EMI Shielding of Conductive Gaskets In Corrosive Environments

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Abstract

This paper describes the results of a study to determine the performance of various types of conductive gaskets in environments of varying corrosivity. All gaskets experience degradation effects with time, be it simple aging in a controlled environment or from salt spray exposure aboard ships. The continuing performance level of a gasket is, therefore, as much a function of its aging characteristics as initial shielding effectiveness. Five basic gasket types were exposed to three different environments and their shielding related properties measured. The three environments examined included indoors, temperate outdoors, and shipboard related. The performance of the various gasket types is evaluated on the basis of their surface transfer impedance behavior.

Introduction

Any enclosure which allows for easy access to internal components must have doors or seams. When the enclosure is designed to prevent external electromagnetic signal interference, or to contain internally generated EM signals, these seams must also include EMI gaskets.

All EMI gaskets will be exposed to environments of varying corrosivity. A very pertinent question, therefore, is how such gaskets, though they provide the required shielding when first installed, continue to perform after a given time of service.

The effects of corrosion and weathering on knitted wire type EMI gaskets have been studied.[1] Also, the visible effects of corrosion on elastomer-based conductive gaskets has been examined.[2] A literature survey, however, has not revealed any practical, applications oriented results comparing the actual EMI shielding performance of the various types of gaskets as they age.

The five basic types of gaskets tested were elastomeric O-ring, flat elastomeric, knitted wire, oriented array of wires, and spiral wound. In addition, variations of these five basic types were tested, resulting in eight different gasket types. These samples are listed below in Table 1.

Sample #	Description
1	Elastomeric O-Ring
2	Flat Elastomeric
3	Flat Elastomeric with Environmental Seal
4	Knitted Mesh
5	Spiral Wound
6	Spiral with Environmental Seal
7	Oriented Array of Wire in Solid Elastomer
8	Oriented Array of Wire in Foam Elastomer

Table 1: Sample Gaskets Tested

Sample Gaskets

All of the samples used in the study were assembled using the basic joint geometry shown in Figure 1. Both the upper and lower plates are of 6061 aluminum. The number of connecting bolts was sufficient to insure uniform compression of the gasket, as required by the gasket manufacturers. For the O-ring samples, the gasket was placed in a machined groove. All other sample gaskets were simply placed between the upper and lower plates (as indicated in the figure). All samples were torqued according to the manufacturer's specifications. For the O-ring samples, the groove provides for a compression stop. The compression of all other samples was achieved by checking the compressed gap, until the rated percent compression was obtained.

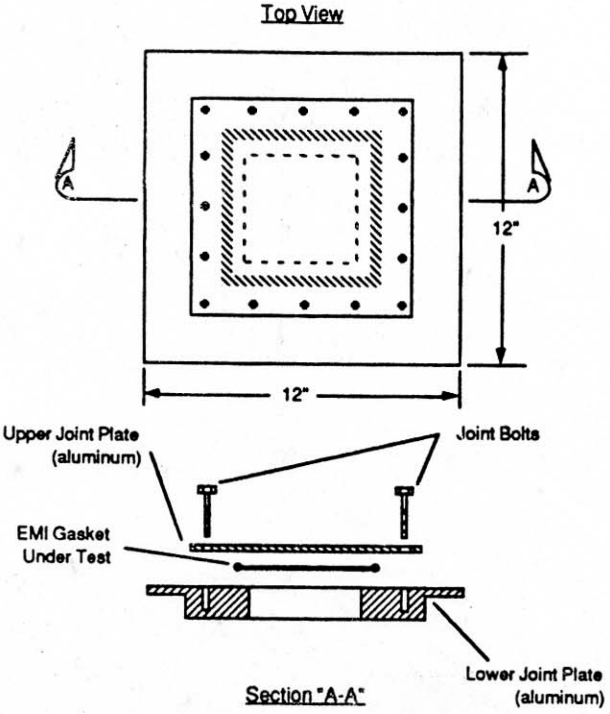

Figure 1: Sample Joint Test Plates

Both the upper and lower plates shown in Figure 1 were plated with a MIL-C-5541 Class 3 chromate conversion coating. The amount of coating was determined by color matching the plates to a sample of known contact resistance.

