# CONDUCTIVE ELASTOMERIC EMI GASKETS

**Conductive elastomers are the designer's first choice for providing environmental protection and EMI shielding in critical military and aerospace applications.**


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## INTRODUCTION

Conductive elastomers can provide excellent environmental protection and EMI shielding simultaneously. They are the designer's first choice in critical military and aerospace applications. Increased awareness of the importance of long-term shielding integrity in commercial and industrial equipment has resulted in wide use of this type of gasketing.

A conductive elastomer is composed of conductive metal particles in an elastomeric binder. Many conflicting design parameters must be considered by the manufacturer in order to produce gasket materials suitable for EMI shielding. The materials must:

- Be highly conductive electrically.
- Be able to withstand elevated temperatures.
- Have good tensile strength.
- Have low compression set.
- Have medium hardness.
- Have good shielding characteristics.
- Exhibit good sealing properties.

The designer must evaluate his choice of gasket material very carefully. Many materials from inexperienced manufacturers are not heat stable and thus lose their electrical conductivity at elevated temperatures. The article "Conductive Elastomer Gasketing: MIL-G-83528" in ITEM 87 covers the evaluation of elastomeric shielding materials.

Almost all elastomer EMI gaskets use silicone for the binder since this material has excellent temperature characteristics. There are four basic types of conductive materials presently used in high quality elastomeric EMI gaskets. These materials and their characteristics are shown in Figure 1. They are:

- Silver-plated copper
- Silver-plated aluminum
- Pure silver
- Silver-plated glass

Each of these materials is available in standard forms such as sheets, extrusions and O-rings.

MIL-G-83528 was developed to help users select reliable materials for use as conductive elastomer EMI shields. Although some of the test suggestions in this MIL-Spec need some modification, the test for heat aging is very useful in screening out unacceptable materials. Most of the physical tests in MIL-G-83528 are standard ASTM test procedures.

Shielding tests suggested in the MIL-Spec can be used effectively only with some modification. A much older, but still quite viable, specification for shielding tests is MIL-STD-285 "Method of Military Standard Attenuation Measurements for Enclosures, Electromagnetic Shielding, For Electronic Test Purposes." This describes the test setups used by most manufacturers to test the materials. The actual shielding values obtained in real-life applications are never as high as those derived from idealized gasket test fixtures. The designer should be aware of this discrepancy. A real-life enclosure is a completely *different animal* from a test fixture.

Volume resistivity before and after heat aging of material, should be

| | Test Procedure | | | | |
|---|---|---|---|---|---|
| Type (MIL-G-83528) | | Type A | Type B | Type E | None |
| Elastomer | | Silicone | Silicone | Silicone | Silicone |
| Conductive Medium | | Cu/Ag | AL/Ag | Ag | Ag/Glass |
| Volume Resistivity (ohm-cm, max) | MIL-G-83528 | 0.004 | 0.008 | 0.002 | 0.01 |
| Shore A Durometer (±7) | ASTM D2240 | 65 | 65 | 65 | 67 |
| Specific Gravity | ASTM D792 | 3.8 | 2.0 | 3.6 | 1.8 |
| Tensile Strength (psi,min.) | ASTM D412 | 220 | 220 | 220 | 160 |
| Elongation (min/max %) | ASTM D412 | 100/300 | 100/300 | 200/500 | 76 |
| Tear Strength (lb/in min) | ASTM D624 | 40 | 30 | 50 | 26 |
| Compression Set (% max) | ASTM D395(B) | 32 | 32 | 45 | 31 |
| Low Temperature Flex (C,min) | ASTM D1329 | -65 | -65 | -65 | -55 |
| Max Continuous Use Temperature (C) | MIL-G-83528 | 125 | 160 | 180 | 160 |
| Shielding Effectiveness (db,min) | MIL-G-83528 | | | | |
| 200kHZ (H-Field) | | 70 | 60 | 70 | 50 |
| 100MHz (E-Field) | | 120 | 115 | 120 | 100 |
| 500MHz (E-Field) | | 120 | 110 | 120 | 100 |
| 2GHz (Plane Wave) | | 120 | 105 | 120 | 90 |
| 10GHz (Plane Wave) | | 120 | 100 | 120 | 80 |
| Electrical Stability | | | | | |
| Heat Aging (ohm-cm,max) | MIL-G-83528 | 0.010 | 0.010 | 0.010 | 0.01 |
| Vibration Resistance (during/after) | MIL-G-83528 | .006/.004 | .012/.008 | .010/.002 | -/.01 |
| Post Tensile Set Resistivity | MIL-G-83528 | 0.008 | 0.015 | 0.010 | 0.01 |
| Emp Survivability (KA/in, perimeter) | MIL-G-83528 | > 0.9 | > 0.9 | > 0.9 | – |

