Performance Data

CONTENTS:

Conductive Elastomers

Compression-Deflection

While standard test procedures have been established for measuring the deflection of elastomers under compressive loads, the practical use of such data is to provide a qualitative comparison of the deformability of different elastomeric materials when in the particular configuration of the test sample.

Solid (non-foam) elastomers are essentially incompressible materials; i.e., they cannot be squeezed into a smaller volume. When a solid elastomer is subject to a compressive load, it yields by deformation of the part as a whole. Because of this behavior, the actual deflection of a gasket under a compressive load depends upon the size and shape of the gasket as well as on its modulus and the magnitude of the load.

The design of a seal should be such that it will be subjected to the minimum squeeze sufficient to provide the required mechanical and electrical performance. The designed deflection of conductive elastomer gaskets should never exceed the maximum deflection limits shown in Table 1.

There is an approximate relationship between the force required to deflect a pure elastomer a given amount, and the hardness of the elastomer. In general, the harder the elastomer, the greater the force required. In the case of Chomerics' metal particle-filled elastomers, this relationship is much less definite, and in some instances, these materials demonstrate deflection/hardness and deflection/thickness behavior contrary to that which would be anticipated for conventional rubber compounds.

The inclusion of metal particles in the elastomer results in a mechanically structured material. This mechanical structure has a marked effect on the deflection of the elastomer under compressive loads, and in some instances, harder materials deflect more than softer materials.

Compressive load-deflection data for many popular conductive elastomer materials and shapes are given in Figures 1-25. (For "line contact" gaskets, it is more convenient to express the load in terms of pounds per linear inch instead of pounds per square inch).

For compression-deflection data on other Chomerics gaskets, contact our Applications Engineering Department.

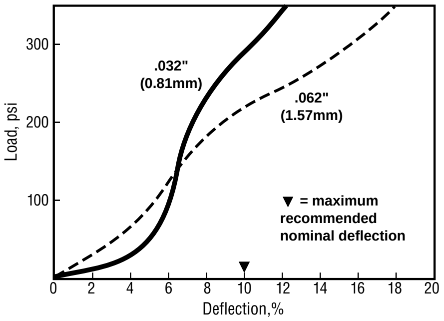


Figure 1 CHO-SEAL 1215 Sheet Stock Compression-Deflection

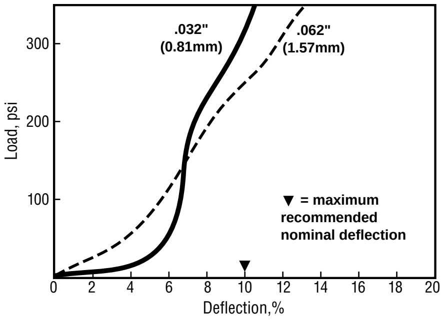


Figure 2 CHO-SEAL 1217 Sheet Stock Compression-Deflection

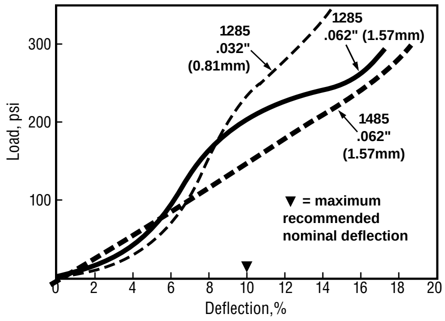


Figure 3 CHO-SEAL 1285 and CHO-SIL 1485 Sheet Stock Compression-Deflection

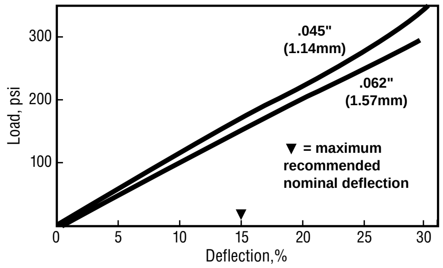


Figure 4 CHO-SIL 1401 Sheet Stock Compression-Deflection

Table 1

RECOMMENDED DEFLECTION FOR VARIOUS CONDUCTIVE ELASTOMER SHAPES			
Cross Section Geometry	**Minimum Deflection**	**Nominal Deflection**	**Maximum Deflection**
Solid O	10%	18%	25%
Solid D	8%	15%	20%
Rectangular (including die-cut)	5%	10%	15%
Hollow O, D and P	10%	50% of inside	100% of inside

Note: For increased deflection requirements, Chomerics can provide special shapes.

