GALVANIC CORROSION MEASUREMENTS ON VARIOUS EMI-GASKETED JOINTS

Virtually all types of EMI gaskets, when installed between aluminum flange surfaces, present some potential for causing galvanic corrosion of the flanges. (Aluminum EMI gaskets are rarely used because aluminum forms a hard, impenetrable, nonconductive oxide.) In almost every practical case, the EMI gasket is made from, or contains, a metal which is *dissimilar* to aluminum (typically monel, tin, carbon, silver, beryllium copper, or a combination of these with other metals). It is this dissimilarity which forms one of the necessary elements of a galvanic corrosion cell.

Actually, three specific conditions must be present in order for galvanic corrosion to occur:

1. The two metals of the cell (the "couple") must be electrochemically "dissimilar";
2. The dissimilar metals must be in electrical *contact* with each other;
3. An "electrolyte" solution must be present (in practical cases, the electrolyte is salt water) and in contact with both metals.

The standard published reference source for "dissimilarity" of metals is called a "Galvanic Series" or "Galvanic Table". However, most such published Galvanic Tables do not include the materials commonly used as EMI gaskets, because conductive gaskets or gasket fillers are not generally pure metals used in mechanical or structural applications (e.g., tin-plated copper, silver-plated aluminum, etc.).

For this test, measurement apparatus was set up to determine the galvanic corrosion potential of various EMI gasket materials. The method approximates the way that the relative corrosion potential (or "EMF") is determined for the published Galvanic Tables, such as the one which appears in MIL-STD-1250. Figure 1 shows the essential details of this setup. The variable being measured is called "Corrosion Potential" or "E_{corr}", and the technique involves measurement of E_{corr} in a 5% NaCl solution for various gasket materials relative to a standard calomel electrode (SCE)[1]. Note that the corrosion potential measurements are accurate to ± 1 mV, and that the microprocessor within Model 276 was programmed by a computer. The corrosion cell and electrode holder conform to ASTM Standard G5-82. (EG&G Princeton Applied Research Electrochemistry System.)

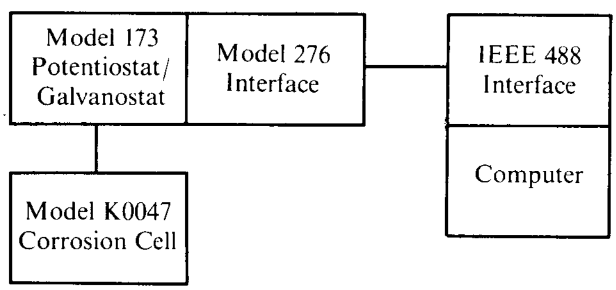

Figure 1. Corrosion Potential Measurement Circuit.

[1]Mansfield, F. and Kenkel, J.V., "Laboratory Studies of Galvanic Corrosion of Aluminum Alloys," Galvanic and Pitting Corrosion — Field and Lab Studies, ASTM STP 576, 1976, pp 20-47.

In order to correlate the data measured in this test setup with other published values of galvanic corrosion potential, samples of aluminum alloy 1100 were measured. Results showed that this test setup correlated with prior published data for aluminum (−730 ± 15mV measured in these tests, as compared to −756 ± 39mV reported in the literature).

In using a Galvanic Table, one predicts the amount of corrosion potential between two materials by noting the difference in E_{corr} (sometimes designated simply EMF) between them. The closer the E_{corr} values, the better the couple will behave in an electrolytic environment; the further apart the two values, the worse the couple will behave in terms of corrosion. It is normally recommended that metals whose E_{corr} values are more than .25 volt apart should be treated carefully when used in contact with each other in marine-type environments.

Table 1 presents the measured E_{corr} values for a variety of EMI gasket materials and for aluminum, copper and silver. The surprising thing about this data is that hybrid EMI materials, such as silver-plated, copper-filled and silver-plated, aluminum-filled elastomers have corrosion potentials close to those of the base metal on which the silver was plated. For example, Table 1 shows clearly that silver-plated, copper and silver-plated, aluminum-filled elastomers have similar corrosion potentials as their

MATERIAL	E_{corr} vs. SCE (Millivolts)
Pure Silver	−25
Silver-filled elastomer	−50
Monel Mesh	−125
Silver-plated copper filled elastomer	−190
Copper	−244
Tin-plated Beryllium-Copper	−440
Tin-plated, copper-clad steel mesh	−440
Aluminum* (1100)	−730
Silver-plated aluminum filled elastomer	−740

* Aluminum alloys approximately −700 to −840 mV vs. SCE in 3% NaCl (ref 1).

Table 1. Corrosion Potentials of Various Metals and EMI Gasket Materials (in 5% NaCl at 21°C after 15 Minutes of Immersion)

substrate metals, copper and aluminum. (It should also be noted that a pure silver-filled elastomer behaves like silver).

Assuming that flange surfaces are made of aluminum, the most compatible EMI gasket from a galvanic corrosion standpoint is the silver-plated aluminum filled elastomer. The worst gaskets in terms of corrosion potential are pure silver-filled elastomers, and monel.