Note: Compression Set is expressed as a percentage of deflection of the material from its initial height. For example if a 1mm thick material is deflected 25%, the deflection is 0.25mm. Compression set of 30% would be 30% of 0.25mm which is 0.075mm.

MIL-G-83528 is a new Military Specification for EMI Conductive Elastomeric Materials.

Figure 1. Material Selection Chart.

tested using the MIL-G-83528 Pressure Probe technique and a good micro-ohmmeter. The resistance values obtained with the surface probe technique are not very reliable although this measurement technique is encouraged by some manufacturers.

Conductive elastomeric materials consist of small particles of silver or particles where the surface has been coated with silver. Other types of metals have been tried without great success. Silver is the lowest cost precious metal that can withstand the continuous use temperatures at which EMI shields must operate. Using special techniques, the particles are dispersed into a polymer so that electrical conductivity throughout the material is obtained. When observed under the microscope, the conductive paths from particle to particle are not visible. However, the particles are connected in chains, many of which are under the surface of the polymer. The paths through the material are long, and the electrical resistance of the material is made up of many small contact resistances. Any given path has a high resistance. However, there are many parallel paths which give the materials a relatively low volume resistivity.

The mechanical properties are governed mainly by the silicone binder. Gasket materials are evaluated on the basis of their physical properties such as elongation, hardness, tensile strength, and tear strength. Conductive elastomers do not have very good mechanical properties when compared to unloaded, non-conductive materials. Nevertheless, the properties of conductive elastomers are quite adequate for gasket applications.

One of the principal concerns of the gasket designer is compression set. For example, if the initial height of a gasket is 0.100 inch and it is compressed down to 0.080 inch, the elastomer will only go back up to 0.095 inch when the pressure is removed. A phenomenon related to compression set is called stress relaxation, which is actually more important than compression set. When the gasket is compressed, the elastomer is deformed. Within the elastomer there is a relaxation of stress which results from the rearrangement of the molecules of the elastomer.

It is important to realize that elastomeric materials are essentially incompressible. They react to a force by becoming deformed; their volume, however, remains unchanged. When deformed, the elastomer tries to escape the compressive force, and stress relaxation takes place. Consequently over a period of time, the elastomer pushes back less against the flanges. In silicones the stress after relaxation is usually 70 to 75 percent of the initial compression force. The best way to compensate for this stress relaxation is to apply more initial compression force than is ultimately required. Then after stress relaxation, the gasket will be compressed to the designed value.

The electrical volume resistivity of all of these materials decreases with increasing deflection force. There are two reasons for this decrease. First, as the material is compressed more, there are more internal conduction chains in parallel circuits within the material, thus lowering the volume resistivity. Secondly, under increasing pressure, more particles on or near the surface of the gasket come into contact with the flange surface, thus lowering contact resistance. Also the particles in contact with the flange tend to bite into the flange overcoming surface contact resistance. In reality *conductive elastomer* is a misnomer since the materials change conductivity with pressure. *Pressure sensitive conductive elastomers* would be more precise. This reaction to pressure can easily be demonstrated by varying the pressure on the probe using either of the suggested MIL-G-83528 volume resistivity test procedures.