Unit Conversion Note:
Load, 1 lb./in. = 0.571 Newton
Load, 1 psi = 0.015 Pascal

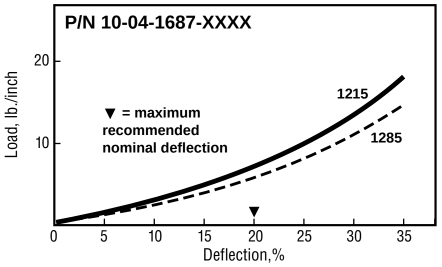


Figure 5 0.070 in. (1.78 mm) Dia. O-Strip Compression-Deflection

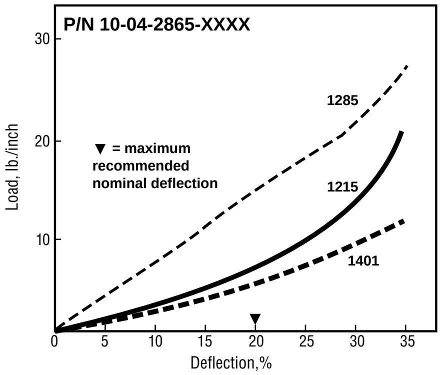


Figure 6 0.093 in. (2.36 mm) Dia. O-Strip Compression-Deflection

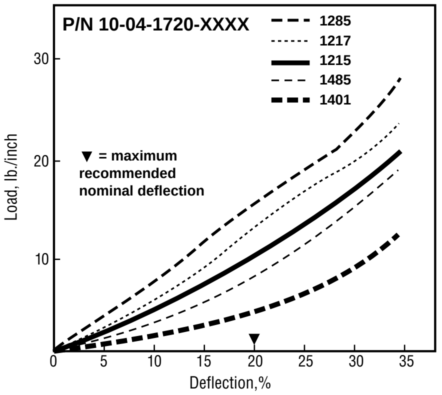


Figure 7 0.103 in. (2.62 mm) Dia. O-Strip Compression-Deflection

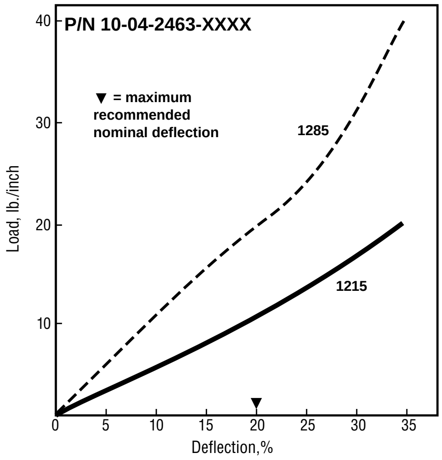


Figure 8 0.125 in. (3.18 mm) Dia. O-Strip Compression-Deflection

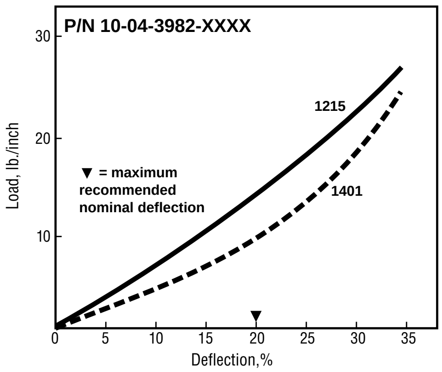


Figure 9 0.150 in. (3.81 mm) Dia. O-Strip Compression-Deflection

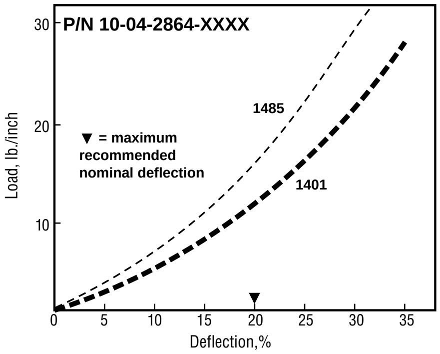


Figure 10 0.216 in. (5.49 mm) Dia. O-Strip Compression-Deflection

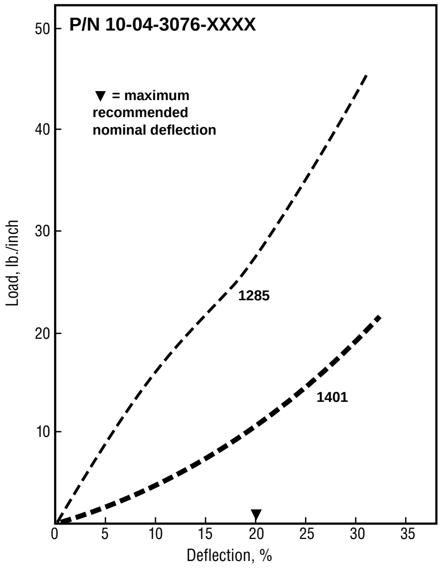


Figure 11 0.250 in. (6.35 mm) Dia. O-Strip Compression-Deflection

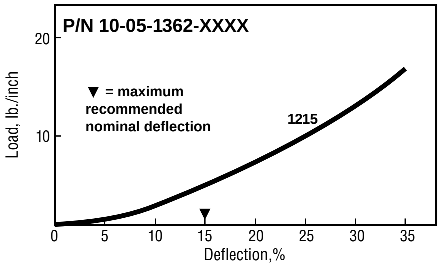


Figure 12 0.068 in. (1.73 mm) High D-Strip Compression-Deflection

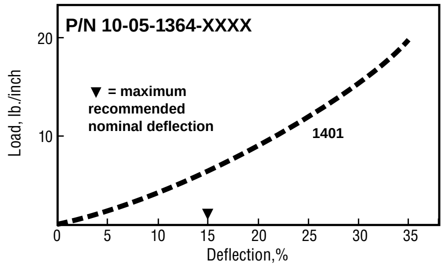


Figure 13 0.135 in. (3.43 mm) High D-Strip Compression-Deflection

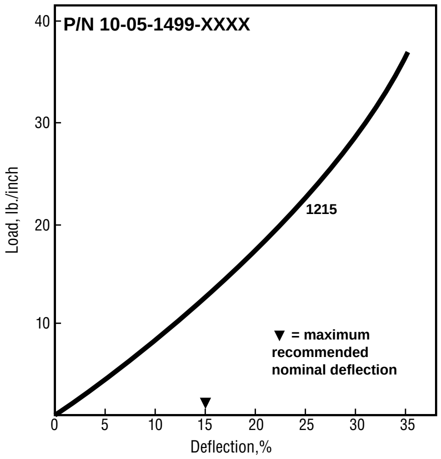


