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# Corrosion Efffects on EMI Gasketed Joints

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ABSTRACT

The effects which corrosion can have on a gasketed joint is documented. This documentation is in the form of illustrating previous published work and the results of moisture and salt spray tests which were performed on gasketed joints. The results include conclusions and recommendations based upon the referenced previously published information and the testing reported in the paper. The recommendations list a series of gasket materials and surface plating which can be successfully used without experiencing excessive corrosion as a function of the required environment and level of shielding.

## INTRODUCTION

The engineering discipline has spent a considerable amount of time and money in an effort to minimize the effects of corrosion on electrical systems. The major intent is to insure that the structural integrity of the equipment survive for the useful life of the electronics. This effort has been in the development of materials and processes used to minimize the effects of the environment on the basic structural material. The development of a galvantic cell has also been addressed to minimize the effects of galvantic corrosion on the structural material, where numerous military specifications such as MIL-E 16400[1], and MIL-STD-889[2] describe acceptable joints to be used in the procurement of military weapon systems.

The requirement of an EMI gasket in the joint to obtain a required shielding integrity offers a difficult situation with regard to corrosion. The gasket must be resilient, highly conductive and be able to last for the life of the equipment. Since the gasket materials in almost all cases are of a different material than the structural joint material it is almost impossible to totally eliminate some effects of corrosion. However, detramental effects can be held within acceptable limits by the careful selection of the joint materials and plated surfaces, and the proper selection of the gasket configuration and material used in its manufacture. Such a selection can represent the lowest cost in terms of the life span of the equipment when preventive maintenance and the replacement of the structural materials and gaskets are considered.

## REVIEW OF THE STATE OF THE ART

The effect which corrosion has on shielding integrity which is used in protecting against EMI and lightning has been recognized as a severe problem by the Aerospace Industry for many years.

There is only one (1) truly acceptable method of protecting a gasketed joint against corrosion. This is to select the joint surfaces and the gasket material such that corrosion does not cause a detramental effect on the operation of the equipment throughout the life of the equipment. This can be obtained by specifying joint surfaces and gasket materials that do not exhibit detramental effects as a function of the environment.* In this selection, the use of weather seals can be incorporated on the external side of the EMI seal to protect the joint from the environment. When the joint surfaces and gasket materials are not compatable, it is often acceptable practice to protect the joint area with a weather seal on both sides of the EMI gasket. In employing such a weather seal, care must be exercised to insure that the weather seal will be effective throughout the life of the equipment.

The problems of corrosion came to national attention when G. Roessler[3] published his paper, "Corrosion and the EMI/RFI Knitted Mesh Gasket." In the paper Mr. Roessler presents a description of the corrosion process, the problems associated with gasketed joints and figures which illustrate the effects of corrosion which the use of wire mesh have on gasketed joints. Figures A1, A2, and A3, in the appendix, illustrate some of the detramental effects which Roessler attributed to a wire mesh gasketed joint when exposed to a salt spray environment. The contents of the figures illustrate that the dc resistance of the mesh gaskets under test was reduced by more that 200%, the change in deflection capability degraded by as much as 30%, and the shielding quality of a joint degraded by as much as 55 dB.

Earl Groshard[4,5] has spent a considerable amount of time and effort documenting the results of work he has been involved with as a member of the professional staff at Boeing. Tables A1 and A2 in the appendix illustrate some of the more important results he has presented to us. The contents of Table A1 illustrates the change in dc resistance of joint materials which have been exposed to a controlled moisture soak. The point he is making is that a change in dc conductivity of joint materials can take place with time. Since this change can cause a detramental effect on the shielding quality of a joint, such a change should be considered in selecting the finish plating for the joints when shielding is a criteria. The contents of figure A2 contains a list of plated base materials and commonly used gasket materials, where the compatibility of the subsequent joint is graded as a function of various environmental conditions. The contents of table A2 is basically concerned with a conductive joint and a combination of materials which will not create a significant galvantic cell when exposed to various environmental conditions.

