THE STABILITY OF SILVER-GLASS FILLED EMI GASKETING: AN EVALUATION

Silver-glass filled EMI shielding gaskets are stable during severe vibration and electromagnetic pulse.

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INTRODUCTION

Ostensibly the military specification MIL-G-83528 (General Specification for EMI/RFI electrical, elastomer shielding gaskets) reflects the current "state of the art" in the manufacture of both EMI gasketing and conductive fillers. It lists different conductive particle-filled compounds and compares their respective performance capabilities in sixteen separate categories. However, conspicuously absent from the list of approved conductive compounds are those filled with silver-coated solid glass spheres.

This article details the results of independent testing on silicone elastomers filled with silver-glass, silver-copper and silver-aluminum particles. Evaluations were conducted in the areas of electrical stability under vibration, electromagnetic pulse survivability (EMP), and thermal aging stability.

The proven EMI shielding performance and cost benefits of silver-coated solid glass spheres for both commercial and military applications have been recognized since the early 1970's. There are, however, sectors of the military EMI community which have not used silver-glass filled EMI gasketing materials apparently based upon test results conducted in 1977[1] on vibration stability and 1981[2] on EMP survivability.

In the 1977 test, a silicone gasket containing an unspecified type of silver-coated glass sphere filler was compared to a gasket containing a silver-coated copper filler. Test results showed the resistivity of the silver-glass gasket was considerably less stable than that of the silver-copper gasket; over the decade since this test was conducted, EMI shielding technology has advanced considerably. In fact, the silver-copper gasket used in the 1977 test would be unstable by today's standards.

Earlier this year an independent testing facility using equipment and procedures approved by the Defense Electronics Supply Center (DESC) tested military specification grade silver-glass, silver-copper, and silver aluminum filled gaskets for stability during severe vibration and intense simulated EMP. The results of this independent study indicate that in both environments, today's advanced silver-glass gaskets are as stable as gaskets filled with silver-copper or silver-aluminum conductive particles. Even so, silver-glass is not yet an approved conductive compound for military specification applications.

In addition to offering shielding effectiveness comparable to other silver-plated particles, modern silver-coated glass spheres offer the advantages of low cost, light weight, and exceptional thermal aging stability. Given their conductive stability under vibration and EMP, and their outstanding economic advantages, the inclusion of silver-glass EMI gaskets in MIL-G-83528 specifications could provide considerable latitude for military equipment designers and manufacturers.

EXPERIMENTAL PROCEDURE

Commercial gasket manufacturers supplied samples of standard die-cut silicone EMI shielding gaskets with three types of conductive fillers: silver-plated copper granules, silver-plated aluminum beads and silver-plated glass spheres. The gaskets had a nominal thickness of 0.062 inch and 65 shore A hardness. The samples were remeasured for volume resistivity determinations. All samples represented the commercial manufacturing capabilities of the manufacturers supplying the military specification samples. The gaskets were measured according to the MIL-G-83528 vibration and EMP survivability qualification test procedures for EMI gaskets, using equipment and procedures approved by DESC.

Electrical Stability During Vibration

Mil-G-83528 allows a wide range of test conditions and control of vibration severity. This evaluation included different conditions and degrees of severity to allow full testing of silver-glass gaskets. The test fixture was mounted on a vibration platform and was driven by a signal generator and a power amplifier. Input and output acceleration, wave shape and phase angle were measured with accelerometers attached to the fixture body and free plate and displayed on an oscilloscope. Gasket resistance was