Of course, other factors besides galvanic corrosion potential must be considered when designing a seam for maximum EMI shielding effectiveness and minimum corrosion. Among the more important design considerations are the following:

1. Mating flange surfaces must be protected from oxidation and corrosion but still be highly conductive. Most common finish is MIL-C-5541 Class 3 chromate conversion coating (Iridite[2] and Alodine[3] are two trade names often used). Other finishes providing greater protection (when properly applied and used) are tin, nickel, and silver epoxy.
   Outside surfaces and flange edges should be protected with non-porous organic coatings such as MIL-P-23377 epoxy polyamide primer and MIL-C-22750 epoxy polyamide coating. This nonconductive coating should be allowed to intrude a short distance into the mating flange area, to further reduce the possibility of galvanic corrosion starting at the outer edge.
2. The EMI gasket should provide an exceptional moisture seal, in order to exclude electrolyte from the flange area. Conductive elastomers are substantially better sealing materials than impregnated wire mesh materials. Depending on flange and fastener design, combination solid rubber/mesh gaskets can be very effective seals.
3. "Dual" or "combo" gaskets are recommended for extreme salt-spray environments. These are conductive/nonconductive elastomers, with the nonconductive portion outboard of the conductive portion (See Figure 2).

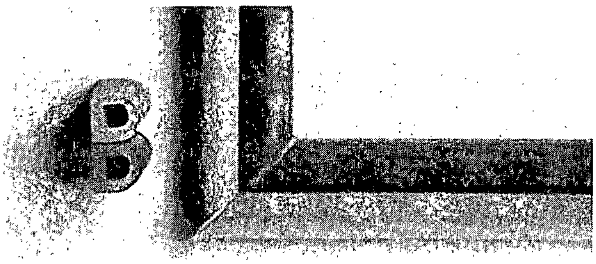

Figure 2. Combo gasket with nonconductive silicone outboard of silver-plated, aluminum-filled gasket. Hollow-D extrusions provide substantial deflection under low closure force.

4. Designing in "sump" areas which will collect and trap moisture should be avoided. Drain holes where water may collect should be provided.
5. The gasket area should be kept small relative to the flange. The galvanic potential difference between the flange and gasket provides the driving force for corrosion but other variables such as the gasket-to-flange area strongly influence the actual corrosion current which flows. Small gasket-to-flange areas will limit the corrosion current.

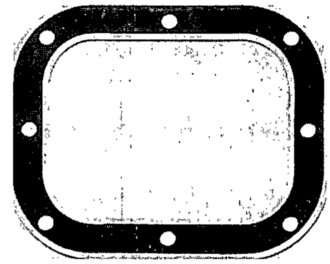

Figure 3. Die-cut combo gasket with nonconductive silicone rubber (light areas) bonded inboard and outboard of the conductive elastomer (silver-plated aluminum particles in silicone rubber).

It should be noted that many designers select monel mesh or tin-plated, copper-clad steel mesh gaskets in the belief they will resist corrosion. In fact, monel mesh has one of the highest corrosion potentials against aluminum of any EMI gasket material. Although monel mesh is often described as "corrosion-resistant", a more accurate term would be "oxidation-resistant". It ages well and maintains its good electrical conductivity in benign environments, but will cause galvanic corrosion of aluminum in salt-spray environments.

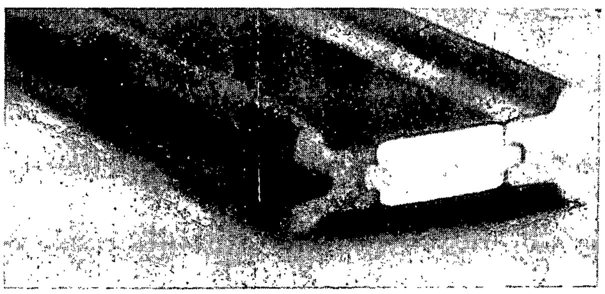

Figure 4. Combo gasket, conductive (silver-plated copper in silicone) and nonconductive (silicone) extrusions bonded to aluminum compression stop. Gasket shape is designed to require minimum closure force and seal gaps which may vary between .200 and .125 inch.

Tin-plated, copper-clad steel mesh is not recommended in salt-spray conditions because the tin-plating can easily be degraded by abrasion during use, leaving substantial amounts of exposed copper. This gasket material is best suited where highest levels of H-Field attenuation are required, but salt-spray conditions will not be present.

As a result of the corrosion potential measurements described above, and its excellent sealing qualities, by far the best EMI gasket material for use against aluminum flanges when corrosion resistance is required, is the silver-plated, aluminum-filled elastomer. However, the design guidelines described in (1)-(5) above should be followed.

This article was written for ITEM 85 by Eric J. Carlson and Dr. W.S. Vincent Tzeng, Chomerics Inc., Woburn, MA.

[2]Allied Kelite Div., The Richardson Company.

[3]AMCHEM Products, Inc.