SEAMS & JOINT DESIGN FOR EMC ENCLOSURES

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Seams

The total shielding effectiveness of an enclosure is limited by the failure of seams to make adequate electrical contact. Seam construction determines to a large extent whether an EMC shielding problem is solved. In the design of seams there are three considerations which will significantly increase the shielding effectiveness of the enclosure:

All seam mating surfaces must be electrically conductive.
The two surfaces of the seam form a capacitor. Since capacitance is a function of area, seam overlap should be made as large as practical to provide sufficient capacitive coupling for the seam to function as an electrical short at high frequencies. Minimum seam overlap to spacing-between-surfaces ratio of 5 is a good rule to follow.
Along the entire length of every seam there should be firm electrical contact at intervals no greater than ë/20 for commercial systems and ë/50 for military systems. This contact can be obtained by using pressure devices such as screws or fasteners, grounding pads, contact straps across the seam, or conductive gaskets.

A seam is formed by joining or overlapping two sections along their edges. If the fasteners provide sufficient pressure and the mating surfaces are conductive, then the fasteners provide an electrical short at the fastener locations. However, if the surfaces between the fasteners are electrically insulated by coatings such as anodize or nonconductive paint, or are separated due to bowing, then electrical contact may not be achieved. In the case of nonconductive finishes, it is possible that electrical contact will not be achieved even by the fasteners themselves. For screw fasteners electrical contact can be achieved through the screw threads; however, this means of achieving electrical bonding is neither reliable or recommended. Corrosion may form between mating threads, increasing contact impedance. Further, the amount of surface contact between mating threads is fairly small and good electrical contact cannot be assured.

Spacing between flanges in cabinets are normally very narrow compared to electrical wavelengths, but seam widths may be electrically long between fasteners or other contact points. The fact that one seam dimension can be electrically long raises concern about its shielding properties. Any seam (or seam segment between fasteners) can be considered a single aperture. At low frequencies all of the seam dimensions appear to be short compared to the half-wavelength and no leakage occurs. At higher frequencies, shielding effectiveness is a function of the longest dimension of the seam (such as fastener spacing) compared to a half-wavelength.

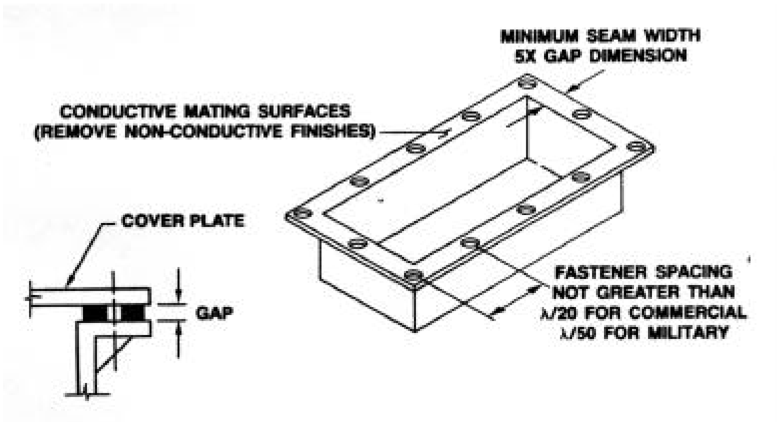
The total number of seams existing between the cover and cabinet lower the cut off frequency as a function of the square root of the total number of seams. Two parameters, then, determine the frequency where the seam shielding attenuation becomes zero: (1) seam length and (2) total number of equal seams.. To achieve maximum shielding, minimize the length of each seam by using additional fasteners. It can be concluded that it is more desirable to have several shorter seams rather than a few long ones.

The shielding integrity of the cover to cabinet seam can be increased by improving the electrical contact around and between the fasteners. A popular method of insuring continuous electrical contact is through the use of conductive gaskets. Conductive gaskets should be considered in the following cases:

Total enclosure shielding requirement >40 dB.	Nonmetallic cabinet material
Enclosures with openings greater than ë/20.	Dissimilar materials used on mating surfaces of seam.
Threat/emission frequencies exceed 100 MHz.	Environmental (i.e., dust/vapor) seals are necessary.
Machined mating surfaces are impractical.	