Spira Manufacturing Corporation[6] has been involved in a significant level of testing. The purpose is to better understand the effects of corrosion on a gasketed joint where the end result is to assist engineers to select the proper gasket with regard to cost, shielding quality and the environmental requirements. Firgures A4, A5, and A6, in the appendix, illustrate results of rf transfer impedance tests which were reported at the 1978 IEEE, EMC Symposium. The most important findings illustrated in the figures is that

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*In the subcontractor specification requirements on the F-18 aircraft. McDonnell Aircraft Company stipulates that dissimilar metal EMI gasketed joint combinations such as silver, monel or silver filled to the aluminum structure shell be avoided. In addition, it is stipulated that all gasketed joints shall incorporate a weather seal on the exterior side of the EMI gasketed seal.

the transfer impedance of the tin plated Spira gasket is approximately the same irrespective of the joint surface material finsihes which were under evaluation. This implies that the dc resistance (which varied greatly between the samples) is not the most critical parameter with regard to the shielding quality of a joint (i.e., The physical joint consists of a resistance in parallel with a capacitance. The results of the tests illustrate that the capacitive reductance above 100 kHz can be the critical parameter).

## TESTING

The testing as illustrated herein was performed to gain a greater insight into the effect which corrosion has on gasketed joints when the SPIRA gaskets are used as the EMI (conducting) seal. The purpose was to assist in defining the type of gasket material and method of implementing the gasket as a function of the environment and the level of required shielding quality.

There were 3 different types of gaskets used in the testing. These types were as follows:

1. Tin Spira (Tin plated beryllium copper where the edge surfaces were unplated).
2. S-Tin Spira (Tin plated beryllium copper where the edge surfaces were plated).
3. SS Spira (301 stainless steel).

Additionally, the S-Tin Spira and the SS Spira gasket materials were held in place on one of the joint surfaces with a copper filled conductive epoxy.

These 5 different gasket conditions were paired with 5 different joint materials. These joint materials were:

1. 2024 aluminum.
2. Iridite plated 2024 aluminum.
3. Nickle plated 2024 aluminum.
4. Cadmium plated 2024 aluminum.
5. Tin plated 2024 aluminum.

The testing consisted of subjecting the 25 different combinations of gasketed joints to moisture and salt spray environments. The moisture soak was conducted per MIL-STD-202E[7] and consisted of exposing gasketed joints to a 95% relative humidity environment (while varying the temperature) for 240 hours. The salt spray was conducted per MIL-STD-810B[8] and consisted of exposing gasketed joints to a 5% salt spray environment for a period of 96 hours. The gasketed joints were tested for dc resistance prior to and at the conclusion of the environmental soak.

The gasketed joints consisted of 2 inch long base materials separated by EMI gasket material one (1) inch long and approximately 1/8 inch in diameter, held together with nylon screws.

The hypothesis upon which the testing was performed was that a change in the dc resistance was directly related to the level or corrosion experienced in the joint. The joint material surfaces and gasket conditions were selected to obtain specific information. The joint material surfaces were selected for the following reasons:

1. Iridited aluminum was selected because it is the surface material most commonly used by the aerospace industry when shielding is a consideration. Because the iridite surface plating deteriates quite rapidly with use, untreated aluminum was also tested.
2. Nickle and cadmium platings are commonly used on aluminum when shielding is a consideration and iridite is not considered sufficiently durable.
3. Many aerospace companies are turning to the tin plating of shielded surfaces where corrosion and shielding (and/or bonding) are both significant considerations.

The gaskets and gasket conditions were selected for the following reasons:

1. The Tin SPIRA and SS SPIRA materials are manufactured from materials presently available in our catalog.
2. The beryllium copper material used in the manufacture of the Tin SPIRA gasket is plated in wide widths and then slit ot size leaving the edges of the material unplated. The S-Tin SPIRA material which was tested was plated after being slit.
3. The copper filled ocnductive epoxy was tested to determine if the use of the epoxy to hold the gasket materials in place would result in detramental effects to the joint.

## RESULTS

The results of the testing are illustrated in Table 1.

A cursory visual inspection of the joints was also performed at the conclusion of the testing. It was noted that the materials which were subjected to the moisture test did not show significant signs of corrosion. This was true for the overall plates as well as the gasketed surfaces and gasket material.

The plates which were subjected to the salt spray test did show significant levels of corrosion, where the corrosion existed on the plates as well as the gasketed surfaces. The one exception was when the S-Tin SPIRA gasket was used. The visual corrosion at the joint surfaces was not considered significant when the S-Tin SPIRA gasket was in contact with the aluminum surfaces and the Iridited, Nickle and Tin plated surfaces.