Exposure Environments

One of the three samples from each of the eight variations was exposed to one of three environments of varying corrosivity. All of the samples have been exposed for a period of six months. Note that for all samples, the joint was not opened at any time during the exposure.

The least corrosive environment consisted of simple aging in a con-

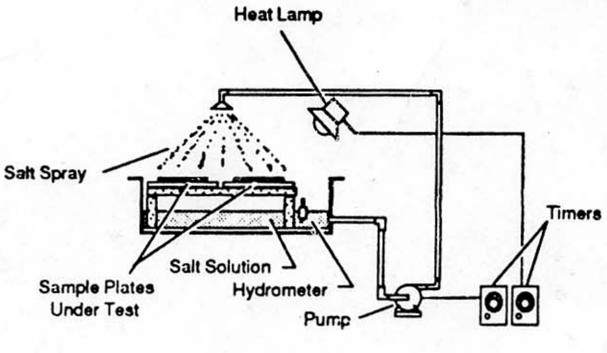

Figure 2: Salt Spray Apparatus

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trolled environment (an air conditioned laboratory). The mildly corrosive environment consisted of the outdoor climate of Atlanta (a building rooftop), such that the samples were exposed to both outdoor moisture and sunshine. The most corrosive environment emulated the conditions on board ship. In this environment, the samples were exposed to a fifteen minute salt water spray twice a day, and a heat lamp for five hours a day. The apparatus used for this exposure is shown in Figure 2. It should be noted that this test makes no effort to replicate the MIL-STD-810D standard test method. Thus, the results given can not be directly compared to measurements involving that test method. The method employed here, however, is a reasonable approximation to a shipboard environment, and can be used to make relative comparisons of the performance of conductive gaskets in corrosive environments.

Note that all measurement contact surfaces (i.e., surfaces in electrical contact with measurement fixtures) on the salt spray samples were protected by covering with clear tape. A blank plate (without any opening) was weathered in the same manner as the gasket samples. When tested, if this sample showed degradation (which could only be from fixture contact impedance), then all sample contact surfaces were further prepared by buffing with steel wool. In this way, it was insured that corrosion of the measurement fixture contact points did not adversely affect the measurements obtained. Since the chromate coating of the sample gaskets has some resistance associated with it, this buffing procedure (which was not implemented until obvious degradation of contact conductance was evident) yielded an apparent increase in the measured shielding related properties of some of the samples.

Measurement Procedure

The method used to evaluate the gaskets' shielding performance was the surface transfer impedance method. The method is similar to that found in reference [3], with the exception that the measurement fixture was modified to accept the samples of Figure 1. The transfer impedance test fixture is shown in Figure 3. Note that the input current is injected through a 50 Ω resistance. The reference voltage is sampled above this resistor through a 1 KΩ resistor. The output voltage is the voltage drop across the gasket. The sample transfer impedance is the ratio of this voltage drop to the input current (as measured by the reference voltage across the 50 Ω resistor). The sample joints transfer impedance was measured from 100 KHz to 200 MHz, using a Hewlett Packard 3577 Network Analyzer. The sensitivity of this measurement was approximately -90 dBΩ.