Figure 14 0.156 in. (3.96 mm) High D-Strip Compression-Deflection

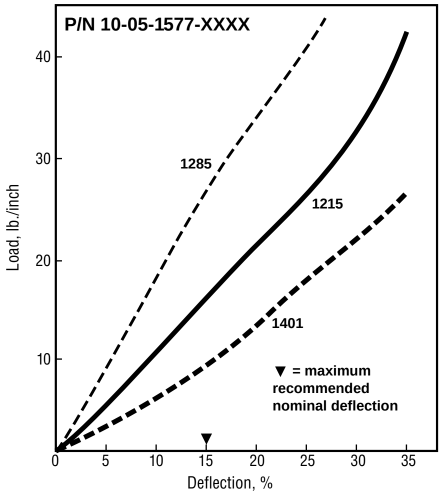


Figure 15 0.175 in. (4.45 mm) High D-Strip Compression-Deflection

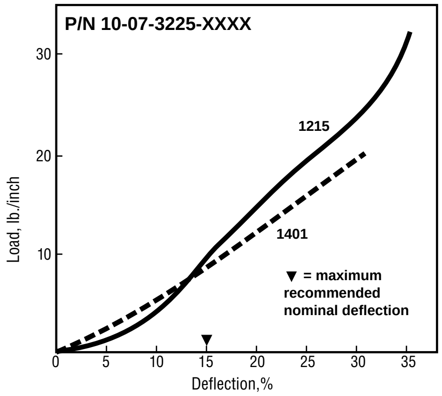


Figure 16 0.125 in. (3.18 mm) Wide Rectangular Strip Compression-Deflection

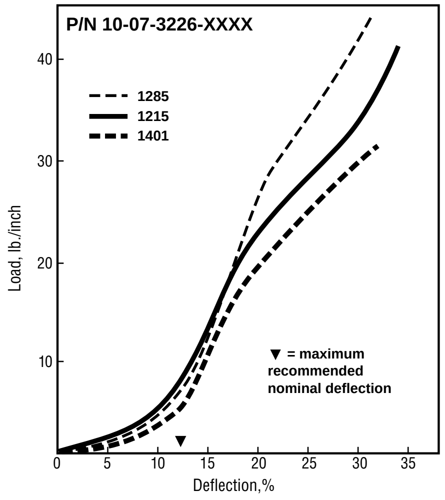


Figure 17 0.250 in. (6.35 mm) Wide Rectangular Strip Compression-Deflection

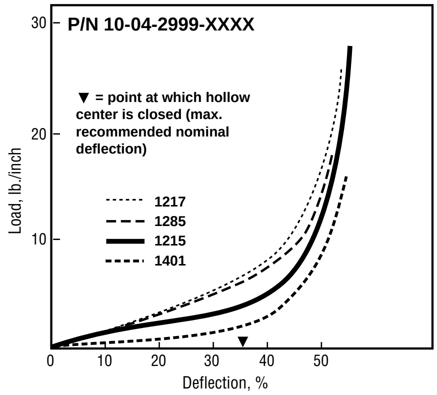


Figure 18 0.125 in. (3.18 mm) Dia. Hollow O-Strip Compression-Deflection

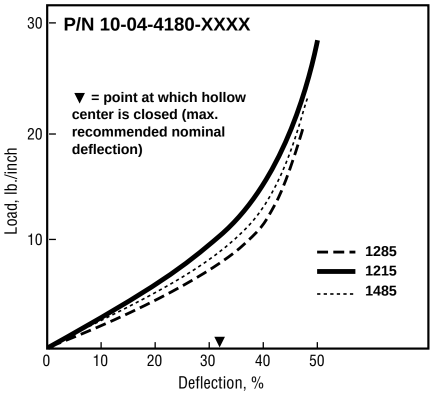


Figure 19 0.156 in. (3.96 mm) Dia. Hollow O-Strip Compression-Deflection

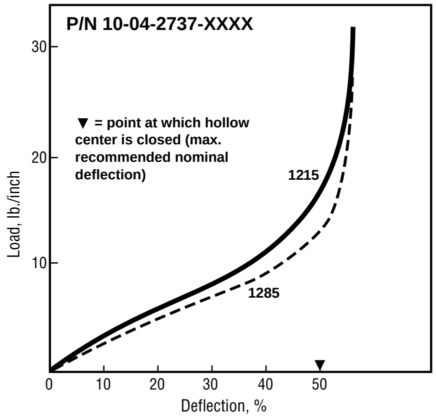


Figure 20 0.250 in. (6.35 mm) Dia. Hollow O-Strip Compression-Deflection

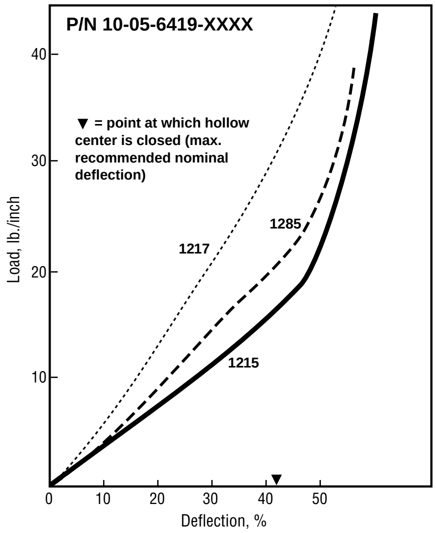


Figure 21 0.156 in. (3.96 mm) High Hollow D-Strip Compression-Deflection

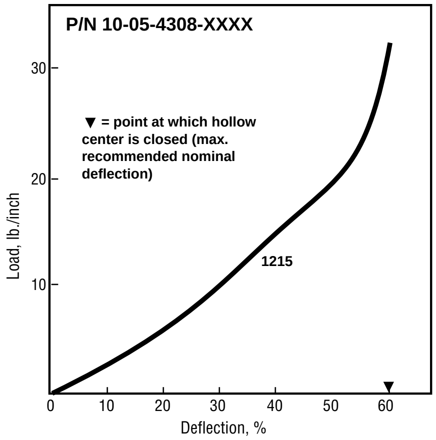


Figure 22 0.312 in. (7.92 mm) High Hollow D-Strip Compression-Deflection

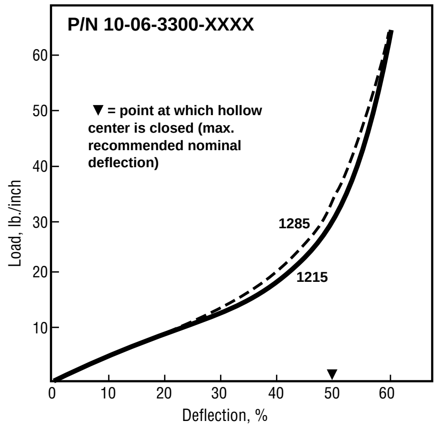