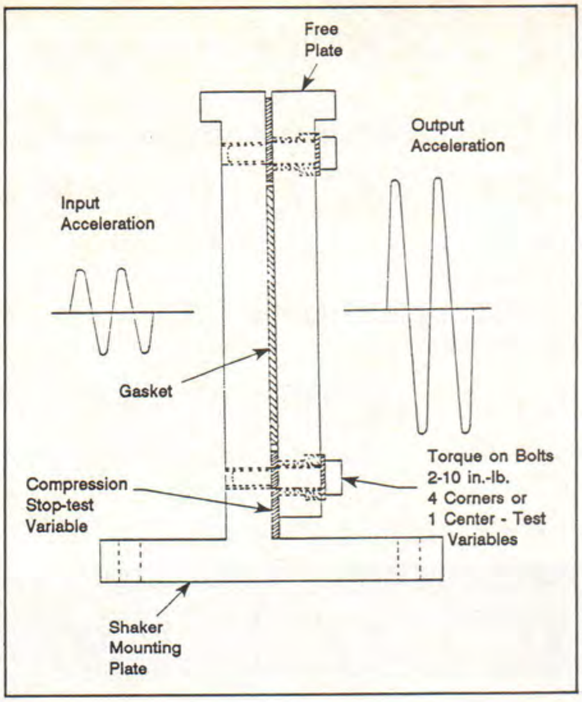


Figure 1. Vibration Test Fixture.

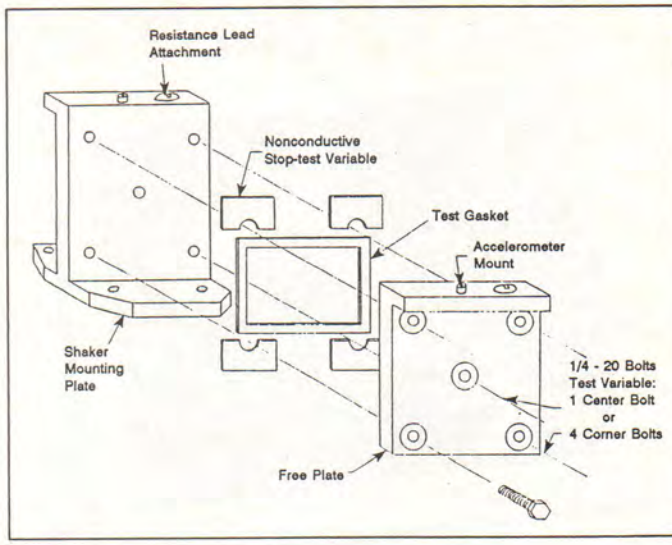


Figure 2. Assembled Vibration Test Fixture.

measured before, during, and after vibration.

The bolting arrangement on the test fixture was modified to allow relatively wide control of vibration severity (Figures 1 and 2). At selected resonance frequencies, the output/input acceleration ratio across the gasket (the amplification factor) would range from 1/1 for a rigidly-closed assembly with four bolts and compression stops, to a high of 4/1 to 7/1 for a loosely-closed assembly without stops. The upper amplification limit apparently depended on the damping characteristics of the gasket. Nonconductive bolt-hole bushings and washers on the free plate insured a nonconductive clamping arrangement.

MIL-G-83528 specifies a resonance frequency scan range of 200 to 1000 Hz. In this test, resonance was in the range of 600 to 950 Hz, which is believed to be a shearing mode. It was generally lower for less rigidly-closed assemblies, which produced higher amplification. Lower frequency and higher amplification cause more dynamic shearing displacement across the gasket. Input vibration intensity was held constant at 10g's peak to peak.

Measurement of EMP Survivability

A simulated coupled EMP was generated by a capacitive discharge circuit, with inductance and impedance adjusted to produce a 1.3 MHz damped sine wave with a 1/e decay time of 1200 nanoseconds. The pulse was monitored with a digital storage oscilloscope on a voltage divider across a 64 milliohm current-viewing resistor. The equipment was capable of generating up to 14kA peak to peak (first cycle) and was fully adequate for the specification test point of 0.9 kiloamps. Figure 3 shows the aluminum test assembly and standard washer-shaped gasket of 9.7 inches average circumference and 0.074- by 0.062-inch cross section specified in MIL-G-83528. Numerous trials at the specification test point of 0.9 kiloampere point to point per circumferential inch of sample had no effect on the gaskets.

Much higher pulse intensities approaching 10 million amperes were required to reach the survivability limits of the silver-glass gaskets. This equivalent was achieved by clamping short cross sections of the standard sample between edges of nonconductive compression stops machined to 90 percent of the sample thickness. Pulse intensities of 600 to 800 kA/in were obtained with sample sections approximately 0.015 inch long. When there was no sample in the test fixture, the current was immeasurable. This finding indicates that the entire current was injected through the small samples.