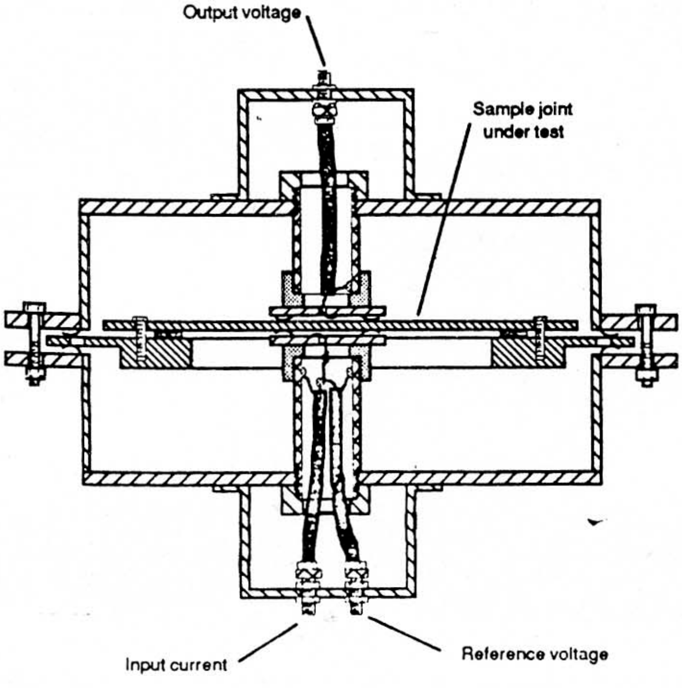

Figure 3: Transfer Impedance Measurement Fixture

Experimental Results

Comparison of Gasket Types in a Particular Environment

Figures 4 thru 6 show the transfer impedance versus time plots for the five basic sample types in the three environments. Note that the samples shown were the "bare" variations (i.e., without environmental seals), and the oriented wire sample is for the solid elastomeric base. All values are given in dBΩ, with the exposure time expressed in weeks of exposure. It should be pointed out in looking at the data in these three plots that the sample plates were first buffed with the steel wool during week six of the exposure period presented. As mentioned previously, since the coating of the sample joints adds from three to four milliohms of contact resistance, its removal causes an apparent decrease in the joint transfer impedance of some of the samples. This is easily seen in the plot for the flat elastomeric sample in the salt environment (Figure 4).

The plots of Figure 4 indicate that the spiral type gaskets performed the best in this environment. This gasket type provided the best initial transfer impedance, having an unweathered transfer impedance of approximately -80 dBΩ. It also degraded the least of the five types, increasing by slightly more than 10 dB over the course of 13 weeks of weathering.

As seen in Figure 4, the flat elastomeric gasket type provided for the worst transfer impedance, with an initial value of about -30 dBΩ, and degrading about 20 dB over the 13 weeks of exposure. Note that, although consistently the worst performer, this gasket did not degrade as much as did the O-ring, knitted mesh, and oriented wire types.

Also, the knitted mesh and oriented wire gaskets in the salt spray environment (Figure 4), had very similar performance, starting at an unexposed -53 dBΩ, and degrading to about -28 dBΩ over the course of the 13 weeks. This indicates that the use of a rubber gasket to encase this oriented wire is not slowing the corrosive process at the gasket to plate interface.

The O-ring type elastomeric gasket exhibited the worst degradation in the salt spray of the five types, increasing 45 dB from an initial value of about -75 dBΩ.

Note that the O-ring type did provide much better initial performance than the flat elastomeric gasket, even though both are of the same material. This is, in part, due to the superior compression characteristics of the O-ring geometry. Much of this increase in performance, however, is likely due to the metal-to-metal contact provided by the O-ring groove joint geometry. Thus, it can be inferred that a groove type geometry (one which provides for metal-to-metal contact all around the sealing surface) is far superior to the "open" type geometry of the other samples (as shown in Figure 1), and that, most probably, all of the gasket types considered would benefit from such a joint geometry.

This enhanced geometry, however, loses some of its advantage under corrosive influences. As mentioned earlier, the O-ring type configuration degraded the most with exposure time. In fact, this gasket degrades more than the knitted mesh type gasket, which is the most susceptible to galvanic action. Therefore, joint geometry alone is not enough to insure adequate shielding with time and physical joint degradation.