Figure 23 0.250 in. (6.35 mm) Dia. Hollow P-Strip Compression-Deflection

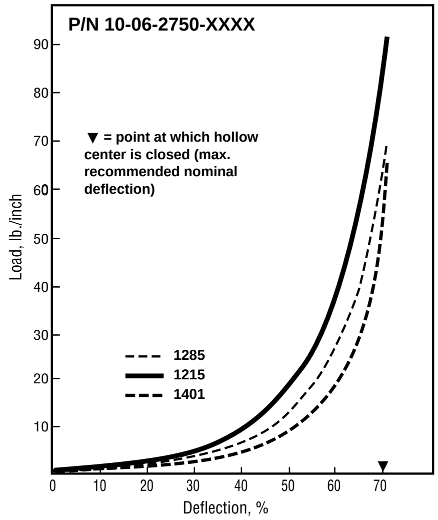


Figure 24 0.360 in. (9.14 mm) Dia. Hollow P-Strip Compression-Deflection

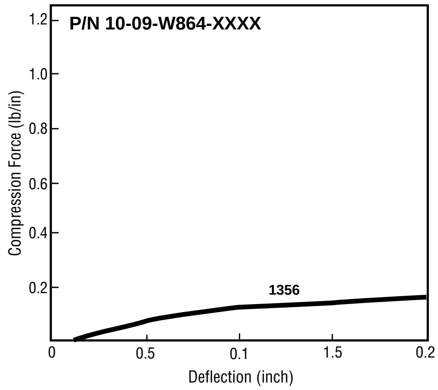


Figure 25 0.410 in. (10.41 mm) High V-Strip Compression-Deflection

Unit Conversion Note:

Load, 1 lb./in. = 0.571 Newton
Load, 1 psi = 0.015 Pascal

Stress Relaxation

As important as Compression Set and Compression-Deflection, is the Stress Relaxation characteristic of a gasket.

If a rubber is subject to a compressive load, it will deflect. There is a stress/strain relationship, which for rubbers is generally non-linear except for very small deflections. After the load is applied, a stress decay occurs within the polymer resulting from the internal rearrangement of the molecular structure. An approximate rule is that the relaxed stress for cured silicone will finally settle at 70 to 75 percent of the initial stress.