A word is in order about flange corrosion protection coatings. To obtain reliable long-term shielding, careful consideration must be given to surface preparation of the enclosure flanges. The surface treatment depends on the environment in which the equipment will operate. For severe marine environments, a chromate conversion (MIL-C-5541) plus a 3-mil silver-filled epoxy coating is recommended. The chromate coating can be Alodine 600, 1200 or 1200S.

Designers are frequently concerned about the galvanic corrosion which takes place when dissimilar metals are in contact with each other and when an electrolyte is present. Normally the best filler for good temperature conductivity and stability is pure silver. Unfortunately silver and aluminum (the most frequent enclosure material) make a bad galvanic couple. Since silicone materials have excellent properties of molecular adhesion, placing a silicone gasket between two mating flanges creates a truly hermetic seal. If the flanges are dry when the gasket is installed, the only place there might be some corrosion is on the outside edge of the gasket. MIL-STD-1250 recommends sealing this edge with non-conductive elastomer.

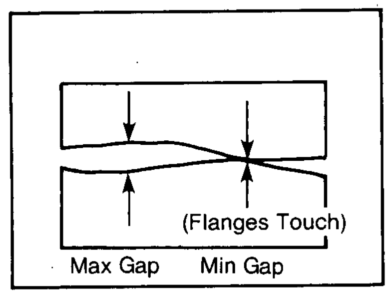


Figure 2. Flange Flatness.

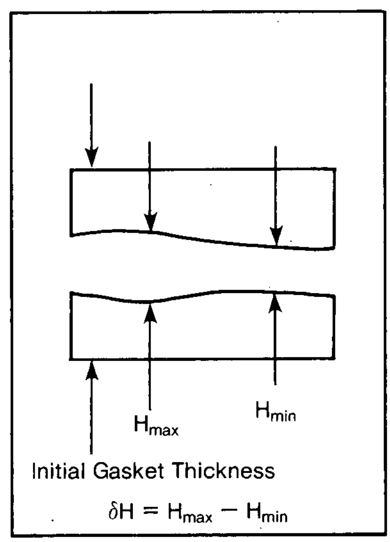


Figure 3. Flanges With Gasket Installed.

## GASKET DESIGN

The three important factors in gasket design are flange flatness, compression load and gasket thickness.

**Flange Flatness.** Flange flatness (Figure 2) is the maximum gap dimension between the two flanges when they are in contact with each other. Figure 3 illustrates the same flanges with a gasket installed. The gasket must be thick enough (H) so that it can be compressed sufficiently to fill in all of the gaps between the flanges. Dimension $H_{min}$ must be such that the allowable percentage of compression of the gasket is not exceeded. For example, with a round gasket where 30 percent compression is allowable, the gasket must have a diameter large enough so that $H_{min}$ will represent at least 70 percent of the uncompressed gasket diameter.

Resilience:

$$R = \text{Percent } H/(kg/cm_2)$$

where Percent H = Percentage of original gasket height.

Generally it is best to use the hardest gasket available which can be compressed sufficiently between the flanges which are to be used because a harder gasket will bite into the mating flanges giving lower contact resistance. Harder gaskets also suffer less stress relaxation than soft gaskets.

**Compression Load.** Minimum compression force for sealing occurs at $H_{max}$. The gasket must make contact even between the maximum flange separation points. The pressure on the gasket must be sufficient so that the system is sealed in the presence of whatever pressure is to be applied to it. Compression force must be sufficient to make the gasket fill all flange gaps. The maximum compression force will be at $H_{min}$.