Contrasting Figure 6 to Figure 5 shows that the same basic ordering (i.e. relative performance) of the five basic types is the same for the rooftop environment as for the salt spray environment. However, all gasket types exhibit much less degradation in the rooftop environment than in the salt spray. As with the salt spray samples, the O-ring sample showed the most degradation of the rooftop gaskets, exhibiting an increase of about 23 dB over 16 weeks of exposure. Also note that the knitted mesh actual exhibits less degradation than the oriented wire, indicating that the encasing rubber gasket of the latter is accelerating the joint interface corrosion. This is possibly due to a crevice type action.

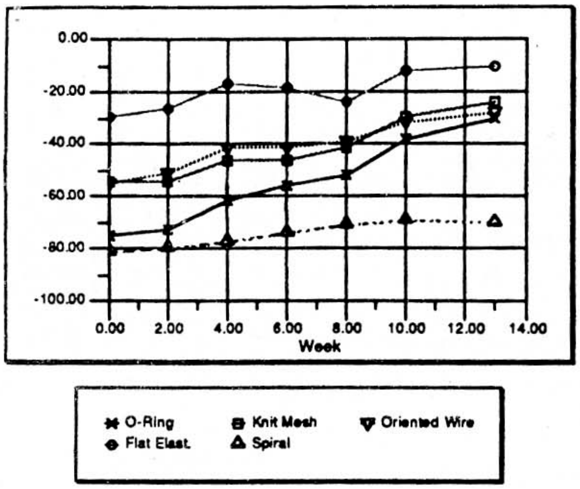

Figure 4: Transfer Impedance (dBΩ) of the Five Basic Gasket Types versus Salt Spray Exposure Time

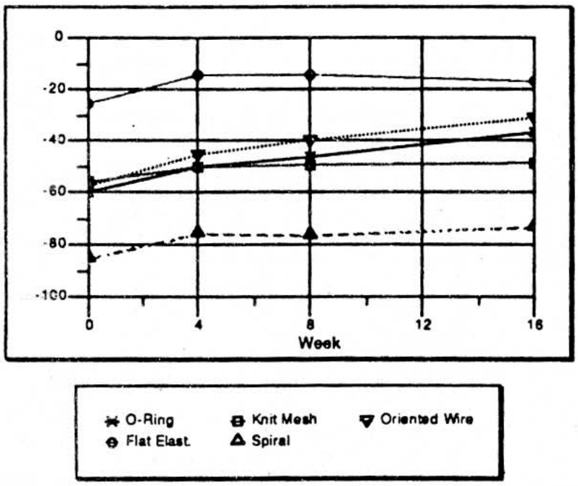

Figure 5: Transfer Impedance (dBΩ) of the Five Basic Gasket Types versus Rooftop Exposure Time

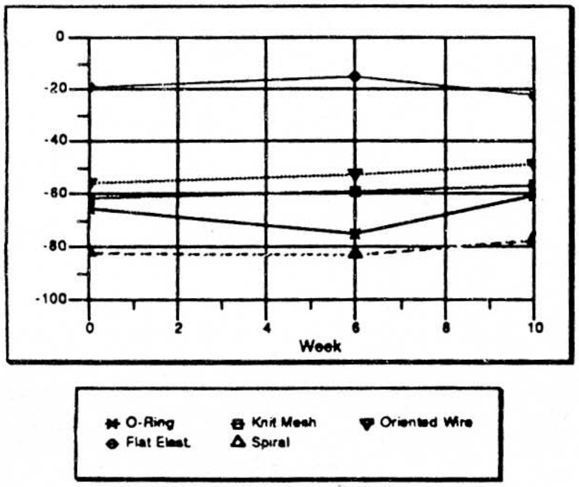

Figure 6: Transfer Impedance (dBΩ) of the Five Basic Gasket Types versus Laboratory Exposure Time

Figure 6 shows that the initial performance of the laboratory samples matches that of the salt spray and rooftop samples. As expected, however, none of the gaskets in this environment shows appreciable degradation over ten weeks of exposure. It should be noted that the apparent dip in the transfer impedance of the O-ring sample in this environment is due to the buffing of the measurement contact surfaces for measurements made on and after week 6 of the tests.