There are two ways in which a rubber gasket can be loaded to a desired value. One way is to load it to a point, let it relax, and reapply the load to restore the original stress. The next time it will relax, but not so much. If this is repeated a sufficient number of times, the correct static load on the gasket will reach equilibrium.

A more practical way to reach the design value of stress is to load the gasket to 125 percent of its final design value, so that after the relaxation process is completed the gasket will settle to 100 percent of the design load. This is very reproducible.

Figure 26 shows a typical stress relaxation curve for Chomerics' conductive elastomers.

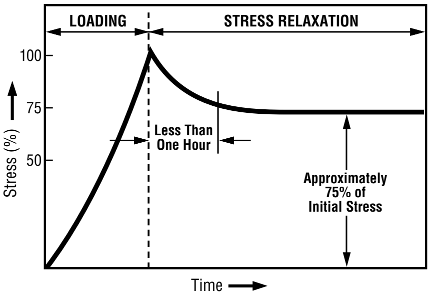
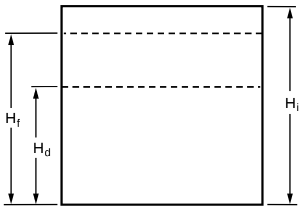


Figure 26 Stress Relaxation

Compression Set

When any rubber is deformed for a period of time, some of the deformation is retained permanently even after the load is removed. The amount of permanent deformation, as measured by ASTM D395, is termed "Compression Set." Compression set is measured under conditions of constant deflection (ASTM D395 Method B) and is normally expressed as a percentage of the initial deflection, *not* as a percentage of the initial height.



