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EMI/RFI GASKETING FOR TACTICAL SHIELDED SHELTER DOOR SEAM APPLICATIONS

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ABSTRACT

Tactical shielded shelters which provide electromagnetic interference/ electromagnetic pulse (EMI/EMP) protection for enclosed electronic equipment typically degrade in shielding performance, often after only 3 or 4 months of exposure to the field environment and normal use. This study determines the specific causes of this degradation, provides recommendations for field maintenance of existing shielded shelters, and assesses design and materials improvements that can be incorporated into the manufacture of next-generation shielded shelters. The study emphasizes the performance and electrical degradation properties of available EMI gasket materials and their mating surfaces used to electrically seal tactical shelter personnel access doors.

PREFACE

This report covers the work performed under Air Force MIPR Nos. FY 1457-81-N0016 and FY 7620820006. The work was administered under the direction of the Systems Support Division, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio. Mr. John Rhodehamel (AFWAL/MLSE) was the Program Project Engineer.

The Principal Investigator for this project was 1LT Bruce L. Cain, Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL). Supervisory and technical assistance was provided by Mr. Ray McCormack, Mr. Paul Nielsen, Mr. Roy Axford, and Dr. William Croisant of CERL-EM. Laboratory testing and instrumentation assistance was provided by Messrs. Gregory Cekander, John Clements, Michael McInerney, and Matthew Sale of CERL-EM.

Dr. R. Quattrone is Chief of CERL-EM. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

SECTION VI

CONCLUSIONS

Research conducted during this investigation has produced the following conclusions:

1. The causes of EMI shielding degradation along the gasketed door seams of tactical shielded shelters can be broadly categorized in the areas of materials selection, design, quality control, and maintenance.

a. The knitted wire mesh gasket material presently installed in the EMI gasket channel generally exhibits poor plating quality; this allows microscopic exposure of both the underlying copper cladding and the steel core. When moisture is present, this material has a high potential to self-corrode in the form of iron oxide (rust) and tarnish. The coated aluminum mating surfaces admit aluminum and aluminum oxide to the electrical interface between the EMI gasket and the mating surface, due either to abrasion of an alodine/iridite coating or to porosity and wear of a flame-sprayed tin coating. When exposed to moisture, iron, copper, and aluminum exhibit excessive galvanic corrosion actions which introduce corrosion products and insulating aluminum oxide buildup into the electrical contact area. At locations of low contact forces, these surface contaminants directly cause the observed shielding degradation. Upon exposure to the corroding metals, the EMI gasket elastomer undergoes an accelerated aging process which is manifested as elastomer memory degradation and subsequent "effective compression set." This compression set reduces local closure forces which further degrade the electrical continuity of the EMI gasket/mating surface interface. In certain combinations of moisture, corrosion action, and compression set, the shielding degradation can be severe at isolated locations along the EMI gasketed seam of the door.

b. The design of the gasketed channel and its mating surface is not optimized to facilitate moisture evaporation and/or drainage away from the electrical contact area. Hence, moisture retention at the seam enhances the effects discussed in Conclusion 1.a. above.

c. The problem of corrosion potential associated with the tin/copper/steel type mesh gasket actually depends more on quality control than on materials and design. Other tested knitted mesh materials showed acceptable tin-plating quality and good corrosion protection. Without effective quality control and quality assurance practice by the gasket manufacturer, any EMI gasket that depends on a plated surface for corrosion protection could introduce this problem to the gasketed seam. Another area of poor quality control is the installation and adjustment of the shielded door by the shelter manufacturer. The difficulty encountered in latching and closing many tactical shelter doors is indicative of improperly adjusted latching mechanisms, which leads to poor control of door closure force tolerances. These types of inadequate quality control can produce significant variations in shielding performance among shelters of similar construction.

d. Failure to perform necessary maintenance/cleaning procedures on the gasketed door seam is potentially a significant cause of shielding degradation. The magnitude of this degradation depends on shelter door use and location, and is therefore not generally quantifiable. However, it is concluded that without regular maintenance, the buildup of metal oxides, adsorbed atmospheric pollutants, dust, and field debris will contribute to shielding degradation, even for the best designs/materials used in the door seam construction. This buildup introduces a nonconductive film between the electrical contact materials which can often severely degrade the door seam shielding capability.

