Evaluation of EMI Seals For Corrosive Environments

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INTRODUCTION

Elastomers filled with conductive particles are used as EMI seals in electronic enclosures which typically are fabricated of aluminum. When the EMI seals are placed between the aluminum flanges and come into contact with electrolytes in the form of moisture or salt fog, a galvanic couple is created. The aluminum flanges corrode, resulting in nonconductive surfaces which increase the electrical resistance across the mating flanges. A study to evaluate the best combination of aluminum finish, elastomer, filler, and seal configuration was conducted. The results of that study are included in this article.

The research is based on various types of seal materials, aluminum surface finishes, and seal configurations. It provides additional information to the engineer who must design an effective EMI seal for corrosive environments.

Electrically conductive elastomers are often used as door or port seals in a variety of electronic enclosures and avionic boxes. The primary functions of the seals are to provide a very low impedance junction across the joint and to act as an environmental barrier, preventing dust and fluids from entering the enclosures. The avionic boxes used on aircraft and ships are typically made of aluminum alloy. When EMI gaskets containing silver-bearing materials are installed between aluminum flanges, a potential for corrosion is created. One cause of corrosion is galvanic attack, which occurs when the silver-bearing EMI seal and mating aluminum flanges come into contact with an electrolyte such as moisture or salt fog.

A precise combination of seal design, flange surface treatment, and material selection is needed for the development of a successful EMI seal for corrosive environments.

BASIC MATERIAL COMPATIBILITY

When selecting an EMI seal for a potentially corrosive environment, the first consideration should be given to material compatibility. However, the selection process should not be limited to this one aspect. Aluminum based EMI materials such as wire mesh or oriented wire embedded in an elastomer would seem a good choice for use in conjunction with aluminum flanges. However, aluminum oxides form a hard, nonconductive surface coating, thereby making these materials unacceptable. Silver-plated aluminum filled elastomers are also potentially compatible materials. Studies on galvanic corrosion have been offered by E. Carlson and V. Tzeng, (**ITEM 1985**), and the Naval Air Defense Center (Lin, Riley, Lee, and Brown, Report No. NADC 8720-60). However, a discrepancy exists between these studies regarding the compatibility of silver-plated aluminum filled elastomers with aluminum alloy flanges due to the different values of galvanic potential assigned to the filled elastomers.

In addition to **basic material compatibility**, other factors must be considered to achieve optimum shielding performance and corrosion resistance. Specifically, these factors are:

1. **Protection of the mating flange** surfaces from oxidation and corrosion. As a general rule, the higher conductivity of the base material, the higher the shielding effectiveness of the junction. In cases where the oxide build-up is rapid and thick, it is best to coat the flange materials with a plating that will produce a relatively soft oxide which can be abraded easily by mechanical contact. Chemical coatings such as Iridite and Alodine have relatively good electrical conductivity. Anodizing the surface is not generally recommended because "anodize" is an oxide of aluminum and is therefore nonconductive.

2. **Design of the interface** so that the area of the anode (flange) is significantly larger than the cathode (seal). The

POLYMER	FILLER
Silicone	Silver-plated Aluminum
Silicone	Silver-plated Copper
Silicone	Silver-plated Nickel
Silicone	Nickel
Silicone	Nickel-plated Graphite

TABLE 1. *Seal Materials.*

FORM
Flat Gasket (Die Cut)
Molded Shape (O-Ring)
Molded-in-place Seal
Dual Material
Single Material

TABLE 2. *Seal Configurations.*

PLATE	PROCESS
Bare	None
Chemical Film	MIL-C-5541 Class III
Electroless Nickel	MIL-C-26074 Class IV Grade A
IVD (Ion Vapor Deposition)	MIL-C-83488 Class I Type II

TABLE 3. *Flange Surfaces.*

EMF difference remains the same. However, the current density is *decreased*, resulting in a reduction of galvanic attack. Flat gaskets (die cuts) will be a poor choice when designing a seal for a corrosive environment because of their large surface area. A molded part (conductive o-ring) placed in a groove, or a molded-in-place conductive seal vulcanized to a lid or retainer will thus be the preferred sealing option because of its minimum contact area.