## CONCLUSIONS

The conclusions which can be reached as a function of the testing with regard to the objectives are as follows:

1. The Tin SPIRA gasket material is as corrosion resistant as the S-Tin SPIRA gasket material when in contact with the aluminum and the iridite and nickle plated joint surfaces in the presence of moisture.
2. The S-Tin SPIRA Gasket should be employed if the joint is not weather sealed and is exposed to a salt environment.
3. Significant detramental effects were not in evidence when the gaskets were held in place with the copper filled conductive epoxy and subjected to the moisture environment.
4. The S-Tin SPIRA gasket used between the tin plated joint surfaces did not show a significant change of resistance while subjected to either the moisture or salt spray environments.
5. The shielding characteristics all three (3) of the tin plated gaskets after being subjected to the moisture and salt spray environments would be expected to be superior to the shielding characteristics of the stainless steel gaskets prior to being subjected to the moisture and salt spray environments when in contact with all of the surface materials under test.

## RECOMMENDATIONS

A gasketed joint can be protected from the detramental effects of corrosion due to moisture and salt spray by the proper selection of the gasket and the proper selection of plating on the joint material surfaces. This selection and subsequent cost can be quite varied, where the specific gasket and joint surfaces to

TABLE 1. DC RESISTANCE TEST RESULTS ON GASKETED JOINTS

| Gasket Material | JOINT SURFACES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2024 Aluminum | | Iridite Plated 2024 Aluminum | | Nickle Plated 2024 Aluminum | | Cadmium Plated 2024 Aluminum | | Tin Plated 2024 Aluminum | |
| | Resistance (milliohms) | | Resistance (milliohms) | | Resistance (milliohms) | | Resistance (milliohms) | | Resistance (milliohms) | |
| | Before | After | Before | After | Before | After | Before | After | Before | After |
| | Temperature-Humidity Soak per MIL-STD-202E (240 hrs @ 95% Relative Humidity) | | | | | | | | | |
| Tin SPIRA | 2 | 35 | 3.5 | 90 | 0.9 | 4.8 | 0.5 | 45 | 0.3 | 2.4 |
| S-Tin SPIRA* | 0.8 | 50 | 1.7 | 60 | 0.9 | 6.8 | 0.2 | 2.4 | 0.1 | 0.2 |
| S-Tin SPIRA | 0.2 | 7.5 | 2.9 | 190 | 0.7 | 4.1 | 1.0 | 1.5 | 0.15 | 0.3 |
| SS SPIRA* | 35 | 1000 | 370 | 370 | 10 | 20 | 40 | 2000 | 40 | 180 |
| SS SPIRA | 60 | 190 | 250 | 2500 | 2.7 | 3.0 | 200 | 2000 | 15 | 1000 |
| | Salt Spray Test per MIL-STD-810 B (96 hrs @ 5% Salt Solution) | | | | | | | | | |
| Tin SPIRA | 1.0 | 70 | 3.6 | 90 | 0.5 | 1.9 | 0.2 | 30 | 0.2 | 4 |
| S-Tin SPIRA* | 0.4 | 17 | 1.3 | 90 | 0.8 | 1.0 | 0.15 | 0.3 | 0.1 | 0.3 |
| S-Tin SPIRA | 0.25 | 60 | 3.3 | 25 | 0.6 | 3.4 | 0.8 | 10 | 0.15 | 0.2 |
| SS SPIRA | 50 | 2500 | 90 | 1800 | 8.0 | 28 | 20 | 290 | 19 | 270 |
| SS SPIRA | 20 | 2000 | 250 | 2200 | 2.7 | 800 | 150 | 1200 | 12 | 20 |

*Secured to one of the joint surfaces with Copper filled conductive epoxy.

be used depend upon the level of shielding required, and the environment which the joint will be subjected to.

A weather seal is always recommended on the exterior side of the EMI seal when the joint is to be exposed to a salt or a high moisture environment. The purpose of the weather seal is to keep the salt and the moisture away from the joint.

Table 2 illustrates recommended gasketed materials and joint surface platings as a function of the environment and level of desired shielding. These recommendations are based upon the testing contained herein and the information reference in the appendix.