Conversion Coating Effects on Elastomeric Gaskets

Since the transfer impedance values shown in Figures 4 thru 6 for the flat elastomeric gaskets were inordinately high, it was decided to make a base line (i.e., unweathered) measurement of such a joint without the chromate coating. To facilitate this, another flat elastomeric sample was prepared, in exactly the same manner as the ones of Figures 4 thru 6, with the exception that the conversion coating was buffed from the gasket contact surfaces with steel wool. Note that the coating was removed only at the gasket contact surfaces; it was not removed from the transfer impedance fixture finger stock contact surfaces as shown in Figure 3.

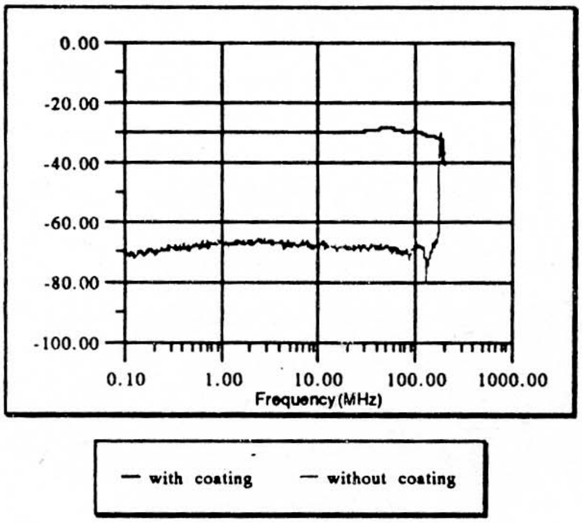

Figure 7: Transfer Impedance (dBΩ) vs. Frequency for Flat Elastomeric Gaskets Wtih and Without Class 3 Chromate Conversion Coating

The initial transfer impedance versus frequency plot of the sample with the conversion coating intact and the transfer impedance versus frequency performance of the sample with the coating removed are shown in Figure 7.

The irregularities at high frequencies of the "without coating" plot of Figure 7 are due to resonances within the transfer impedance fixture. The upper frequency limit of the fixture of Figure 3 is, therefore, approximately 100 MHz.

The plots of Figure 7 indicate that the chromate coating degrades the performance of this type of gasket by a factor of 100 (40 dB). Since the coating used was extremely light, this degradation is caused by this type of gasket's inability to "bite" through the coating. In fact, concern for this very problem was expressed by the manufacturer of this type gasket prior to testing. The manufacturer supplied sample aluminum coupons, which were said to be "properly" coated, such that the samples for these tests could be coated in a like manner. All of the sample plates were then coated by matching the color of these sample coupons. Even with all of these precautions, the inability of the elastomeric gasket type to penetrate the coating resulted in a 40 dB degradation in performance.

Comparison of Exposure Environment Within a Basic Gasket Type

The differing effects of the three exposure environments on a specific basic gasket type is seen in comparing plots 4 thru 6. The gasket type which shows the least effect of increasing corrosivity of the exposure environment was the spiral. The type showing the greatest vulnerability to increasing corrosivity was the O-ring type gasket. The performance of these specific types in the three environments is shown in Figures 8 and 9, respectively.

It is seen in Figure 8 that the spiral type gasket exhibited similar performance in all three exposure environments. All three samples had an initial, unweathered performance of about -83 dBΩ. The salt spray sample degraded approximately 10 dB over the course of 13 weeks of exposure. The rooftop and laboratory samples exhibited about 7 dB and 4 dB degradation in 16 and 10 weeks respectively. Thus, the salt spray sample exhibited only about 7 dB more degradation than the laboratory sample.