**Gasket Height.** Depending on the physical form of the gasket (flat, round, hollow round, etc.), there is a maximum amount of compression which can be applied to the gasket. Usually, flat gaskets can be compressed only about 10 percent. This compression requires considerable pressure with most flat gaskets, frequently as much as 100 psi. To keep total required compressive force as low as possible with flat gaskets, the gasket width should be as small as possible consistent with good sealing and shielding. Round gaskets can be compressed up to about 30 percent while hollow round gaskets can be compressed up to 50 to 80 percent. Figure 4 shows recommended deflection of various cross sectional types of gaskets.

| Cross-Section | Recommended Deflection (Min – Max) |
|---|---|
| Flat | 5 – 10% |
| Solid-O | 10 – 30% |
| Solid-D | 10 – 20% |
| Rectangular | 5 – 12% |
| Hollow-O | 40 – 80% |
| Hollow-D | 40 – 80% |

Figure 4. Recommended Deflection of Various Cross-Sectional Types of Gaskets.

It is easy to see that if the maximum gap between the flanges ($H_{max}$ in Figure 3) is 0.005 inch, then the gasket used must be thick. Choosing an O-strip which can be compressed 20 percent instead of a flat gasket, allows a smaller cross-section of gasket material to fill the gaps. A flat gasket should be used only when there is no other alternative. If it is not possible to have grooves for placing strip gaskets, there may be no way to avoid a flat gasket.

Although there are many different cross sections which can be produced by standard manufacturing methods, by far the most useful shapes are the O-strip and the hollow-O strip. Extruded compression force O-strips can be compressed more and with less compression force than flat gaskets. Hollow O-strips can be compressed even more, but they are not available in very small diameters. Other cross-sections such as P-strips and U-strips, have specialized uses. See Figure 5 for drawings of the various standard cross-sections available. Figure 6 shows the compression curve for a typical material.

## DESIGN PROCEDURE

1. Choose the minimum pressure needed for the amount of sealing necessary. This calculation is determined by the pressure difference between the inside and the outside of the enclosure. Always be sure to include a safety factor.
2. Decide on an average applied pressure. Determine this by the total force that can be exerted by the bolts