Spira Manufacturing Corporation manufactures two different types of gaskets which are designed to provide for a positive moisture seal, and are called "SPIRA COMBO" gaskets. Figure 1, illustrates the "Basic" Spira Combo gasket where the gasket is designed to be employed between flat joint surfaces. The gasket can be used where the unevenness of the joint is as much as 1/32 inches. As is illustrated, the gasket can be held in place with an adhesive backing. The adhesive backing used is solvent activatable and is not placed under the "O" ring moisture seal. The solvent activated adhesive tape is used for its superior strength and life. The adhesive is not placed under the moisture seal to insure a positive seal.

Figure 2 illustrates our "D" Spira gasket. The gasket was developed in conjunction with the engineering staff at the Librascope Division of the Singer Company. The specific concern in the design was to provide for a positive weather and EMI seal that has a long life and can be easily replaced in the field. As is illustrated, it is recommended that the gasket be retained by the groove.

When space does not permit the use of a weather seal, the Spira Shield gaskets can be used per the recommendations of table 2. When the environmental requirements include salt spray, placing the gasket in a groove as illustrated in figure 3 is recommended. If the required environment only includes moisture then the gasket can be contained in a groove as illustrated in figure 4, where a copper filled conductive epoxy can be used to hold the gasket in place.

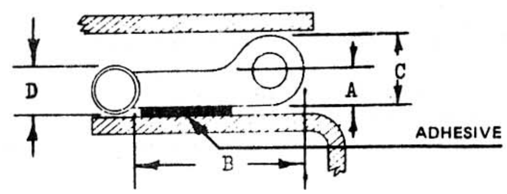



Figure 1. BASIC SPIRA COMBO GASKET

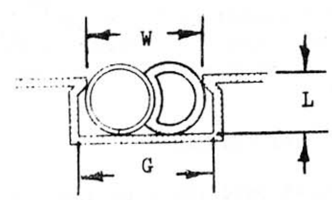
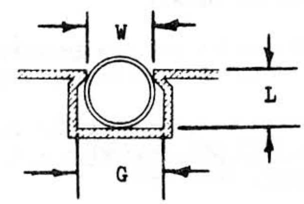
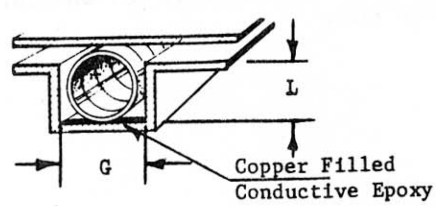



Figure 2. "D" SPIRA COMBO GASKET




RECOMMENDED INSTALLATION FOR SPIRA SHIELD GASKET

Figure 3




ALTERNATE RECOMMENDED INSTALLATION FOR SPIRA SHIELD GASKET (Moisture Environment Only)

Figure 4

Table 2. RECOMMENDED GASKET MATERIALS AND JOINT SURFACE PLATINGS

| Level of Shielding (Transfer Impedance) | ENVIRONMENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | MOISTURE | | | | SALT SPRAY | | | |
| | With Weather Seal | | Without Weather Seal | | With Moisture Seal | | Without Moisture Seal | |
| | Gasket Mtl. | Joint Surfaces[1] | Gasket Mtl. | Joint Surfaces[1] | Gasket Mtl. | Joint Surfaces[1] | Gasket Mtl. | Joint Surfaces[1] |
| Superior- ($3X10^{-6}$ ohm meters-160 dB below 377Ω) | Tin Spira | Tin[2] | Tin Spira[3] | Tin[2] | Tin Spira | Tin[2] | S-Tin Spira | Tin |
| Excellent- ($10^{-4}$ ohm meters-130 dB below 377Ω) | Tin Spira | Iridite,[4] Cadmium or Tin | Tin Spira[3] | Iridite,[4] Cadmium or Tin | Tin Spira | Iridite,[4] Cadmium or Tin | S-Tin Spira | Tin |
| Good- ($3X10^{-3}$ ohm meters-100 dB below 377Ω) | Tin Spira | Iridite, Cadmium, or Tin | Tin Spira[3] | Iridite, Cadmium, or Tin | Tin Spira | Iridite Aluminum, Cadmium, or Tin | S-Tin Spira | Tin |
| | -or- | | -or- | | -or- | | | |
| | SS Spira | Nickle | SS Spira[3] | SS Spira | SS Spira | Nickle | | |

NOTES:

(1) Based upon Earl Groshard's information (Table A1 in appendix).
(2) It is probable (based upon the contents of figures A4, A5 & A6,) that Iridite and Cadmium will offer this level of shielding quality as well as Tin.
(3) The gasket can be held in place with a copper filled conductive epoxy.
(4) The results indicate that unplated aluminum can be used, however this in never recommended.