3. **Keeping moisture out** of the joint or flange area by use of a properly designed environmental seal in conjunction with EMI shielding/sealing.

TEST ASSEMBLIES

Three types of seals, used in four different fixtures, were used in the salt spray test: flat gasket (die cut), molded shape (o-ring), and molded-in-place seals. The materials, seal configurations, and flange surface finishes which were evaluated are shown in Tables 1, 2, and 3.

The 6061-T6 aluminum plates were machined to a finish of 63 RMS and plated with the following finishes: bare, chemical film, ion vapor deposition (IVD) or electroless nickel. All outside non-relevant surfaces were then coated with epoxy primer (MIL-P-23377) and a top coat of aliphatic polyurethane (MIL-C-83286).

FLAT GASKETS (DIE CUTS)

The flat gasket assembly consisted of a flat gasket (die cut) sandwiched between two aluminum plates held together by 12 #8-32 stainless steel screws. One plate had through holes while the other plate had threaded holes. An additional hole on the side of each plate was made for a #8-32 screw. A nylon string was wrapped around the screw and the assembly suspended on poles inside the salt spray chamber. The gaskets were 5"x 5" with a 3.5"x 3.5" cut out in the center with punched holes to allow for bolt clearance (Figure 1).

MOLDED SHAPES (O-RINGS)

The o-ring assembly had two plates bolted together with 16 #8-32 screws. One plate was flat with through holes, while the other plate had a machined (o-ring) groove and threaded holes. The molded part (o-ring) was placed in the groove and compressed between the two plates (Figure 2).

MOLDED-IN-PLACE SEALS

The conductive materials in the molded-in-place seal assembly, consisting of a single seal with two crowns, but in two different configurations were molded into flat round aluminum retainers within pre-machined grooves. The retainers were then sandwiched between two aluminum plates retained by four $^{1}/_{4}$"-20 screws. Both seal configurations had two crowns molded on each side of the retainer. The dual seal had a nonconductive, environmental seal material for the outside crown and a conductive material for the inside crown. The single mate-

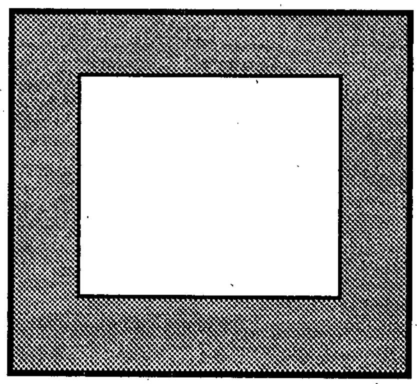

FIGURE 1. *Flat Gasket (Die Cut).*

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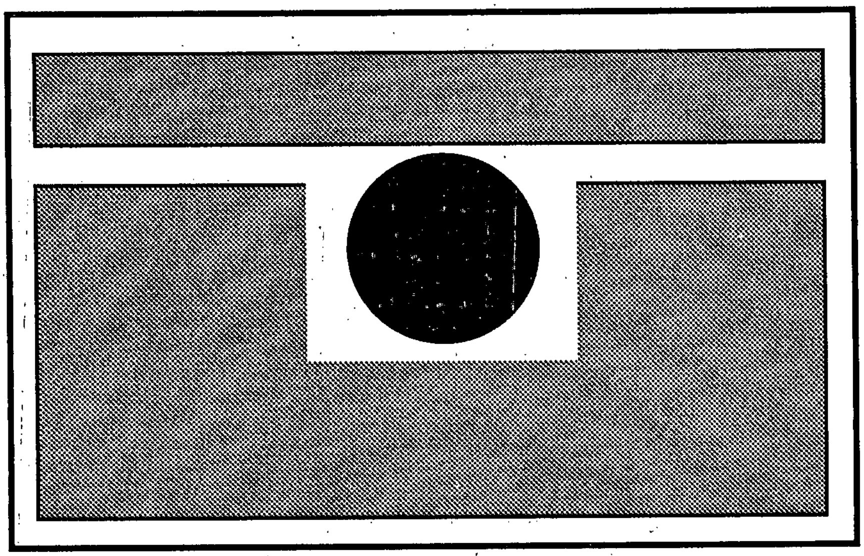

