Conductive Elastomer Sealing & Shielding Technology

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SEALING AND SHIELDING FOR EMI/EMC

To control electromagnetic interference (EMI) and/or achieve electromagnetic compatibility (EMC), many electrical and electronic devices require a shielded enclosure. Typically, the protective shielding package allows for access doors or ports for installation and service of the electronic device contained therein. Often the package must also provide protection against mechanical damage and exclude moisture, dust, or other environmental contaminants. A variety of materials and design configurations generally familiar to readers of this publication have been developed to meet these shielding and sealing requirements.

THE ROLE OF CONDUCTIVE ELASTOMERS

Electrically conductive elastomers can be used to meet the most stringent shielding and sealing requirements. Typically, conductive elastomer seals are designed to provide sufficient electrical conductivity across the enclosure/seal/cover junction to maintain the EMI shield, provide a grounding path, and act as an environmental barrier to prevent dust and fluids from entering the electronic enclosure. In order to do this effectively, the seal must provide a continuous, uninterrupted sealing line around the perimeter of the enclosure opening(s).

The resilience of the elastomeric material allows the seal to conform to minor dimensional variations between mating surfaces, and generates a mechanical sealing force that prevents differential pressure from forcing foreign material across the junction into the enclosure. Elastomeric resilience also maintains sealing integrity under conditions of relative movement between mating flanges that may occur due to vibration or differential thermal expansion. Thus the physical integrity of an uninterrupted sealing line is critical to both environmental sealing and EMI shielding.

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EFFECTIVE CONDUCTIVE ELASTOMER MATERIALS

The development of elastomeric materials with adequate conductivity to provide effective EMC across the range of environmental conditions required in aerospace/defense applications presents some formidable technical challenges. Conductivity must be maintained by contact among metallic particles that must be free to move in three dimensions in response to physical deformation of the elastomer, yet must maintain sufficient particle-to-particle contact to provide relatively uniform and stable conductive paths. Conductive particle loading must be sufficient to assure electrical continuity, but the elastomer matrix filling the voids between conductive particles must also have sufficient tensile strength, resilience, and resistance to compression set (a measure of the degree to which an elastomeric element fails to return to its original configuration after prolonged deformation) to maintain physical integrity.

MIL-G-83528A

Pioneers in the development of conductive elastomer materials addressed some of these problems, resulting in the widespread production of viable conductive elastomers. However, the polymer chemistry and particle technology of these first generation products resulted in electrical and mechanical performance that has proven only marginally effective relative to actual aerospace/defense EMI/EMC requirements.

In fact, the existing MIL-G-83528A specification reflects a compromise between the actual sealing and shielding requirements of applications and the performance limitations of first generation conductive elastomer technology. In particular, long-term upper temperature limits of 125°C, outgassing of volatile components with subsequent shrinkage and potential embrittlement of the elastomer, and large increases in volume resistivity at elevated temperatures due to oxidation of filler particles are examples of the limitations of first generation technology. These limitations have shaped current MIL-G-83528A material specifications and test requirements to a significant degree.

Later efforts to develop a particle technology which was consistently effective for aerospace/ defense EMI/EMC applications were guided by four principles for material design. In essence, research determined that:

1. Conductive elastomer performance is strongly affected by certain key aspects of particle microstructure, including particle configuration, plating density, plating process conditions, and the absence of micro-contaminants.

2. Short-term and long-term stability of the elastomer matrix across a very wide temperature range is critical to successful performance under field conditions.

3. Given 1 and 2 above, the material designer must also take into consideration how the filler particles and elastomer matrix interact and work together structurally.

4. Conductive elastomer development should be directed toward maximizing performance and minimizing relative cost.

Each of these principles should be implemented in the development of conductive elastomer materials. The results achieved should demonstrate the fundamental soundness of these principles and the degree of success with which they are implemented.

The factor most critical to the successful performance of conductive elastomer materials under field service conditions is the stability of electrical properties over time. Field service conditions can involve repeated cycles of pressurization and depressurization; repeated cycling across a temperature range greater than the MIL-G-83528A specified range of -55°C to +160°C; prolonged periods of exposure to temperatures of 160°C or greater; vibration; dynamic movement caused by numerous access door openings and closings; exposure to chemically active liquids including salt water, synthetic hydraulic fluid, petroleum based fuels and oils, and other liquids or solid foreign materials; and physical handling of the conductive elastomer material by trained or untrained personnel during fabrication, installation, and maintenance.