H_i = Initial height
H_d = Deflected height (Normally 75% of H_i)
H_f = Final height (After load is removed)

$$\text{Compression Set} = \frac{(H_i - H_f)}{(H_i - H_d)} \times 100\%$$

Figure 27 Formula for Calculation of Compression Set

For gaskets that are used once, or where the gasket/flange periphery relationship is constant (such as a door gasket), compression set is of minor significance if the original load condition and the service temperature are within the design limitations of the gasket material.

For gaskets that are randomly reseated one or more times in normal service life, it is important that the maximum change in gasket thickness does not exceed twice the maximum mismatch between the opposing mating surfaces.

Shielding Effectiveness

Most shielding effectiveness data given in Table 3 of the Conductive Elastomer section (pages 32-34) is based on a MIL-G-83528B test method, with a 24 in. x 24 in. aperture in a rigid enclosure wall and about 100 psi on the gasket. It is a valid and useful way of comparing various gasket materials, but does not reflect the shielding effectiveness one can expect at seams of typical enclosures. CHO-TM-TP08 is a modified version of the MIL test that provides typical values achieved in actual applications. Since many factors will affect the actual shielding effectiveness of an enclosure seam (flange design, stiffness, flatness, surface resistivity, fastener spacing, enclosure dimensions, closure force, etc.), the only way to determine shielding effectiveness for real enclosures is to test them.

Figures 28 and 29 provide data on shielding effectiveness for actual enclosures. The data in Figure 28 shows the difference in attenuation between a shelter door closed with no gasket and the same door closed against a CHO-SEAL 1215 hollow D-strip gasket. Instead of single data points at each frequency tested, a range of data is shown for each frequency, representing the worst and best readings measured at many points around the door. Figure 29 shows the effects of closure force on shielding effectiveness of an enclosure tested at high frequencies (1-40 GHz) using CHO-SEAL 1215 solid D-strip gaskets.

In order to establish reasonable upper limits on gasket resistivity, it is necessary to understand the relationship between flange interface resistance and EMI leakage through the flange. Figure 30 presents this relationship for an aluminum enclosure 3 in. x 3 in. x 4 in. deep, measured at 700 MHz. Die-cut gaskets 0.144 in. wide by 0.062 in. thick, in a wide range of resistivities, were clamped between the gold-plated flanges of this enclosure. Simultaneous measurements of flange interface resistance (all attributable to the gaskets) versus RF leakage through the seam produced a classic S-shaped curve. For the gasket configuration used in this test, the dramatic change in shielding effectiveness occurs between gasket volume resistivities of 0.01 and 0.4 ohm-cm. Since real enclosures do not have gold-plated flanges, but rather have surface finishes (such as MIL-C-5541 Class 3 chromate conversion coatings) which also increase in resistance over time, it is recommended that gasket volume resistivity be specified at 0.01 ohm-cm max. for the life of the equipment.

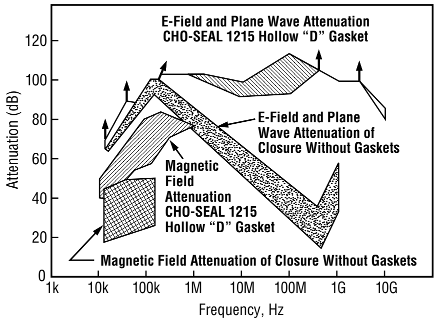


Figure 28 Shielding Effectiveness of a Shelter Door Gasket (14 kHz to 10 GHz)

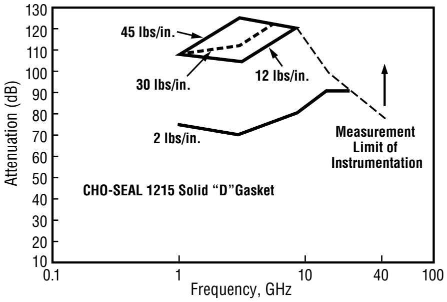


Figure 29 Effect of Closure Force on Shielding Effectiveness (1 GHz to 40 GHz)