FIGURE 2. *Molded Shape (O-Ring) Exploded.*

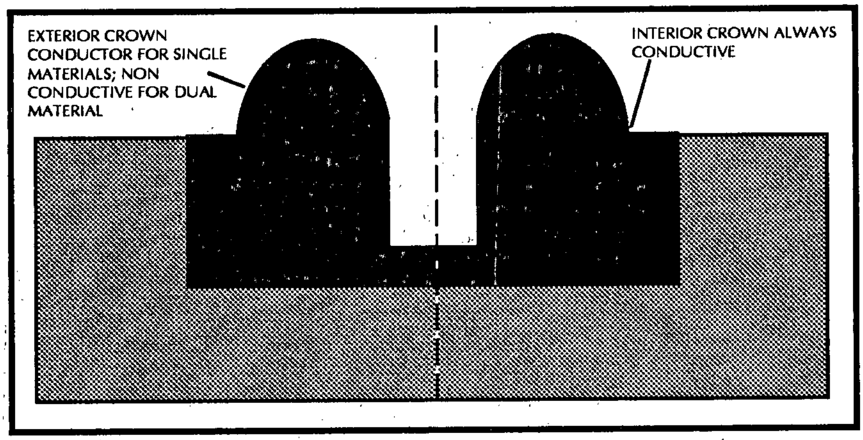

FIGURE 3. *Molded -in-place Seal.*

rial seal had both crowns of a conductive material. The aluminum retainers were 0.125" thick x 2.5" diameter and coated with various plated finishes. A cross section of this seal is shown in Figure 3.

JUNCTION RESISTANCES

The fixture used to evaluate the junction resistances of seal surfaces was similar to the flat gasket (die cut) assembly except the fixture was 2 x 2 inches square and had four holes.

TESTING & EVALUATION

TEST PROCEDURE

The salt spray test was performed in accordance with ASTM B117-73 and NADC-87020-60. The test plates were assembled with stainless steel fasteners and placed in the salt spray chamber. Test fixtures were then exposed to five 168-hour periods followed by a single 672-hour period for a total of 1500 hours. After each of the six exposure periods, all seal assemblies, except those tested with a junction resistance fixture were opened, photographed, washed, reassembled, and masked again, whereupon the testing cycles continued.

EVALUATION SYSTEM

The evaluation system used in this study not only looked at pits and deterioration, but also tears, rippling, corrosion intrusion, inside edge corrosion of fastener holes, percentage of coverage, oxide deposits and colors. It:

- Examined all visible aspects of corrosion,
- Measured each aspect empirically, and
- Measured each aspect with greater resolution.

The degree of corrosion encountered has been rated as:

10 = untouched
through
1 = destroyed

RESULTS & DISCUSSION

Three types of EMI seal designs - i.e., flat gaskets (die cuts), molded shapes (o-rings), and molded-in-place seals - were evaluated in this study. The results are discussed under separate headings.

FLAT GASKETS (DIE CUTS)

As is clear from Table 4, the nickel-filled elastomers and the nickel-plated graphite-filled elastomers (experimental), exhibited the best performance. The gaskets showed little apparent damage against any flange finish. Although three flange finishes - bare aluminum, chemical film, and electroless nickel - did not exhibit any preference, bare aluminum is not recommended because it has the tendency to form a non-conductive hard oxide which can result in higher resistance across the junction. Silver-plated copper filled elastomer showed a poor performance regarding the condition of the gaskets and flanges. The silver-plated aluminum filled elastomer had very little effect on the flanges, but the gaskets showed heavy to moderate deterioration. The silver-plated nickel filled elastomer gaskets were in excellent condition but the flanges showed a certain degree of corrosion. (Chemical film-treated flanges performed better than electroless nickel-treated flanges.)