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AIR AGING TESTS

One of the most conspicuous limitations of first generation conductive elastomer materials is their limited resistance to elevated temperatures. First generation conductive elastomers employ low molecular weight silicone and fluorosilicone polymers with a relatively high percentage of volatile components.

Over time, the loss of these volatile components will inevitably result in shrinkage and will generally result in some significant degree of embrittlement of the elastomer. Individually or jointly, these factors can reduce the resiliency of the sealing element against the mating flange and compromise the integrity of the sealing line. In the case of conductive elastomeric seals, loss of sealing integrity inevitably means the loss of shielding integrity.

To avoid these material problems, second generation conductive elastomers are formulated using high molecular weight polymers with extremely low levels of volatile components. Compounds provide a resilient matrix which retains conductive particles in a positional relationship that is extremely stable under normal sealing deformations. This provides excellent long-term electrical stability.

COMPARISON OF CONDUCTIVE ELASTOMERS

EXPERIMENTAL PROCEDURE

Tests were conducted to measure changes in volume resistivity, weight loss, and hardness of three second generation silver-plated copper conductive elastomers and three first generation materials of corresponding compositions. The three types of material tested were MIL-G-83528A Type A (Ag/Cu-silicone), Type C (Ag/Cu-fluorosilicone), and Type K (Ag/Cu-silicone).

Because the performance of materials beyond the limits established by MIL-G-83528A is important, three samples of each of the six materials were tested for six days (three times the requirement per MIL-G-83528A) at temperatures of 156±2°C. In a second procedure three samples of each of the six materials were tested for six days at temperatures of 185 ±5°C (25° C higher than MIL-G-83528A temperature requirements).

Volume resistivity measurements were made in accordance with the MIL-G-83528A (Paragraph 4.6.10) test method. The specimens were wiped with isopropyl alcohol and conditioned for two hours at room temperature before they were measured for electrical resistance. Median values of three measurements were evaluated.

Weight loss was measured by weighing the samples before and after exposure to elevated temperatures on an analytical balance with accuracy to four significant digits. Samples were weighed within 30 minutes of removal from the oven. Weight loss values reported were the average of three measurements.

Hardness was measured in accordance with ASTM D2240 before testing, and after testing and conditioning of the samples for two hours at room temperature. Three sample discs were plied together to measure hardness. Median values of these measurements were evaluated.

RESULTS

Test results showed that no first generation materials retained volume resistivity values within specification limits for the duration of the test. At the higher (185°C) temperature, volume resistivity of all first generation materials fell outside specification limits within the first few hours of exposure.

As expected, all of the elastomeric materials exhibited weight loss during accelerated heat aging (as they do at a much slower rate at room temperature). However, weight loss of first generation materials ranged from approximately two to four times the weight loss of corresponding second generation materials. After exposure at 156°C for six days, second generation materials remained within the normal 1.0 percent total mass loss specification limit established by NASA for space applications.

All silicone materials demonstrated significant increases in hardness over the six day test period at both 156°C and 185°C. The initial rate of change in hardness was faster and the magnitude of total increase in hardness over the six day test period was greater for first generation materials. Characteristically, fluorosilicone materials did not demonstrate significant changes in hardness at either test temperature.

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IMPLICATIONS OF TEST RESULTS

Changes in weight indicate the loss of volatile components and volumetric shrinkage. Accompanying increases in hardness indicate a loss of resilience. Shrinkage and loss of resilience are both indicators of reduced sealing performance. However, the most conspicuous effect demonstrated by the testing was the significant difference between first generation and second generation materials in volume resistivity changes due to exposure to elevated temperatures for durations beyond the relatively modest requirements of MIL-G-83528A.

CONCLUSION

Experimental test results clearly indicate the superiority of second generation materials for effective service in the field under real world conditions for both short-term and long-term performance. Designers and specifiers charged with developing effective shielding and sealing configurations for critical defense, aerospace, and avionics applications must be aware of the wide disparity in performance that exists among currently available conductive elastomer materials.

For many applications, nominal compliance with MIL-G-83528A is not sufficient. Many users of conductive elastomers have established higher shielding and sealing requirements and more stringent performance envelopes. For critical applications, it is essential that designers evaluate the actual operating conditions conductive elastomer seals will be exposed to over the expected service life of the application and select materials most likely to deliver the required level of performance.

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