In contrast, the O-ring sample of Figure 9 shows a fairly wide disparity in its performance in the three environments. The laboratory sample exhibits only about 3 dB of degradation in performance over the 10 week exposure period. Note that the dip in this plot, as mentioned earlier, is due to the polishing of the measurement contact surfaces for measurements made on and after the 6th week. The salt spray sample, however, exhibited a degradation of 45 dB over the 13 week exposure period. This represents in increase in transfer impedance (i.e., in Ω) for the salt spray sample of about 125 times that for the laboratory sample. As would be expected, the rooftop sample exhibits a degradation of about 22 dB in 16 weeks of exposure, which is about midway between the degradation shown by the lab and salt spray samples.

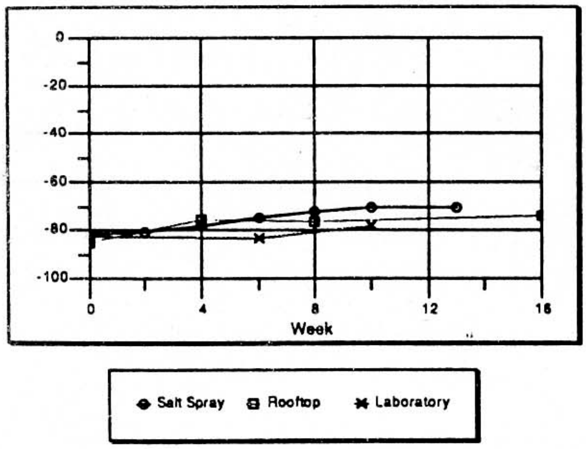

Figure 8: Spiral Wound (Sample #5)
Transfer Impedance (dBΩ) vs. Exposure Time

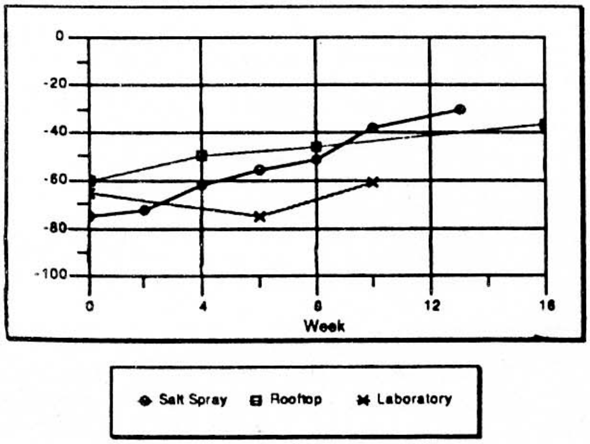

Figure 9: Elastomeric O-Ring (Sample #1)
Transfer Impedance (dBΩ) vs. Exposure Time

As was noted earlier,this disparity in degradation is probably due to the fact that much of the shielding of the O-ring type sample can be attributed to its superior joint geometry, which provides for metal to metal contact (while the other samples' geometries do not). This advantage, however, is less and less apparent as corrosion of this metal to metal contact surface occurs.

The performance of the knitted mesh, oriented wire, and flat elastomeric gaskets is not specifically shown in a plot like those of Figures 8 and 9. This information, however, can be extracted by comparing the graphs of Figures 4 thru 6. In doing so, it can be seen that the knitted mesh and oriented wire show similar performance characteristics, with the salt spray samples showing a degradation about three to four times that (in dB) of their laboratory counterparts. The flat elastomeric shows relatively little disparity between the degradation of the samples in the three environments. All three of these samples showed similar degradation, and all three showed poor performance in all three environments. Refer to Figures 4 thru 6 to see this. As noted earlier, this poor performance is probably due to the inability of this gasket to "bite" through the chromate conversion coating.

