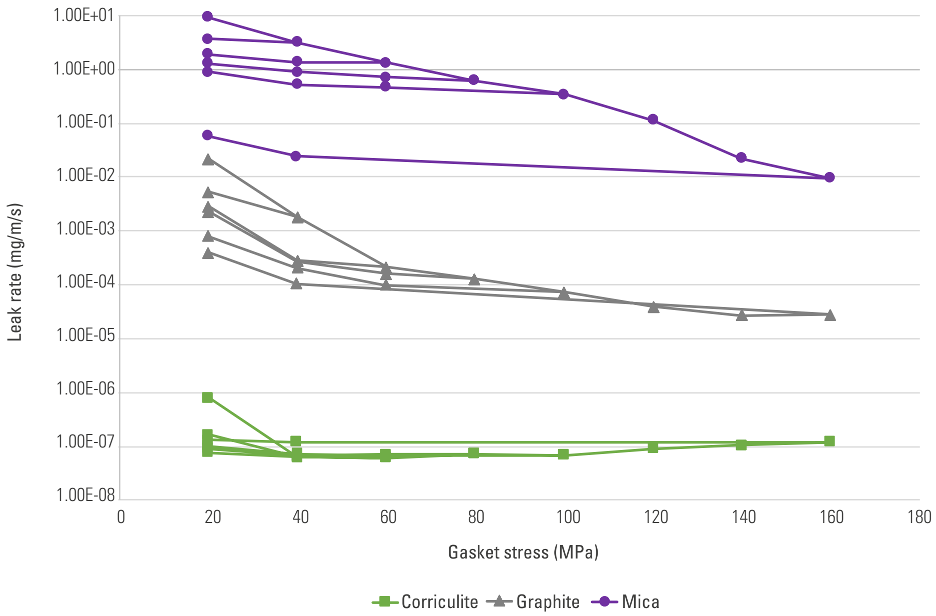
Graph 2 clearly demonstrates the superior sealing performance of **Corriculite** over both graphite and mica under assembly and operational (unloading) conditions. Mica performs particularly poorly with graphite performance lying somewhere in between the two.

Across the whole applied stress range **Corriculite** is a minimum of 100,000 times tighter than the mica gasket, at lower stresses the difference exceeds 1,000,0000 times tighter. Another notable observation is the difference in vertical axis spacing and gradient of the unloading curves of **Corriculite** and mica.

As shown in graph 2, the **Corriculite** unloading curves are flat and much more closely spaced, essentially merging into one, indicating that the leakage behaviour of the gasket is less sensitive to 'in service' unloading, i.e. the sealing performance is consistent irrespective of the applied gasket stress.

In conclusion **Corriculite** is several magnitudes tighter and maintains its tightness to a higher degree under fluctuating stress when compared to both graphite and mica.

Graph 2: Leakage comparison at room temperature,
a flat line indicates no change in sealing performance.

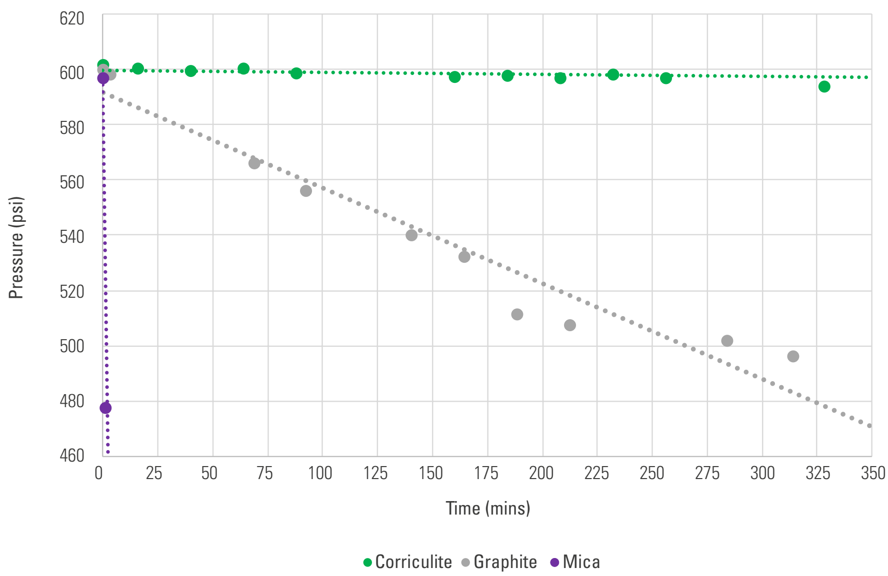


SUBMERGED TESTING:

Submerged sealing tests were carried out on three SWGs; filled with **Corriculite**, graphite and mica. The test involved assembling the gaskets in a closed flange assembly with stainless steel weld neck flanges with a fixed volume.

The test assembly was then pressurised to 600 psi (41.4 bar), the maximum rated working pressure for the flange class tested, and submerged in a container of artificial seawater room temperature water for a period of two weeks. Throughout the test period the assembly pressure was recorded on a regular basis.