2. The solutions to the shielding degradation problems can also be generally placed in the categories of materials selection, design, quality control, and maintenance.

a. Tin-plated mating surfaces will provide the best overall performance for door gasket and mating surface applications, except in the sliding contact configuration with fingerstock. A corollary to this conclusion is that the tin-plating must be of acceptable quality and thickness (see Section V). It is not possible to recommend a particular EMI gasket, since the gasket system selected depends on how well maintenance can be performed. In this context, fingerstock may be ruled out, since its effective mechanical operation (i.e., sliding contact) is strictly dependent on adequate lubrication and cleaning in a field environment. Also, fingerstock requires precise door closure alignment to prevent finger breakage.

The tin-plated spiral gaskets performed very well, both mechanically and electrically. With lubrication, their electrical contact quality was equivalent to or better than that of sliding contact fingerstock, and even in the unlubricated or dry contact condition, it was much better than that of the mesh gasket. Also, the spiral gasket material performed well in corrosion testing due to its high-quality tin-plating. Two drawbacks to the immediate use of spiral gasketing are:

(1) The effective cleaning of a "captivated gasket" channel to remove dust, etc., will require partial disassembly of the channel in the field.

This could be eliminated by soldering the gasket to the channel; however, this introduces replacement complications.

(2) The spiral gasket and mating contact edge have not been fully optimized in a marketed door gasket configuration. Although the design tested in this investigation performed well, further developmental design would be required before incorporation into a shelter seam.

Although the knitted mesh gasket material performed poorly in most of the testing because of poor tin-plating, it is still a viable candidate for use, if a good quality of tin-plating can be assured. The use of a steel core in the mesh wire for better permeability is not required, since the shelter is made from nonpermeable aluminum. With this consideration, it is concluded that the tin-plated phosphor bronze mesh material, which showed good tin-plate quality, is a better choice than tin/copper/steel for the wire material. A better choice of elastomer for the mesh gasket should also be made. The "hollow D" concept using solid silicone (Section V) should reduce the compression set problem. Since the "hollow D" elastomer with tin-plated phosphor bronze mesh was not actually tested in this study, further verification should be completed before its use in shelters is formally adopted.

The electrical mating surfaces of the door seam also need surface finish improvements. Testing revealed that arc-sprayed tin can be directly applied with good adhesion to aluminum, and that it provides a good mating surface for mesh-gasket-type materials. For mating to spiral gasket or fingerstock, a fused or "reflowed" tin surface is preferable. Shelters already using flame-sprayed tin mating surfaces should be checked to insure that the coating thickness is adequate. To minimize the porosity effects of arc- and flame-sprayed materials, a minimum of 10 mils thickness should be applied. It was found that alodine/iridite coating surfaces are generally too susceptible to abrasion to be effective as a door gasket mating surface coating.

b. Several door seam and shelter modification design concepts could easily be added to current shelter designs to reduce gasket environmental exposure. Even without material changes in existing shelter designs (i.e., new gasket and mating surface finishes), the reduction of moisture retention at the gasket could reduce the degradation problem.

c. A major contributor to the shielding degradation problem is lack of adequate quality control in several areas. It is recommended that an effective quality control and assurance program be instituted and enforced within the context of shelter procurement. Much of the degradation problem can be eliminated by refusing to accept shelters with poor quality gasketing, improperly fitted doors, etc. Shielding effectiveness acceptance testing alone will not assure sustainable shielding performance.

d. After materials and design improvements have been made in the shelter construction details, some routine door seam cleaning and maintenance will still have to be done in the field. The frequency and methods for this maintenance will depend on:

(1) Shelter location

(2) Shelter use

(3) The types of improvements actually made in design and materials of the door seam.

Therefore, specific maintenance routines are not proposed. The outline given in Table 2 applies to mesh-gasketed seams that are susceptible to corrosion (i.e., most of the shelters already fielded). In any case, a nominal cleaning frequency of once per week should be sufficient to keep down the dust accumulated during normal use. More detailed maintenance procedures should be developed after the three maintenance stipulations listed above have been specified.