The following is the overall performance of the gaskets and flanges, ranked in *decreasing* order:

- Nickel-filled silicone
- Nickel-plated graphite filled silicone
- Silver-plated nickel-filled silicone
- Silver-plated aluminum-filled silicone
- Silver-plated copper-filled silicone

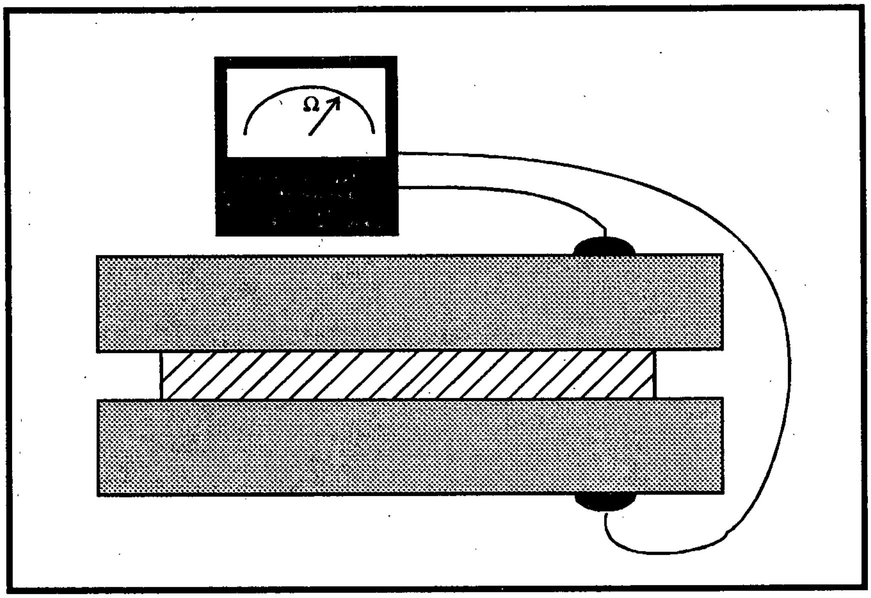

***FIGURE 4.** Junction Resistance Fixture.*

GASKET MATERIAL	SURFACED EXAMINED	BARE ALUMINUM	CHEM FILM	ELECTROLESS NICKEL	ION VAPOR DEPOSITION
Ni/Sil	Gasket	8	7	9	--
	Plate	7	7	6	--
Experimental Ni-Graph/Sil	Gasket	8	8+	8+	--
	Plate	7	7	6	--
Ag-Al/Sil	Gasket	5	5	2	3-
	Plate	8	8	9	6
Ag-Cu/Sil	Gasket	4	4+	6	3
	Plate	4	4	3	2
Ag-Ni/Sil	Gasket	8	8	8+	--
	Plate	5	6	2	--

***TABLE 4.** Galvanic Rating - Flat Gaskets (Die Cuts).*

GASKET MATERIAL	SURFACE EXAMINED	RATING
Ag-Al/Sil	Seal	9+
	Plate (Bare)	8
	Cover (Chemical Film)	9
Ag-Ni/Sil	Seal	9+
	Plate (Bare)	8
	Cover (Chemical Film)	9

***TABLE 5.** Galvanic Rating - Molded Shapes (O-Ring).*

Regardless of the performance of the flat gaskets (die cuts), they would not be recommended because of creep and compression set in the gasket after an interval of time. Compression set results in the loss of the seal line and allow moisture or fluids to intrude into the assembled parts.

MOLDED SHAPES (O-RING)

As shown in Table 5, the molded o-rings made from silver-plated aluminum and silver-plated nickel did not show deterioration on the seal or on the flanges. The molded shape (o-ring) placed in a groove represented a marked improvement over the flat gaskets (die cut); however, grooves are needed for retaining the seal in the flanges. Silver-plated copper was not tested as a molded shape (o-ring), but based on the data obtained from the flat gasket test, the material can be inferred to be problem-free.

