Tim Hurley, GPT Industries, USA, explains how fibreglass reinforced epoxy products can be used to prevent galvanic corrosion in flanged piping systems.

Advancing CORROSION CONTROL

Corrosion costs the global oil and gas industry billions of dollars a year. A significant contributor to these costs is galvanic corrosion in flanged piping systems that are used in the exploration, production, refining and the transportation of resources. Galvanic corrosion occurs when dissimilar metals with different electrochemical potentials come into contact in the presence of an electrolyte – in most cases, moisture.

A basic corrosion cell is created when the less noble metal serves as the negative pole (anode) and the more noble metal serves as the positive pole (cathode). The electrolyte bridges the metallic path through which current flows from the anode to the cathode. Positive ions pass from the anode into the electrolyte, releasing free electrons in a process called 'oxidation'. The electrons then flow to the cathode, from which some return to the electrolyte as negative ions in a process called 'reduction'. The cathode loses no metal in this process. However, the negative ions combine with other elements, which causes corrosion at the anode.

Galvanic corrosion can be controlled by simply eliminating the metallic path between the anode and cathode by isolating pipe flanges with the use of isolating gaskets, bolt sleeves and washers (Figure 1). However, even properly isolated flanges are subject to several modes of failure. Washers can be reversed or crack, sleeves can crack and gaskets can crack or absorb moisture. Many users attempting to isolate a flange have relied on phenolic gaskets, sleeves, washers, fibre gaskets and filled PTFE gaskets. Unfortunately, all of these materials absorb moisture, rendering them virtually ineffective as isolating components.

In addition to reversal during installation, contributors to washer failure include the presence of a foreign object such as a small pebble or weld splatter under the washer, exposure to moisture, and exposure to moisture followed by cold temperatures. Abrasion can also contribute to washer failure. Figure 2 shows the results of abrasion testing on steel washers coated with four types of Xylan® fluoropolymer coating for preventing corrosion, along with a coated hardened steel washer.

Three of the five washers were then exposed to a 5% salt spray to assess their corrosion resistance. After 2000 hrs, the coated hardened steel washer showed little noticeable effect. After 1800 hrs, 20% of the Xylan A-coated washer was covered with a medium red rust. After 1200 hrs, more than 15% of the Xylan B-coated washer was similarly covered with red rust.

Isolating bolt sleeves can crack if they are too long. Other contributors include torsional, angular and lateral misalignment of flanges and exposure to moisture.

Misalignment of flanges will create point loading issues on the sleeves, penetrating the material and creating metal to metal contact. Sleeves also can cause isolation issues if they are too short. Metal to metal contact can occur or conductive debris can build up, which creates a metal to metal bridge. It should be noted that not all sleeve materials are compromised by moisture absorption, which is discussed in greater detail below. Another common problem is gasket failure due to improper installation, torqueing, lubrication and, perhaps most important, improper material selection.

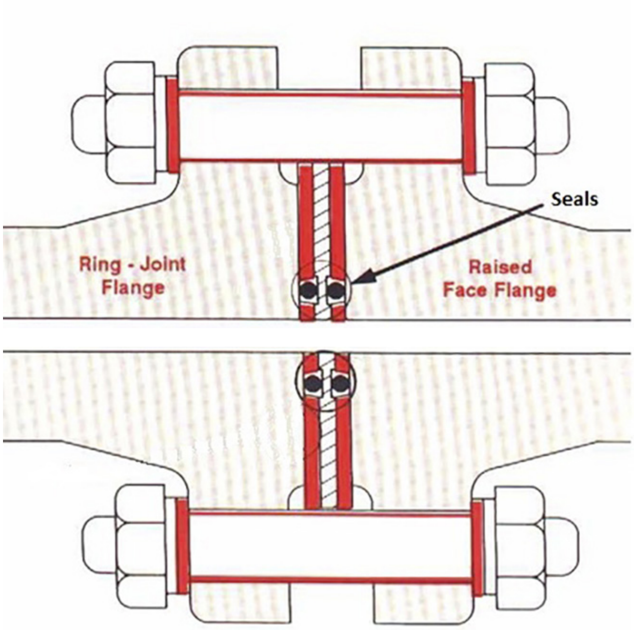

Figure 1. Flange isolating gaskets, bolt sleeves and washers are highlighted in red.