## ACKNOWLEDGEMENT

Grateful acknowledgement ot C. Nelson[9] of the Librascope Division of Singer for perfoming the moisture and salt spray test on the gasketed joints whose results are described herein.


## REFERENCES


1. Mil-E-16400, General Specification for Electronic Interior Communication and Navigation Equipment.

2. Mil-Std-889, Dissimilar Metals.

3. Roessler, G.D., "Corrosion and the EMI/RFI Knitted Wire Mesh Gasket," Frequency Technology, March 1969.

4. Groshart, E., "Corrosion Control in EMI Design," Proceedings of the 1977 EMC Symposium and Exhibition, Montreux, Switzerland, July 1977.

5. Groshart, E., "Corrosion Control in EMI Design," Proceedings of the 1975 IEEE International Symposium, on Electromagnetic Compatibility, San Antonio, Texas, October 1975.

6. Kunkel, G., "Corrosion Effects on Field Penetration through Aperatures," Proceedings of the 1978 IEEE International Symposium on Electromagnetic Compatibility, Atlanta, Georgia, June 1978.

7. Mil-Std-202E, Test Methods for Electronics and Electrical Component Parts.

8. Mil-Std-810B, Environmental Test Methods.

9. Nelson, C.R., "Environmental Test Report of EMI Gasket Assemblies," Test Report Number 9-0810, Librascope Division of Singer, May 1979.

APPENDIX

The contents of this appendix consists of Figures A1, A2, A3, A4, A5, and A6, and Tables A1 and A2. The information so contained is described in the text and is reprinted or extracted from the reference articles by permission of the authors or publishers as appropriate.

Table A1. RESISTANCE MEASUREMENTS OF SELECTED MATERIALS

| Material | Finish | Resistance (Milliohms) | | |
|---|---|---|---|---|
| | | Initial | At 400 hr 95% RH | At 1000 hr 95% RH |
| Alum | | | | |
| 2024 | clad/clad | 1.3 | 1.1 | 2.0 |
| 2024 | clean only/clean only | 0.11 | 5.0 | 30.0 |
| 6061 | clean only/clean only | 0.02 | 7.0 | 13.0 |
| 2024 | light chromate conversion/same | 0.40 | 14.0 | 51.0 |
| 6061 | light chromate conversion/same | 0.55 | 11.5 | 12.0 |
| 2024 | heavy chromate conversion/same | 1.9 | 82.0 | 100.0 |
| 6061 | heavy chromate conversion/same | 0.42 | 3.2 | 5.8 |
| Steel | | | | |
| 1010 | cadmium/cadmium | 1.8 | 2.8 | 3.0 |
| 1010 | cadmium-chromate/same | 0.7 | 1.2 | 2.5 |
| 1010 | silver/silver | 0.05 | 1.2 | 1.2 |
| 1010 | tin/tin | 0.01 | 0.01 | 0.01 |
| | | | | |
| Copper | clean only/clean only | 0.05 | 1.9 | 8.1 |
| Copper | cadmium/cadmium | 1.4 | 3.1 | 2.7 |
| Copper | cadmium-chromate/same | 0.02 | 0.4 | 2.0 |
| Copper | silver/silver | 0.01 | 0.8 | 1.3 |
| Copper | tin/tin | 0.01 | 0.01 | 0.01 |
| | | | | |