RESULTS AND DISCUSSION

Vibration Stability

The silver-glass filled EMI gaskets maintained high conductivity during the severest vibration environments specified by the MIL-G-83528 test procedures. Moreover, they proved to be as stable under intense vibration as gaskets made with silver-copper and silver-aluminum fillers. In all cases, the silver-glass compounds performed within the MIL-G-83528 limits set for silver-copper and silver-aluminum compounds.

Figure 4 shows silver-glass gasket resistivities before, during, and after vibration. The least severe condition

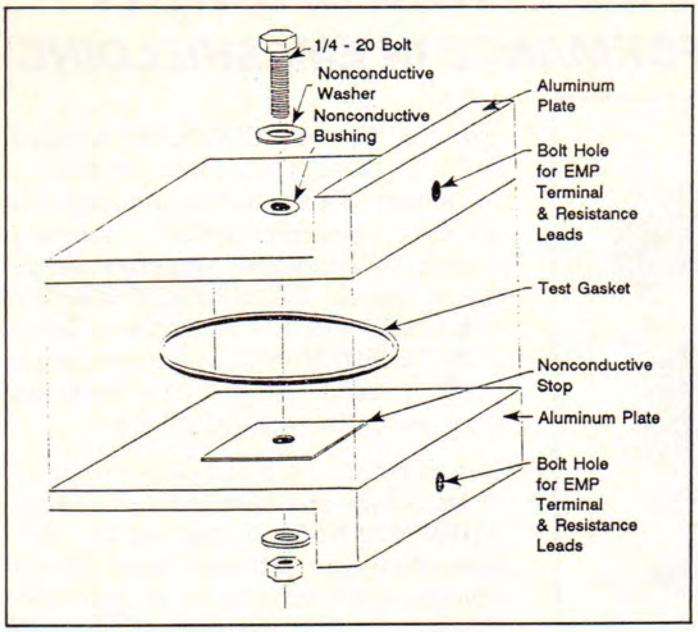


Figure 3. EMP Test Fixture with Standard Test Sample.

(4 bolts, with compression stops, 10 inch lbs. torque) is routinely used for gasket qualification tests with OEM's. The other two illustrated conditions (4 bolts, without stops, 2 inch lbs. torque, and 1 bolt, without stops, 8 inch lbs. torque) represent increasingly severe conditions, with relatively loosely-closed fixtures having low closure torque on four bolts or one bolt without compression stops.

Vibration severity, which is correlated to dynamic shearing displacement across the gasket thickness, is proportional to the amplification factor and is inversely proportional to the square of the resonance frequency. The range of test conditions is believed to encompass actual worst-case vibration environments of dynamic shearing. The severest tests probably corresponds to "loose-bolt" conditions. (Some OEM engineers question the practicality of this "loose-bolt" test.) Nonetheless the silver-glass gaskets maintained stability under all testing conditions and are considered stable under MIL-G-83528 limits for vibration.