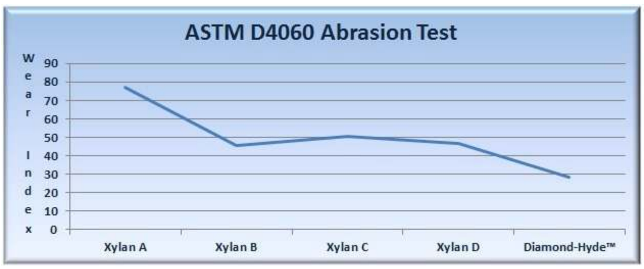

Figure 2. Coated hardened steel washer outperformed fluoropolymer coated steel washers in abrasion tests.

Phenolics vs. fibreglass reinforced epoxy

50 years ago, the best isolating gaskets were made of phenolics – extremely hard polymers made of phenol and formaldehyde and commonly used for pool balls. Cotton, paper or canvas cores provided flexibility that the gaskets would crack without during installation.

These materials were not optimal in terms of their isolating properties. When exposed to rain, snow melt or ground water, they absorbed moisture, in turn reducing their isolating effectiveness. Another problem with phenolic gaskets occurred when snow melted on a flange, wetting the core material and refreezing when the temperature dropped. The formation of ice in the core caused it to expand, cracking the gaskets from within. Even if it did not cause them to crack, this action permanently weakened phenolic gaskets.

Today, phenolics are largely giving way to fibreglass reinforced epoxy (GRE) as the material of choice for isolating gaskets. GRE meets the requirements of the National Electrical Manufacturers Association and is commonly used for computer motherboards and other electronic applications. Not only is GRE much stronger than phenolics, it also absorbs virtually no moisture when in contact with water.

Within the GRE family of materials, GR-10 is most commonly used for isolating gaskets as it provides excellent properties and performance. When GR-10 is compared with phenolic based on water absorption, compressive strength of the materials when went, flexural, tensile and impact strength, the values are all significantly higher for GR-10. This, therefore, deems it superior to phenolic as a material for sealing or isolation.

Moreover, when the dielectric strengths of GR-10 and phenolic both dry and wet are compared, phenolic does not perform the isolating function well. To provide effective electric isolation, a material should have a dielectric strength of at least 500 V/mil (0.001 in.). Paper-cored phenolics rate 500 V/mil, while dry state phenolics with canvas or cotton cores rate only 150 V/mil. When exposed to moisture, all three versions drop to between 28 and 85 V/mil.

Users' experiences with phenolic flange isolation kits arex replete with tales of cracked gaskets and washers (Figure 3). As a result, the use of phenolics for these components has decreased dramatically over the last 10 years.

Their use for isolating sleeves has similarly declined due to side loading issues from bolt threads cutting through the material and shorting the flanges. Besides their fragility, phenolics cannot withstand the effects of exposure to moisture. As a result, more and more companies are considering their corrosion and isolation issues and eliminating them in favour of more robust isolating materials.

There are two ideal solutions for stopping galvanic corrosion in flanged piping systems, one for aboveground piping systems and the other for belowground systems. For aboveground systems, the optimal solution consists of a metallic cored G10 isolating gasket with a sealing element on the inside diameter (ID), a G10 sleeve and a coated, hardened steel washer. G10 is an excellent material, but as a gasket it has permeation issues, hence the metallic core. Since it is conductive, the metallic core appears to be counterintuitive. However, it must be noted that it is sandwiched between sheets of G10. Therefore, its conductivity is not a consideration.

The seal (preferably PTFE) is permanently installed on the ID of the gasket, stopping the media from contacting the G10. The ideal ID seal is constructed in a concave shape. Therefore, as the pressure increases, it drives the PTFE against the flange surface, creating a tighter seal. This is one of the few instances where higher pressure results in a better seal, leaving the G10 to perform its primary function – flange isolation. This combination is superior to other metallic cored G10 isolation solutions because its electrical isolation is not compromised by hydrotesting and it creates a longer path isolation environment.