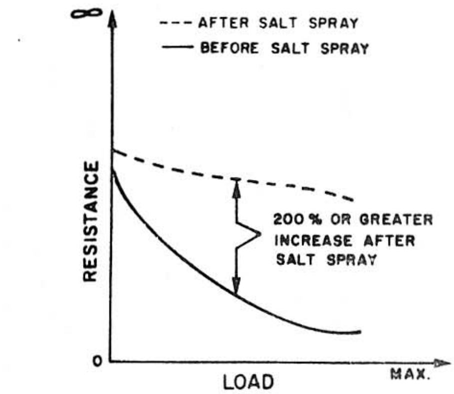



Figure A1. TYPICAL CONTACT RESISTANCE CURVE FOR WIRE GASKETS UNDER TEST

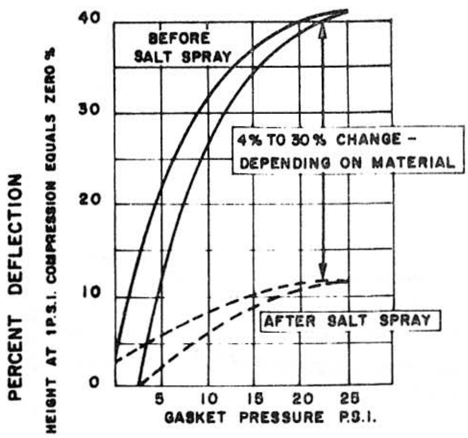
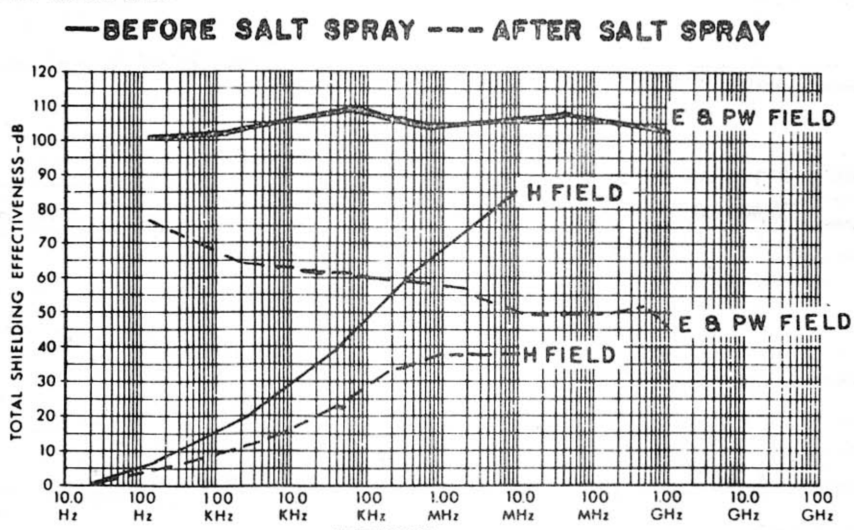



Figure A2. TYPICAL % DEFLECTION CURVE FOR THE WIRE MESH GASKETS UNDER TEST




Firgure A3. TYPICAL ATTENUATION CHARACTERISTIC CURVE FOR THE WIRE MESH GASKETS UNDER TEST

## TABLE A2-DISSIMILAR MATERIALS

| GASKET MATERIALS | MATERIALS: Aluminum Clad, 1000 3000, 5000 6000 Series Casting 356 | | | | | | | | Aluminum 2000,7000 Series | | | | | | | | Carbon and Alloy Steel AISI-410 | | | | | | | | | Corrosion Resistant Steels | | | High Nickel and PH Steels | | | Copper Alloys | | | | Miscellaneous | | | | Titanium | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FINISHES | None | Mil-C-5541 Class 1A | Mil-C-5541 Class 3 | Electroless Nickel | Cadmium Plated Bare | Cadmium Colored Chromate | Cadmium Clear Chromate | Chromium | Mil-C-5541 Class 1A | Mil-C-5541 Class 3 | Electroless Nickel | Cadmium Bare | Cadmium Colored Chromate | Cadmium Clear Chromate | Chromium | Tin | Cadmium Bare | Cadmium Colored Chromate | Cadmium Clear Chromate | Nickel | Electroless Nickel | Chromium | Tin | Lead | Silver | Passivated | Cadmium (Passivated) | Tin | Passivated | Cadmium (Passivated) | Tin | Tin | Silver | Gold | Solder (Lead-Tin) | Silver Paint | Zinc Paint | Silver Adhesive | Carbon Adhesive | None | Nickel |
| Aluminum | A | A | A | D | A | A | A | A | A | A | D | D | A | A | A | A | A | A | A | D | D | A | A | D | X | C | A | A | C | A | A | A | X | X | A | X | X | D | D | D | D |
| Tin Plated | A | A | A | D | A | A | A | A | A | A | D | A | A | A | A | A | A | A | A | D | D | A | A | A | A | A | A | A | A | A | A | A | A | A | A | D | A | D | D | D | D |
| Monel | C | D | D | A | D | D | D | A | D | D | A | D | D | D | A | D | D | D | D | A | A | A | A | D | A | A | D | A | A | D | A | A | D | D | A | D | D | D | D | A | A |
| Silverelastomer | E | C | C | D | C | C | C | A | C | C | D | E | C | C | A | A | C | C | C | D | D | A | A | X | A | D | E | D | D | E | D | D | A | A | D | A | X | A | A | D | D |
| Stainless Steel | C | C | C | A | C | A | A | A | D | C | A | D | A | A | A | A | C | A | A | A | A | A | A | D | A | A | D | A | A | D | A | A | A | A | A | A | X | A | D | A | A |
| Beryllium Copper | C | C | C | D | C | C | C | D | C | C | D | C | C | C | D | C | C | C | D | D | D | C | C | D | D | C | C | D | C | C | C | C | C | C | C | D | C | C | C | C | C |