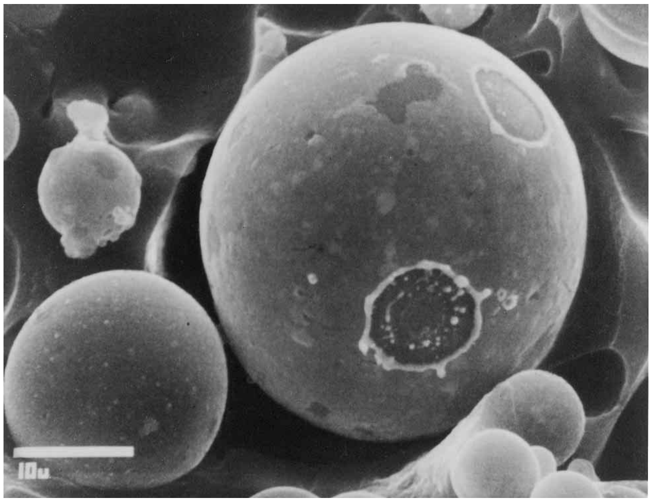


Figure 32 Scanning Electron Microscopy Illustrates EMP Damage Mechanism for Silver/Glass Elastomers

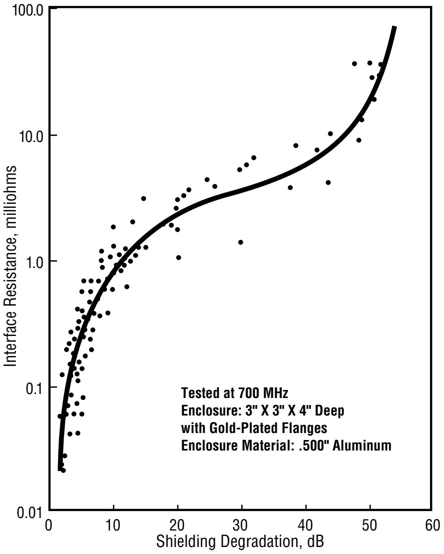


Figure 30 Interface Resistance vs. Shielding Degradation at a Flange Joint

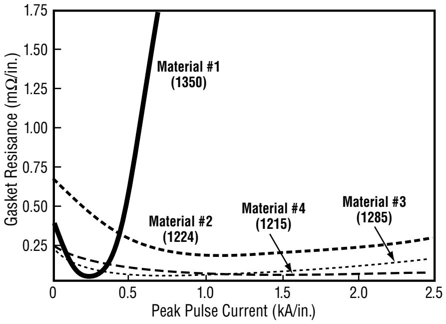


Figure 31 EMP Current Response of Conductive Elastomer Gaskets

Unit Conversion Note:
Gasket Resistance, 1 mΩ/in.= 25.4 Ω/mm
Peak Pulse Current, 1 kA/in.= 25.4 kA/mm

EMP Survivability

In order for an enclosure to continue providing EMI isolation during and after an EMP environment, the conductive gaskets at joints and seams must be capable of carrying EMP-induced current pulses without losing their conductivity. Figure 31 shows the EMP current response of various types of conductive elastomer gaskets. Note that gaskets based on silver-plated-glass fillers (1350) become nonconductive at low levels of EMP current, and should therefore not be used when EMP is a design consideration. Figure 32 is an electron microscope photo which clearly shows the damage mechanism. Silver-plated-copper filled (1215) gaskets have the highest resistance to EMP type currents, showing no loss of conductivity even at 2.5 kA/inch of gasket (peak-to-peak). Pure silver (1224) and silver-plated-aluminum filled (1285) gaskets have less current carrying capability than silver-plated-copper materials, but are generally acceptable for EMP hardened systems (depending on specific EMP threat levels, gasket cross section dimensions, etc.).

Vibration Resistance

Certain conductive elastomers are electrically stable during aircraft-level vibration environments, while others are not. The key factor which determines vibration resistance is the shape and surface texture of the filler particles. Smooth, spherical fillers (such as those used in silver-plated-glass materials) tend to move apart during vibration, leading to dramatic increases in resistance and loss of shielding effectiveness (although they normally recover their initial properties after the vibration has ended). Rough, less spherical particles resist vibration with very little electrical degradation. Figure 33 shows the effects of vibration on three types of conductive gaskets. Although Chomerics' silver-plated-copper filled 1215 gasket, with rough, irregular particle agglomerations, exhibits excellent stability during vibration, users of conductive elastomers should be aware that smooth, spherical silver-plated-copper fillers can be almost as unstable as silver-plated-glass fillers.