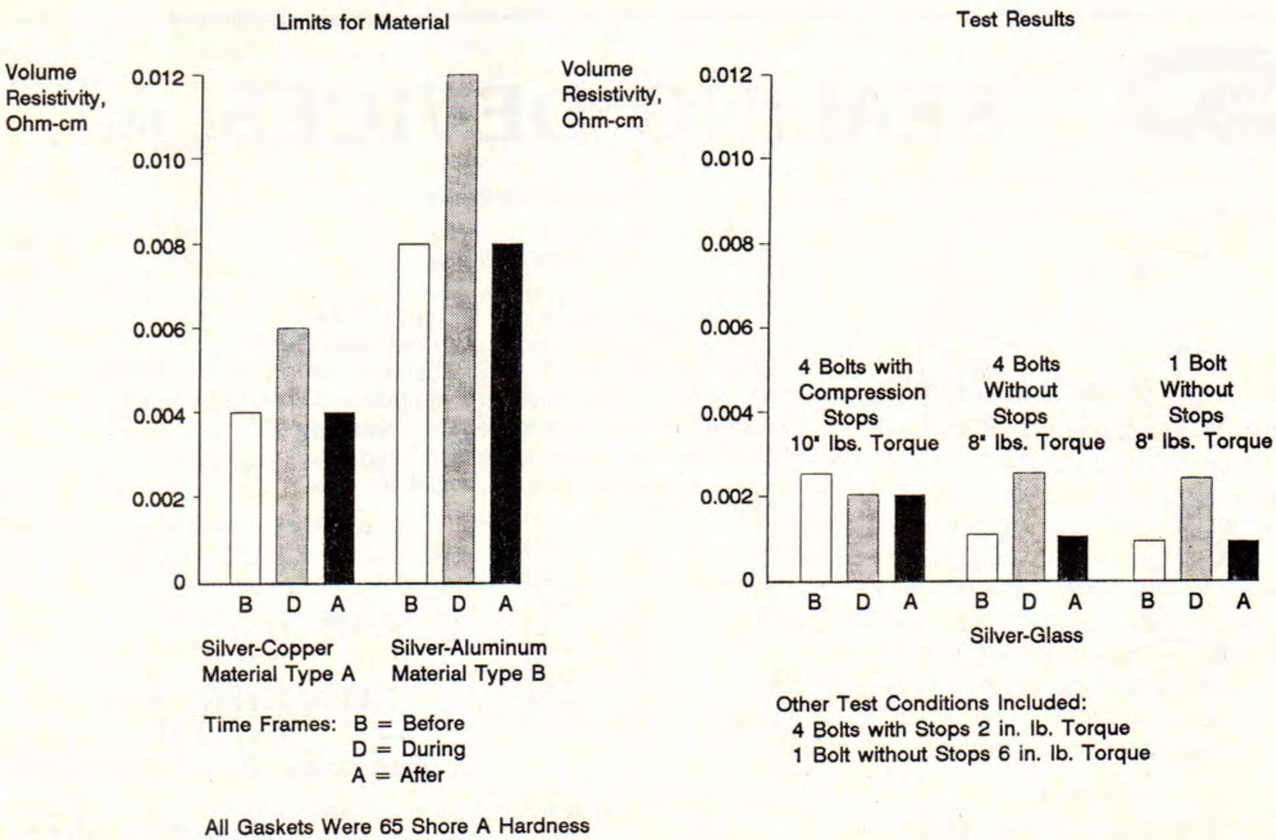


Figure 4. Electrical Stability During Vibration of EMI Gaskets.

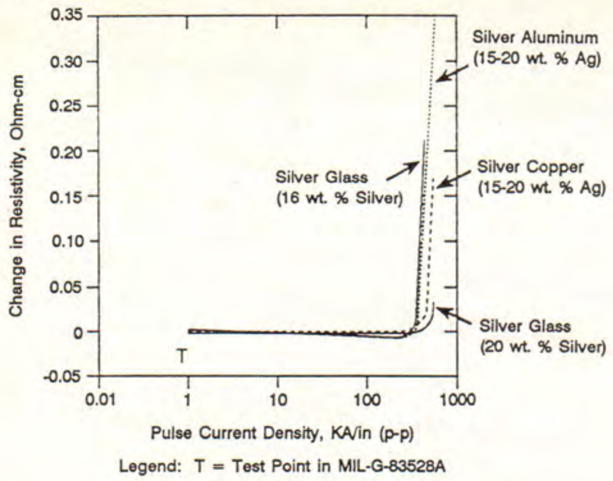
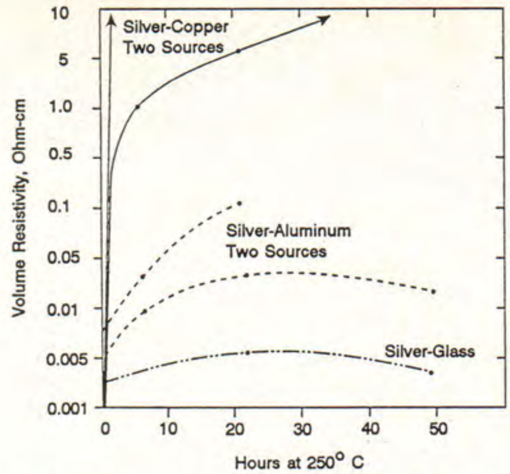


Figure 5. High Intensity Pulse Test Results.