MOLDED-IN-PLACE SEALS

Three materials were tested in the form of a seal with two crowns molded into a single gland, with one or both crowns being conductive, as shown in Table 6. None of the assemblies showed considerable corrosion. In conjunction with aluminum flange surface finishes, chemical film exhibited the best combination, followed by ion vapor deposition and electroless nickel. Silver-plated nickel filled material was not tested against chemical film, but based on other data it can be inferred to be problem-free.

JUNCTION RESISTANCES

The four $^1/_4$" -20 fastening screws were electrically isolated with nylon inserts. Ten-inch lengths of insulated solid copper wire were soldered to screws attached to the side of each aluminum plate (Figure 4). These wires allowed electrical resistance readings between the two

GASKET MATERIAL	SURFACE EXAMINED	DUAL MATERIAL (D)	SINGLE MATERIAL (M)
Ag-Al/Sil	Seal	9	9
	Plate (Chemical Film)	9	8+
	Retainer (Chemical Film)	9	9
Ag-Al/Sil	Seal	--	9
	Plate (Chemical Film)	--	8-
	Retainer (Ion Vapor Deposition)	--	7
Ag-Cu/Sil	Seal	9	--
	Plate (Chemical Film)	8	--
	Retainer (Chemical Film)	9	--
Ag-Ni/Sil	Seal	9+	9+
	Plate (Electroless Nickel)	7	6
	Retainer (Electroless Nickel)	3	3

TABLE 6. *Galvanic Rating - Molded-in-Place Seals.*

	RESISTANCE (MILLIOHMS)					
HOURS OF EXPOSURE	LEAD WIRES	Ni/Sil	(experimental) Ni-Graph/Sil	Ag-Al/Sil	Ag-Cu/Sl	Ag-Ni/Sil
0.0	0.560*	3.20	3.65	3.04	4.70	3.00
163.5	0.002	3.64	4.02	3.26	5.09	3.44
326.0	0.183	3.10	3.62	2.89	4.34	3.34
492.3	0.003	3.17	3.79	3.05	4.52	3.58
658.0	0.003	3.03	3.59	2.89	4.30	3.50
822.3	0.003	2.91	3.39	2.79	4.04	3.27
1508.0	0.077	2.93	3.27	2.71	3.84	3.33

* Expermental error.

TABLE 7. *Effects of Salt Spray on Junction Resistance.*
NOTE: Plates were coated with Electroless Nickel.

plates through the conductive gasket to be measured.

Junction resistances of several conductive elastomers as a function of time is shown in Table 7. The data indicates that, regardless of the condition of the gasket and plates, the junction resistance remained fairly constant. It can be inferred that the shielding performance will not be impaired, even if corrosion intrusion occurs. The results presented here are not altogether conclusive.

SUMMARY

Extensive sealing experience indicates that a precise combination of seal design, flange surface treatment, and material selection is needed for the development of a successful EMI seal for corrosive environments. The order of preference of each criterion is as follows:

DESIGN:
1. A combination seal with separate glands to provide an environmental and EMI seal for high reliability in the harsh environment.
2. A molded-in-place seal with two crowns in a single gland, with one or two crowns being conductive.
3. A molded shape with specially engineered gland dimensions and profile geometry.

FLANGE SURFACE TREATMENT:
1. Chemical film Class 3.
2. Bare metal without surface treatment, provided the junction resistance is within the limits of the application.
3. Electroless nickel for nickel or nickel-plated graphite.

MATERIALS:
1. Silver-plated nickel filled silicone.
2. Silver-plated aluminum filled silicone.
3. Nickel or nickel-plated graphite filled silicone.

Galvanic corrosion is a complex problem and does not have a single simple solution. Selection of the optimum material and design depends upon the total environmental spectrum within which any given seal is expected to function. Factors such as media, pressure, temperature and exposure time must be taken into consideration.

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