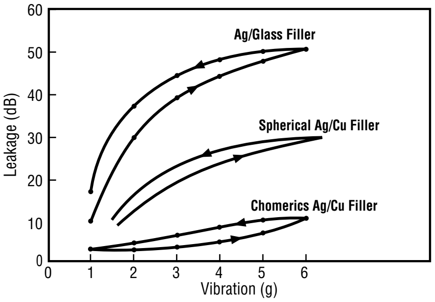


Figure 33 Effects of Vibration on Shielding Effectiveness of Conductive Elastomer Gaskets

Heat Aging

The primary aging mechanism which affects electrical stability of conductive elastomers is the oxidation of filler particles. For materials based on pure silver fillers, particle oxidation is not generally a problem because the oxide of silver is relatively soft and reasonably conductive. If the filler particles are non-noble (such as copper, nickel, aluminum, etc.) they will oxidize readily over time and become nonconductive. Even silver-plated base metal powders, such as silver-plated-copper or silver-plated-aluminum will become non-conductive over time if the plating is not done properly (or if other processing variables are not properly controlled). These are generally *batch control* problems, with each batch being potentially good or bad.

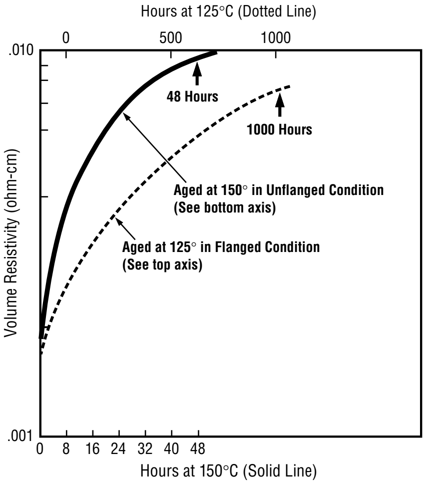


Figure 34 Typical heat aging characteristics of Chomerics' plated-powder-filled conductive elastomers. Flanged 1000-hr test recommended for qualification. Unflanged 48-hr. test recommended for QC acceptance.

The most reliable method of predicting whether a batch will be electrically stable is to promote the rate at which poorly plated or processed particles will oxidize, by heat aging in an air circulating oven. For qualification, 1000 hours (42 days) at maximum rated use temperature (with the gasket sample deflected 7-10% between flanges) is the recommended heat aging test for accelerating the effects of long-term aging at normal ambient temperatures. A quicker heat aging test, which correlates well with the 1000 hour test and is useful for QC acceptance testing, involves a 48 hour/150°C oven bake with the gasket sample on an open wire-grid tray (rather than being clamped between flanges). Figure 34 shows typical data for volume resistivity versus time for each of these tests.

Note: It is essential that no source of free sulfur be placed in the aging oven, as it will cause the material to degrade electrically and mask any oxidation aging tendencies. Common sources of sulfur are neoprenes, most cardboards and other paper products.

Outgassing

Many spacecraft specifications require that nonmetallic components be virtually free of volatile residues which might outgas in the hard vacuum environment of space. The standard test method for determining outgassing behavior is ASTM E595-93, which provides for measurement of total mass loss (TML) and collected volatile condensable materials (CVCM) in a vacuum environment. Data for a number of Chomerics conductive elastomers, based on ASTM E595-93 testing done by NASA Goddard Spaceflight Center, is presented in Table 2. The normal specification limits or guidelines on outgassing for NASA applications are 1% TML max., and 0.1% CVCM max.

Table 2

OUTGASSING DATA FOR CONDUCTIVE ELASTOMERS (PER ASTM E595-93)

Material	Special Post Curing	TML %	CVCM %	NASA GSFC Data Reference
CHO-SEAL 1212	None	0.40	0.13	15140
CHO-SEAL 1215	None	0.45	0.10	15142
CHO-SEAL 1217	None	0.45	0.01	15231
CHO-SEAL 1221	None	0.35	0.02	15249
CHO-SEAL 1224	None	0.41	0.10	15211
CHO-SEAL 1285	None	0.62	0.09	15251
CHO-SEAL 1287	None	0.63	0.03	15165
CHO-SIL 1401	None	0.92	0.37	15213
CHO-SIL 1485	None	0.36	0.08	15167
CHO-SEAL 1501	None	0.50	0.10	15247