3. Conducting the various testing approaches for EMI gasket performance quantification has produced the following general conclusions.

a. CW shielding effectiveness testing is of limited use in gasket developmental and comparison testing because the results quantify the performance of an entire assembly and not just the gasket. However, in verifying performance of the final design, it would be useful if the test panels are similar in construction and materials to those used for tactical shelters. The best frequencies for comparison testing of good gasketed systems are 100 kHz to 200 kHz, magnetic, using coaxial- and coplanar-loop antenna orientations.

b. Transfer impedance testing is an effective way to directly compare gasket current transport properties at frequencies of interest in EMI/EMP protection. However, it is important that the test fixture have a characteristic device impedance near 50 Ω to be compatible with most test instrumentation. The test fixture used in this study did not possess this characteristic, and the transfer impedance was therefore much harder to determine. Although the transfer impedance plots presented are known to deviate ± 10 percent from the actual value at certain frequencies, it is believed that the amount and direction of this deviation is the same for all gaskets tested. Therefore, comparison of transfer impedance performance for different gasket materials is valid within the context of this limitation.

c. The use of simulated door closure testing is very important in comparing door gasket performance. Although only DC resistance measurements were used to characterize wear and corrosion changes on the gaskets, the supplemental visual observation of the gaskets under cyclic loading gives a good indication of gasket durability that cannot be obtained from electrical testing alone. For instance, physical damage to the gasket and mating surface can often produce better electrical performance readings, even though this damage reduces long-term performance capability.

d. An area of concern not fully assessed in this study is the effect of different current levels to obtain gasket comparison data. For instance, some gasket materials may perform well under low level (10 mA) DC current testing, but can be degraded after conducting an EMP level pulse current. Also, current levels above 1 amp (DC or AC) may produce localized "joule heating" at surface asperity contacts, thereby altering the surface's ability to conduct low-level currents or subsequent EMP currents. This concern is analogous to the correlation of CW vs. EMP shielding effectiveness testing. For instance, the nature of current flow from an EMP is drastically different from that generated using loop antennas in MIL-STD-285 testing. From theoretical considerations the "optimum current levels" for EMI gasket testing could be determined. This is important because the current levels used can affect the results.

4. Of immediate interest is the refurbishment of the many tactical shielded shelters now in use, which are experiencing various levels of shielding degradation as a result of aging effects at the gasketed door seam. Based on the results of this study and the fact that most fielded shelters are designed to accept mesh gasketing in the door channel, the following refurbishment method is proposed:

a. Remove old mesh gasket material.

b. Grit-blast the gasket channel and door mating surfaces to remove old coating material and to expose the aluminum surface.

c. Clean the blasted surfaces with trichloroethane base solvent and allow them to dry.

d. Apply arc-sprayed tin to channel and door mating surfaces (10 mils).

e. Install new EMI mesh gasket material.*

f. Adjust door closure tolerances as needed.

This process could also be done using flame-sprayed tin over a bond coat. This outline is provided as a refurbishment starting point. Other gasketing materials or methods of tin-plating could be used. The important parameter is the quality of the final tin-plated surfaces.

* A three-cover tin-plated phosphor bronze mesh material over the usual type of closed-cell silicone sponge elastomer would work well enough, assuming good tin plating is present. A "hollow D" elastomer may not work in this refurbishment, since the mating surfaces are designed for a rectangular sponge material.

5. The following comment concerns new technologies now becoming available for commercial application of surface finishes. Most of the tin-plating methods discussed in this report are susceptible to both wear and fretting at dry contact. Vacuum plasma deposition, chemical vapor deposition, ion plating, ion implantation, and many post-plating heat treatment techniques (e.g., surface laser fusion) have high potential for providing enhanced metal surface properties (particularly wear and corrosion protection). Tin-plated surfaces applied by traditional methods will eventually require replating because they will be susceptible to wear. The new coating methods offer potential for conductive surfaces with extremely low maintenance requirements. By reducing the maintenance requirements for the gasketed door seam, long-term shielding protection can be better assured.