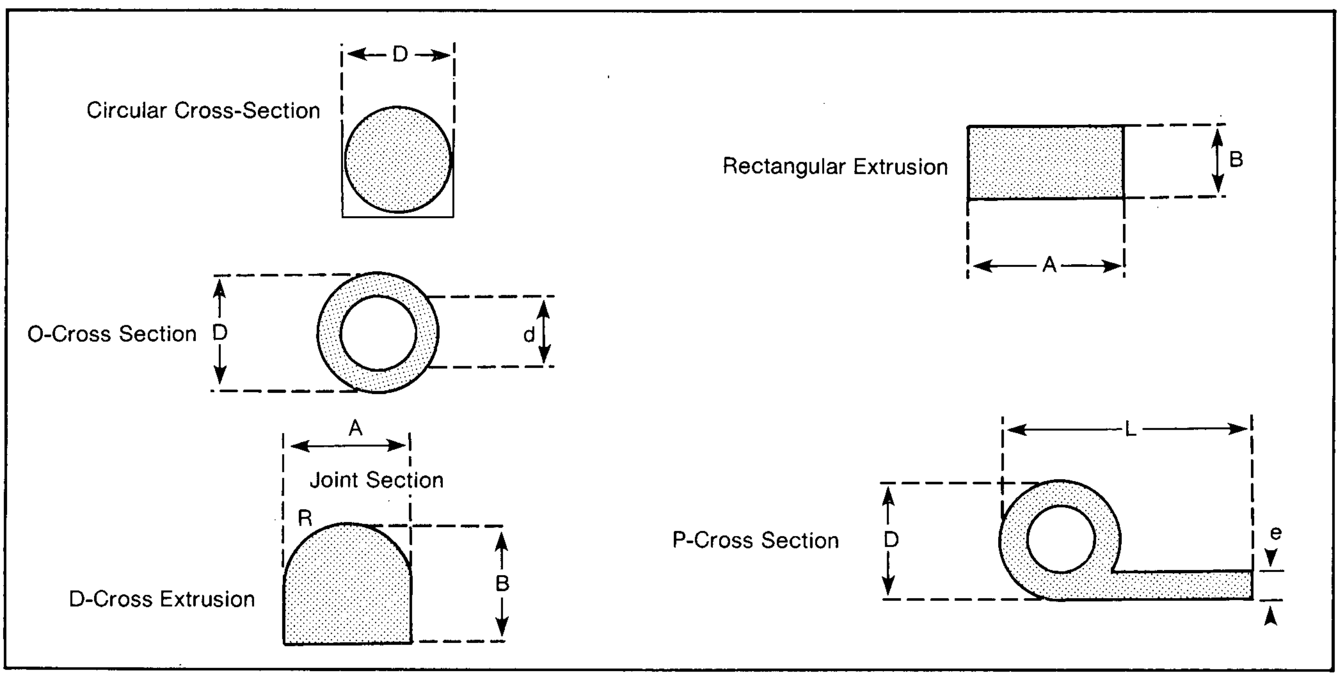


Figure 5. Various Standard Cross-Sections Available.

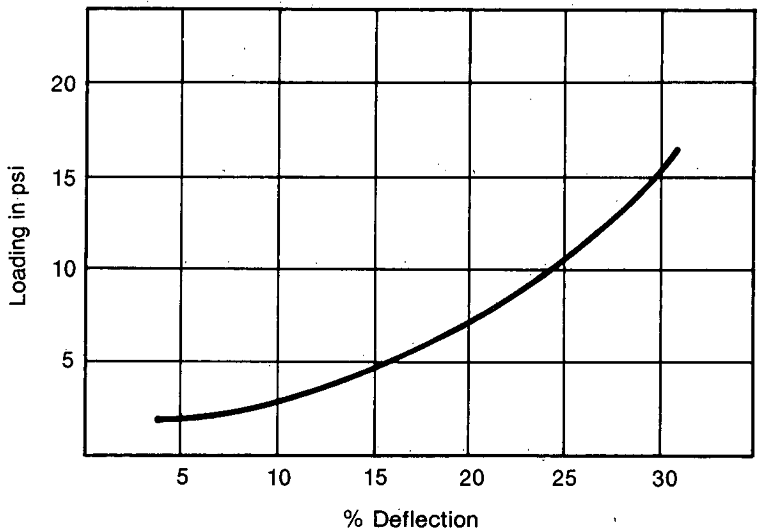

Figure 6. Compression Curve For a Typical Material.

or other devices used for applying compressive force to the gasket.
3. Determine the percent of deflection which must be obtained from the gasket.
4. Calculate the required height of the gasket.

## HINTS FOR DESIGN PROCEDURE

If compressibility must be increased, the designer can use a thicker gasket and greater compression force or he can use softer gasket material. The first choice involves greater costs while the second risks greater stress and possible damage to the gasket. Thus, the best design principle is to use O-strip gaskets and compress them as much as possible without damaging the gasket and to use the hardest gasket material available which can be compressed with the available bolts. If the enclosure is such that considerable pressure cannot be applied to the gasket, then use hollow O-gaskets.

For shielding very large enclosures, doors, or other sites where a groove is not available, use hollow P-strip gaskets. Adhere the tab of the P-strip to the flange with non-conductive adhesive. Be careful that none of the non-conductive adhesive gets under the O part of the gasket because it will interfere with the electrical continuity between gasket and flange.

## CONCLUSION

Electrically conductive elastomeric gaskets are ideally suited to critical military and aerospace applications which operate at high temperatures and which require excellent sealing and shielding characteristics. The best EMI conductive elastomer gasket solution is to use extruded gaskets in grooves wherever possible. When grooves are not available, try to use a hollow P-shaped gasket. Use flat gaskets only as a last resort. Carefully evaluate conductive elastomer materials by insisting on materials which will pass MIL-G-83528 heat aging tests. ■