Integral Environmental Seal Costs and Benefits

As given in Table 1, variations of the flat elastomeric and spiral type gaskets with integral environmental seals were also tested in the salt spray and rooftop environments. The geometry for these samples were exactly the same as their non-environmental seal counterparts, with the exception that each gasket included an attached, non-conductive, environmental seal which faced to the "outside" of the sample joint (i.e., toward the edges of the plates of Figure 1). These samples were then exposed in exactly the same manner as their non-environmental seal brethren.

Figure 10 shows the relative performance of the flat elastomeric type gasket both with and without environmental seal in both the salt spray and rooftop environments.

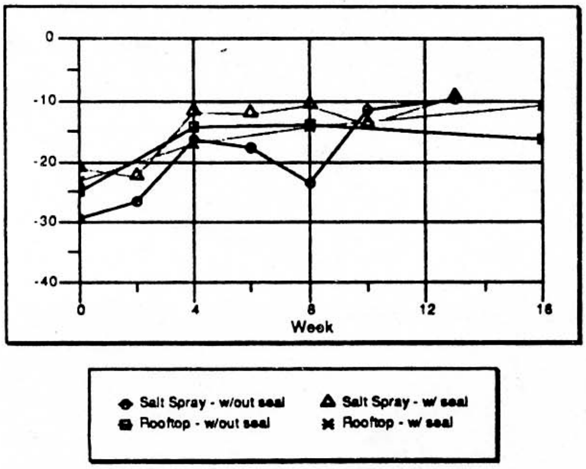

Figure 9: Flat Elastomeric With and Without Environmental Seal
Transfer Impedance (dBΩ) vs. Exposure Time

As seen in Figure 9, the samples with the environmental seals had an initial transfer impedance which was higher than their non-environmental seal counterpart by about 5 to 10 dB. The salt spray sample with seal exhibited less degradation with time than did the salt spray sample without seal, indicating that the seal helped in this environment. The rooftop samples, however, did not show this benefit, with the non-seal sample actually performing better than the environmental seal sample. Again, this situation could have been drastically different had the samples not had the chromate conversion coating at the gasket sealing surface.

A plot comparing the spiral gasket type with and without environmental seal is shown below in Figure 10.

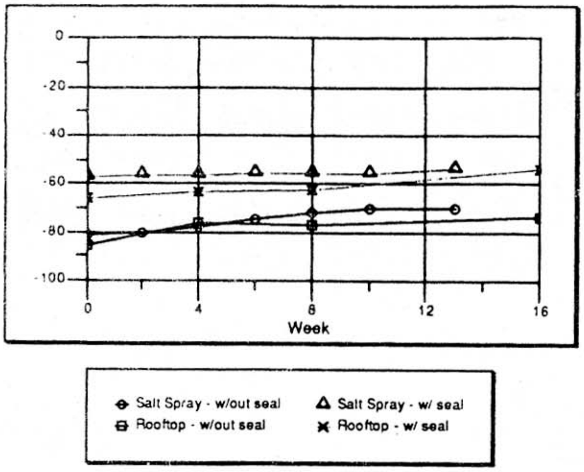

Figure 10: Spiral Wound With and Without Environmental Seal Transfer Impedance (dBΩ) vs. Exposure Time

As with the flat elastomeric samples, the spiral samples with the environmental seals had an initial transfer impedance which was higher, by about 20 dB, than their non-seal counterparts. However, the salt spray samples show a definite advantage, about 2 dB versus about 7 dB, in the use of the environmental seal. The rooftop samples, show virtually no advantage from the use of the environmental seal.

It should be noted when analyzing the data of Figures 9 and 10 that then environmental seal provided sealing in only one "direction". That is, the inner edge of both gaskets was indirectly exposed to the corrosive environment. Thus, the assessment of the advantage of such seals in reducing the degradation caused by such exposures is probably not shown as strongly as it could be in the data.