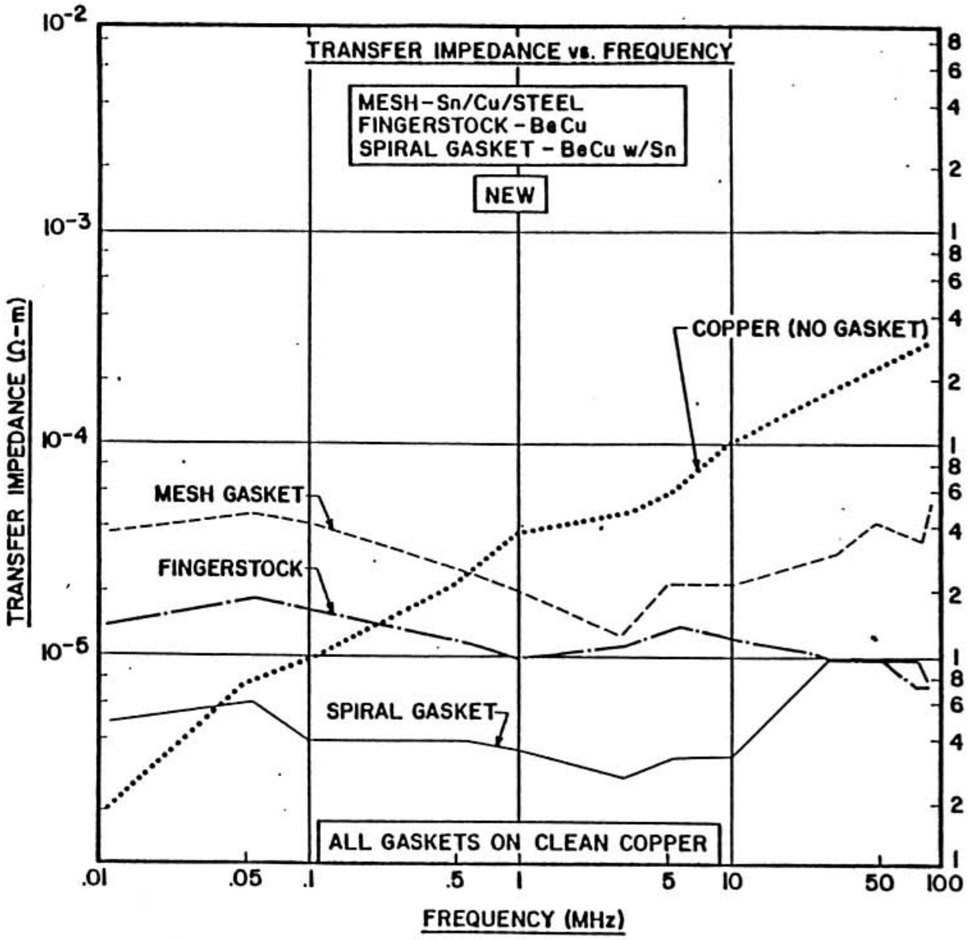

Figure 36. Gasket "Type" Comparisons: Transfer Impedance (New).