LEGEND/NOTES

A-Compatible.
B-Requires sealing only if exposed to salt atmosphere or high humidity. Edge priming may be satisfactory.
C-Requires sealing if exposed to humid environment.
D-Compatible in environment of controlled temperature and humidity only.
E-Requires sealing regardless of exposure.
X- Not usable.

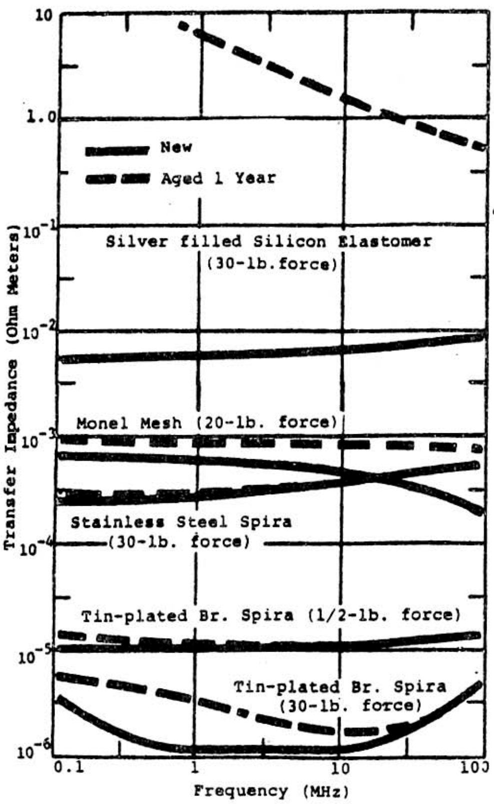



Figure A4. TRANSFER IMPEDANCE TEST RESULTS USING IRIDITED ALUMINUM PLATES

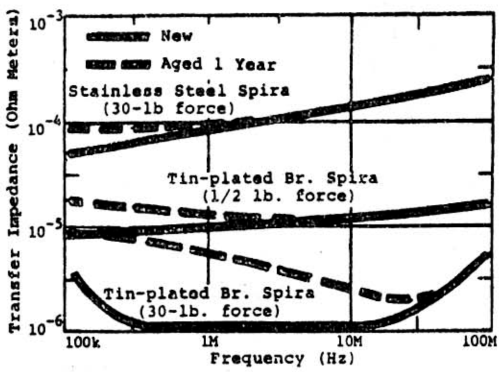



Figure A5. TRANSFER IMPEDANCE TEST RESULTS USING TIN PLATED ALUMINUM PLATING

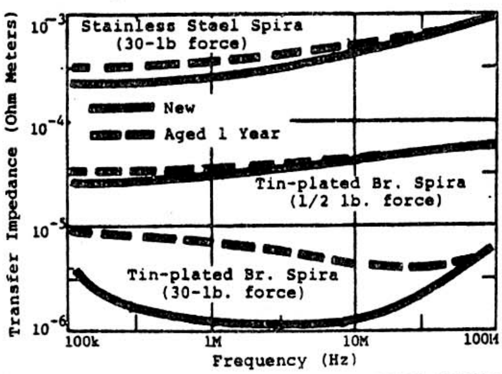



Figure A6. TRANSFER IMPEDANCE TEST RESULTS USING CADMIUM PLATED ALUMINUM PLATES