It is clear, however, that, for both gaskets, an initial performance penalty is paid for the use of such non-conductive, environmental seals. Thus, such seals should only be used where they are necessary, such that the advantage in decreased degradation with corrosive exposure outweighs the initial performance penalty.

Foam versus Solid Elastomer with the Oriented Array of Wire Gaskets

As indicated in Table 1, two types of oriented array of wire gaskets were tested. The first, and the one discussed earlier in the experimental results, used a solid, non-conductive elastomeric base gasket to bind the array of conductive wires together. The second used a foam elastomer as the base gasket.

Figure 11 shows a plot contrasting the performance of these two gasket types in the salt spray and laboratory environments. The rooftop data is not shown, because the two types exhibited virtually identical performance in this environment.

It is expected that the foam type gasket would have better initial performance due to its better compression characteristics than the solid variation. This fact is evident in Figure 11. The foam variations had an initial transfer impedance that was about 5 dBΩ better than the solid type.

It was also expected, however, because the foam is open cell and should soak up moisture, that the solid variations will exhibit less degradation with exposure than the foam types. Figure 11 shows that exactly the opposite is the case. The salt spray foam gasket exhibited about 20 dB of degradation with 13 weeks of exposure, while the solid type exhibited almost 30 dB of degradation. Similarly, the lab foam sample exhibited approximately 3 dB of degradation, while the solid variation exhibited a little more than five.

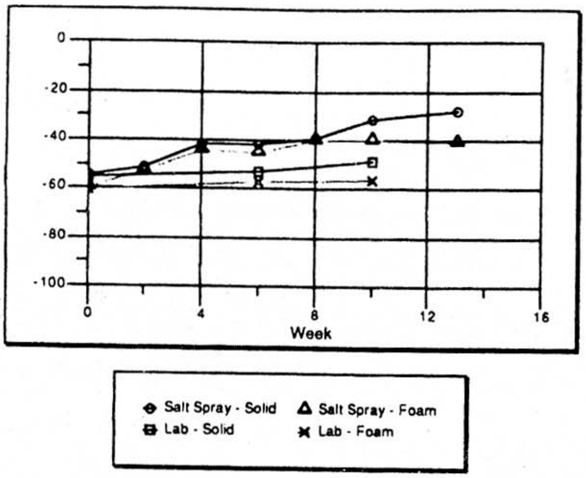

Figure 11: Solid vs. Foam Elastomer Base Gasket in Oriented Array of Wire Samples Transfer Impedance (dBΩ) vs. Exposure Time

A possible reason for this effect is the crevice corrosion discussed earlier. Since the foam type gasket allows for more circulation, compared to the solid variation, of any electrolytic fluid at the sealing interface, it seems likely that such electrolyte would have lower acidity, and therefore lower corrosivity, for the foam gaskets. This conjecture is supported by the data of Figure 11.

Conclusions

The shielding performance of five basic conductive gasket types (with eight total variations) subjected to three environments of varying corrosivity was studied. The environments were selected to simulate a controlled, indoor environment; a temperate outdoor environment, and shipboard conditions. The gasket shielding performance was measured using the surface transfer impedance method.

The results indicate that the spiral type gaskets perform best, both in terms of initial performance, and resistance to degradation with corrosion. The O-ring type elastomeric exhibited the worst degradation with weathering, probably due more to the degradation of its initially superior joint geometry, which provides for metal to metal contact. The flat, cut type elastomeric type performed the worst in terms of initial, probably due to its inability to penetrate the thin chromate coating. Oriented array of wire and knitted wire mesh types were also studied, and they showed similar performance, midway between that of the spiral and the elastomeric gaskets. The results of the experiments indicate that the oriented array type may have a problem with crevice corrosion effects.

The benefits and costs associated with integral environmental seals was also studied. It was found that their is an initial performance penalty associated with such seals, but in corrosive environments, they provide protection from degradation due to exposure.

References

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