Heat-aging characteristics of silver-plated glass, silver-plated aluminum and silver-plated copper EMI shield gaskets. As illustrated – silver glass compounds offer highest temperature application flexibility, and longest useful service life.

Figure 6. Aging Stability Comparison.

Electromagnetic Pulse Survivability

EMP tests of military grade gaskets made with silver-glass, silver-copper and silver-aluminum fillers were conducted in accordance with the MIL-G-83528 qualification test condition, which specifies 0.9 kA p-p per circumferential inch of sample. Test materials included glass spheres with coating thicknesses of 500, 900, 1200, 2200, and 2800 angstroms. The 500-angstrom coating is considerably thinner than that of silver-glass spheres actually used in EMI gasket manufacture.

All of the silver-glass EMI gaskets surpassed the EMP conditions specified in the testing procedures. Moreover, the gasket samples made with the thicker-coated silver-glass spheres had threshold limits comparable with the silver-copper and silver-aluminum gasket samples having comparable silver thicknesses. At the MIL-G-83528 test point, there was no evidence of change in resistance in any of the tested gaskets. Examination by scanning electron microscopy revealed no damage in the silver plating on any of the three particle types.

All conductive particles, however, will ultimately reach a failure point and then suddenly increase in resistivity. In this study, our theoretical calculations indicated that two orders of magnitude greater pulse energy would be required to melt the silver coating on any conductive filler. This hypothesis is based on two assumptions. First, pulse energy is divided among millions of contact points within the silicone gasket. Second, the high thermal conductivity of silver produces relatively mild ohmic heating at each contact point and that heat is conducted to cooler regions of the particles almost as fast as it is generated. It was theorized that inordinately high power densities would be necessary to generate ohmic heat fast enough to counter the rapid heat dissipation and to satisfy the heat capacity and heat of fusion requirements of silver.

Testing this theory on standard size samples would require pulse currents approaching 10 million amperes, which is greater than available equipment could generate. An alternative equivalent test injected the standard pulse current through gasket samples reduced in length by over two orders of magnitude. This technique allowed the concentration of 800 times greater powder density within a unit volume of gasket and into each particle-to-particle contact point.

Results of the high intensity pulse tests (Figure 5) confirmed our theory. The gasket made with glass spheres coated with 500 angstroms of silver (4 weight percent silver) survived 45 times greater pulse intensity than the test point specified by MIL-G-83528. The result is equivalent to a standard size test gasket withstanding 400,000 amperes of pulse current.

The failure threshold increased with the thickness of the silver plating. Spheres with 2200 and 2800 angstroms of silver coating (16 and 20 weight percent on glass) had threshold limits of 400 to 500kA/in, or the equivalent of 4 million to 5 million amperes for standard size gaskets. The 15-20% silver-aluminum and 15-20% silver-copper samples had threshold limits comparable with gasket samples made with the 15-20% silver plated glass spheres.

These results refute the Booth and Hodgson study[2], which indicated that silver-glass gaskets lose conductivity at test points considerably milder than 0.9 kA/in. That work was based on a hypothesis that the silver coating on the spheres was too thin to carry current at particle contact points.

Further testing of these gaskets to determine thermal aging stability was conducted. Samples of silver-glass, silver-copper, and silver-aluminum particle filled silicones were run at 250° C with volume resistivity measurements taken at time intervals up to fifty hours. As shown in Figure 6, the silver-glass compound clearly exhibited superior heat aging stability with a negligible increase resistance at the full fifty-hour time span over the as-received values.

CONCLUSIONS

The electrical stability of EMI gaskets during vibration, and the corresponding stability of shielding effectiveness, correlates more closely with optimization of gasket technology than with the type of conductive filler particle used to make the gasket. Today's newly designed military specification grade silver-glass gaskets can positively maintain shielding effectiveness in conditions of extreme vibration.