A longer path isolation environment is preferred because it allows for the occurrence of the electrochemical reaction of highly conductive media such as brine solutions, especially when the media flow has been brought to a halt. The metal to metal path is short enough that ion transfer can still occur. Longer path isolation can also prevent arcing of stray currents and cathodic protection (CP) current migration beyond the isolation boundary. For example, a standard metallic cored G10 isolating gasket has two layers of G10 (0.07 in.), sandwiching an approximately 0.125 in. metallic core. An electrical arc simply bridges the 0.07 in. However, with a PTFE ID seal, the stray current must arc approximately 0.26 in. A PTFE ID seal also stops media from causing either flange face erosion or corrosion, provided the installed gasket seal ID is approximately equal to the ID of the flange. This also reduces both cavitation issues in the media stream and the potential for pipe wall erosion downstream of the flange installation.

Isolating gaskets with ID seals also offer benefits in piping systems with exotic metallurgy. Ordinarily, the metallic core of a G10 isolating gasket must be the exact same metallurgy as the piping system in which it is installed to prevent the gasket itself from creating a corrosion cell. With a PTFE ID seal, the metallic core of the gasket is inconsequential because the electrolyte never comes into contact with it. This can reduce lead times and provide significant financial savings.

For belowground piping systems, the most effective CP protection isolation solution is a monolithic isolation joint (MIJ). This is a proven isolation system that eliminates a number of issues that plague flange isolation kits when installed underground. Flange isolation kits that are installed underground should be contained in a vault in order to keep moisture from the assembly. The flange gap area is often filled with wax to keep conductive debris from electrically bridging the flange faces. Furthermore, the flange's assembly is often wrapped with a non-conductive barrier tape.

Much effort goes into protecting flange assemblies underground for a variety of reasons. Nuts and bolts require a lot of energy to manufacture. The more energy that is put into a metal to bring it to its finished state, the more quickly it seeks to revert to its natural state. In addition, the sharp crevices of the threads of these fasteners are an ideal breeding ground for corrosion. A MIJ has no nuts or bolts. It is designed using standard flange design theory, compressed in the manufacturing process and welded into a monolithic structure.

Within the structure is isolating materials and sealing materials. The entire unit is installed by welding it into the piping system. This process means no PCC-1 installation practices required, no misaligned flanges, no using the wrong torque value, no forgetting to use a 'star' pattern when torqueing, no reversing the washers and scores of other potential failure modes caused by human error. MIJs can be manufactured in a multitude of sizes, classes, wall thicknesses and options, such as grounding connections, coatings and built-in pipeline decouplers.

A typical MIJ epitomises long path isolation with distances of 1 - 6 ft, depending on the pipe diameter. This completely stops any electrochemical reaction from one pipe end to the other. The design life of MIJs is typically 20 - 25 years. They are, therefore, intended to last the life of the pipeline. One disadvantage of MIJs is that once installed, they are permanent fixtures and accessibility to the pipe is limited unless it is cut. However, this is not normally an issue for underground applications. In addition MIJs can be buried directly in the ground, eliminating the need for vaults to contain flanged assemblies. A robust coating should be applied on both the ID and OD of an MIJ, so that they can withstand contact with earthen objects and resist the effects of pigs cleaning the ID of the pipe.

Another advantage of MIJs is that they can be individually hydrotested, pneumatically tested, electrically tested, holiday tested and coating thickness tested before being installed to ensure a long, successful service life.

In summary, effective electrical isolation and corrosion control can best be achieved by using PTFE-sealed, metallic cored G10 gaskets and sleeves with appropriate washers; hardened steel or stainless steel washers with abrasion resistant isolating coatings; and adherence to manufacturer recommended installation procedures and ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly for aboveground pipeline installations. For underground piping systems, coated monolithic isolation joints that have been designed and tested for direct bury are recommended.

Figure 3. The tendency of phenolics to crack has eliminated them from flange isolation applications.