As shown in graph 3 **Corriculite** registered a loss of pressure lower than 1% compared to a pressure loss of around 17% for the graphite gasket. The mica gasket leaked so severely that in only the first hour the pressure loss was in the order of 20% and the mica test was abandoned. The test clearly indicates the fundamental structural related weakness of mica.



Graph 3: Pressure vs time elapsed (immersed flange)

04. TESTING contd.

THERMAL CYCLE TEST:

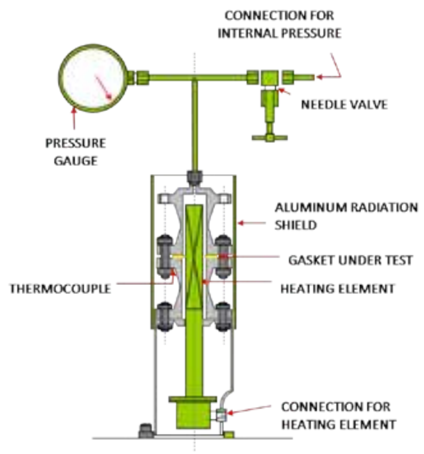
The thermal cycle test is an industry recognised test developed by Shell Global Solutions to evaluate gasket sealing performance under thermal cyclic loading. It involves placing a gasket in a test assembly comprised of two flanges. The flange assembly is closed and a bolt stress of 40 kpsi is applied using hydraulic tensioning equipment. The test assembly is then pressurised to 51 bar to record any pressure drop over the next hour.

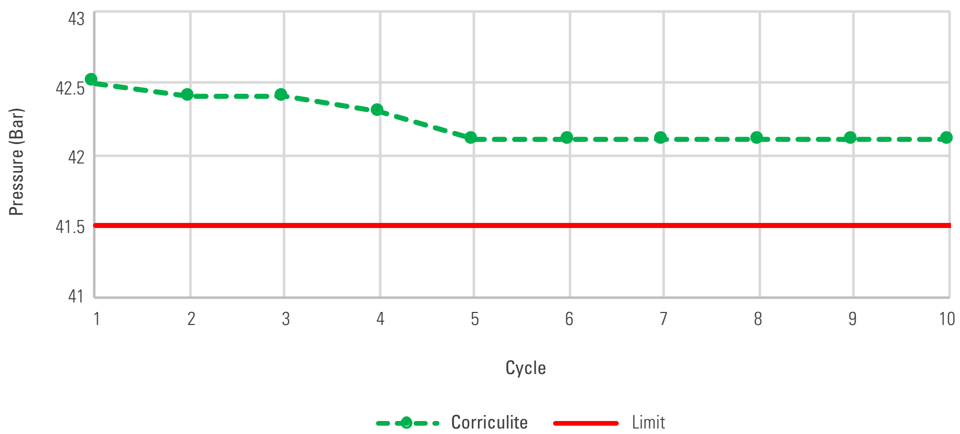
Any pressure drop greater than 1 bar denotes test failure. If the ambient leakage test is successful then a second high temperature phase is undertaken. This involves depressurising the test assembly and heating it up to the selected temperature, in this case 225°C.

Once at temperature the test assembly is pressurised to 42.5 bar and allowed to stabilise after which a second pressure decay test is carried out over the following hour. The test rig is then allowed to cool to room temperature, while remaining under pressure. This thermal cycle and pressure decay test routine is carried out over another two cycles.

The maximum allowable pressure drop over the ambient phase and subsequent three thermal cycles is 1 bar. In graph 4, the red line indicates the limit below which **Corriculite** would have a pressure loss of over 1 bar, therefore failing the test. The green line indicates the actual pressure loss at each cycle.

For the purpose of this test, the number of thermal cycles was extended to ten, showing **Corriculite's** performance over an extended period and greater number of thermal cycles.





Graph 4: Thermal cycle at 225° C

05.
CONCLUSION

Gasketed flanged connections found in corrosive sensitive environments such as seawater and hydrocarbon services may be subject to corrosion and degradation. Extremely difficult to detect, flange face corrosion has the ability to directly affect seal integrity ultimately leading to loss of containment, compromising safety, impacting on the local and wider environment and causing costly unplanned outages and maintenance.

Little attention has been focussed on the role of the gasket in such corrosion sensitive applications. Current material options namely graphite and mica have serious short comings with regard to the potential for active initiation and/or propagation of galvanic corrosion or complying with the needs of increasingly stringent emissions requirements.

Corriculite, the latest innovation in the Flexitallic range of sealing products, has been specifically developed to inhibit and delay the onset of galvanic induced flange face corrosion while providing a high integrity seal, offering a cost-effective tool for the proactive management of gasketed, pressure bound bolted connections.

To find out more about how **Corriculite** can help reduce flange face corrosion within your applications, visit **corriculite.com**

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