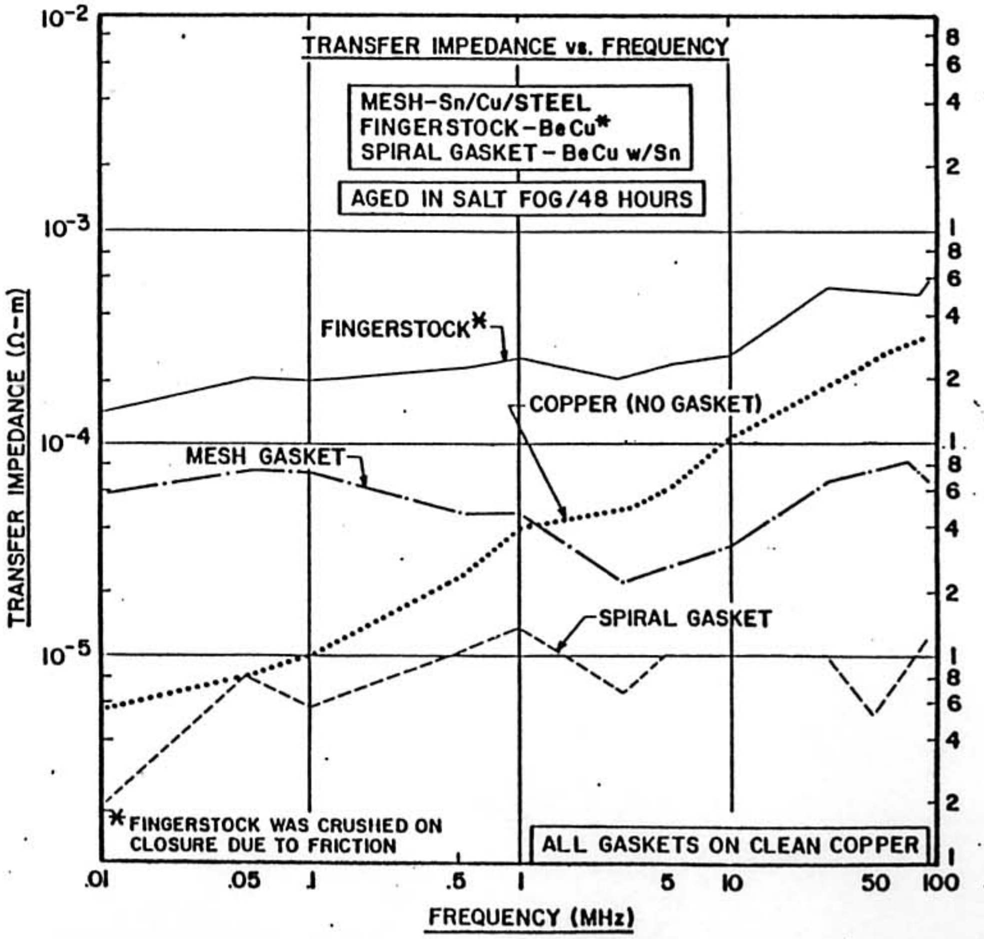

Figure 37. Gasket "Type" Comparisons: Transfer Impedance (Aged).

4.5 SUMMARY OF TESTING TRENDS

a. Mesh gasket material.

(1) Effective compression set and resultant loss of closure force is a significant degradation factor.

(2) Poor quality of tin-plating (tin/copper/steel) leads to variable but high corrosion potential with moisture.

(3) Good tin-plated surfaces were found on tin-plated phosphor bronze mesh.

(4) Application of conductive lubricant to the mesh improves corrosion behavior and electrical contact quality.

(5) CW shielding effectiveness is good in the new condition, but is very susceptible to short-term excessive degradation with aging (Reference 4).

(6) "Shelter mesh" was electrically inferior to "other" tin/copper/steel mesh and more susceptible to extensive rusting.

b. Fingerstock material (bare beryllium copper)

(1) Low closure force, good electrical performance, and excellent contact resistance stability under sliding contact were observed.

(2) Bare gasket surface is preferrable to tin-plated surface for reducing sliding friction.

(3) Corrosion performance may be highly dependent on the beryllium copper alloy and temper; in most corrosion testing, behavior was adequate, and was very good in the lubricated condition.

(4) The mating surface is prone to moderate wear at finger edges, and is susceptible to extreme wear in the unlubricated condition.

(5) Lubrication is mandatory to prevent rapid finger wear and breakage.

(6) CW shielding effectiveness is excellent in the new condition and sustainable with normal lubrication and cleaning to remove wear particles (Reference 4).

c. Spiral gasket material.

(1) Low closure forces and excellent electrical performance were observed, with good contact resistance stability when lubricated. In the unlubricated condition, fretting of the tin-plate may occur under low closure forces.

(2) Tin-plated surfaces showed little or no wear in direct contact design.

(3) Excellent corrosion protection is provided by the superior tin-plated gasket surface.

(4) CW shielding effectiveness is good, but long-term sustainability was not directly verified.