The shape and substrate of the conductive particles do not appear to have a bearing on electrical stability under vibration. Loss of gasket conductivity during vibration is caused by a time-average loss of conductive contact between particles within the conductive network. The degree of instability within a gasket is determined by the characteristics of the elastomeric silicone matrix as it is optimized for the particle size distribution, surface area, and dispersion characteristics of each type of conductive filler.

Instability, then, depends on how well the conductive particles are held in contact by the cross-linked silicone matrix during varying conditions of vibration. Regardless of particle shape, there is only one point of conductive contact between any two adjacent particles; and on the microscopic scale of contact points, all surfaces approximate spheres.

Also, instability does not appear to be inherent in the nature of the particle substrate. The more critical criterion in EMI gasket stability is the strength and uniformity of the silver coating bonded to a particle, be it glass, aluminum, or copper.

The results reported here, as well as advances in gasket manufacture, bring the validity and reliability of EMI shielding gasket vibration test qualifications into question. In private conversations, aerospace manufacturers have reported that their data show vibration amplification across black box assemblies on missiles and jet aircraft may reach 100/1 in brief but intense vibration surges. These same manufacturers cannot measure the local vibration

INSPECTION	UNITS	TOLERANCE	MATERIAL TYPE M	MATERIAL TYPE N
Operating Temperature	°C	Min / Max	-55 / +200	-55 / +200
Specific Gravity	Sp gr 23/23C	±13%	1.9	1.9
Hardness	Shore A units	±7	65	75
Compression/Deflection	Percent	Min	3.5	3.5
Tensile Strength	Pounds per square inch	Min	200	200
Elongation	Percent	Min / Max	100 / 300	100 / 300
Compression Set	Percent	Max	30	40
Tear Strength	Pounds per inch	Min	30	35
Volume Resistivity (as Received)	Ohm-cm	Max	.006	.008
Shielding Effectiveness 20 MHz-10 GHz (E-Field)	dB	Min	110	110
Electrical Stability During Vibration	Ohm-cm	Max		
During			.008	.012
After			.006	.008
Electrical Stability After Break	Ohm-cm	Max	.008	.015
Low Temperature Flex	°C	Max		
TR10			-55	-55
TR70			-55	-40
Volume Resistivity (After Life Testing)	Ohm-cm	Max	.009	.010
EMP Survivability	kA per inch of perimeter	Min	0.9	0.9
Fluid Immersion[1]	—	—	N/S	SUR

M - Silver-glass-silicone, 65 Shore A
N - Silver-glass-fluorosilicone, 65 Shore A

[1] N/S = Not Survivable
SUR = Survivable

Figure 7. Characteristics of Silver-Coated Glass Material Type EMI Shielding Gaskets Proposed for MIL-G-83528.

environment experienced by EMI gaskets between clamping flanges in the electronic subassemblies. They do, however, design their equipment with the proper number of bolts to ensure long standing clamping of the parts. The amount of induced motion of the clamping flanges across a gasket is typically limited by designs incorporating compression stops or metal-to-metal closures.

Valid measurement of vibration in such environments is obviously important in critical applications. Cooperative research with manufacturers of critical military equipment would help determine the anticipated vibration environments of gaskets. Generation of such data would then indicate appropriate qualification test conditions that would provide a realistic measure of gasket reliability.

Modern silver-glass sphere gaskets are unaffected by electromagnetic pulse intensities far in excess of standard qualification conditions specified by MIL-G-83528. Figure 7 illustrates the MIL-G-83528 proposed values of silver-glass filled gaskets. Silver-coated glass spheres impart other benefits to EMI gaskets, notably, lower cost compared with other fillers, light weight, exceptional thermal aging stability, and a chemically inert particle core. In critical military applications where, for example, weight reduction or thermal aging is a factor, designers and manufacturers of critical military equipment should have the latitude to specify silver-glass spheres as an alternative to the other silver-plated conductive fillers.■

ACKNOWLEDGEMENT

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REFERENCES

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