Seam Design

The primary function of an EMI seam gasket is to minimize the coupling efficiency of a seam. The reflection and absorption functions of the EMI gasket are to a large extent masked by metal cover plates and fasteners which provide the major contribution towards the restoration of the enclosure integrity. This fact does not diminish the important role of the EMI gasket in the enclosure design nor the adequate design of the enclosure to minimize enclosure discontinuities.



In the design of a shielding enclosure, the impedance between the mating seam surfaces should be as nearly equal to the enclosure material as possible to permit uniform current flow throughout the enclosure. Any significant difference in seam impedance, including that introduced by the gasket materials, can produce nonuniform current flow resulting in the generation of EMI voltages. These voltages can then be sources of radiated energy both into or out of the enclosure.

To provide effective shielding, the seam design should incorporate the following features:

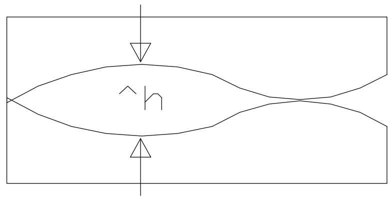
Mating surfaces should be as flat as economically possible.	Coating should be removed in the area of mating surfaces.
Mating surfaces requiring dissimilar materials should be selected with galvanic action in mind	Mating surfaces should be cleaned to remove all dirt and oxide films just prior to assembly of the enclosure parts.
Protective coatings having conductivity < half that of the mating surfaces should be avoided.	Surfaces requiring a protective coating should be plated with tin, nickel, zinc or cadmium.
Fasteners should be tightened from the middle of the longest seam toward the ends to minimize buckling.	Bonded surfaces should be held under pressure during adhesive curing to minimize surface oxidation.
Edges of exposed seams should be sealed with a suitable protective compound and preferably one which is conductive to prevent the intrusion of moisture.	Flange width should be at least five (5) times the maximum expected separation between mating surfaces.

Even with these precautions in the manufacturing, preparation and assembly of enclosure parts, mating surfaces are seldom perfect.

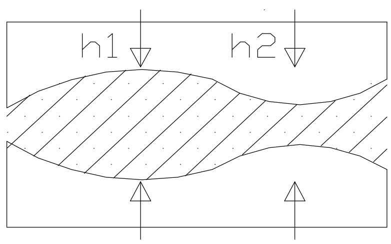
Gasket Design

In EMI shielding, many mechanical and electrical design considerations are interdependent. One of the more important ones is joint unevenness. Joint unevenness refers to the degree of mismatch between mating seam surfaces. It results when the mating surfaces make contact at irregular intervals due to surface roughness or to bowing of cover plates because of improper material selection, thinness of the cover plate, too few fasteners, excessive bolt tightening, or improper gasket selection. Ideally, gaskets should make firm, continuous and uniform contact with seam surfaces. Performance of any shielding product can be degraded by improper application. Joint unevenness is an excellent example of a mechanical restraint which can have an adverse effect on the electrical performance of a gasket.

Figure 7-1 depicts an enlarged cross sectional view of an enclosure seam. Figure 7-la shows the seam without gasketing material joining only at the irregular high spots between the surfaces. As pressure is applied, the irregular high spots become flattened resulting in more surface area and more points coming in contact to support the plate. Basically it is the function of a resilient gasket which bridges these gaps but at a much lower closing pressure. The ideal gasket will bridge irregularities within its compression-deflection capabilities without losing its properties of resiliency, stability or conductivity.



a) without gasket



b) with gasket

The maximum joint unevenness is the dimension of the maximum separation between the flanges of the seam when the two surfaces are just touching. This separation is designated as vh as shown in the following figure :

With a gasket in place, the maximum spacing (h1) between mating surfaces occurs at the minimum gasket compression. Conversely, the minimum spacing (h2) occurs at the maximum gasket compression. The difference between the maximum (hl) and the minimum (h2) spacing is vh. The gasket under these extreme conditions undergoes its severest mechanical test at the maximum deflection and severest electrical test at the minimum deflection.

There are, therefore, four important properties of an EMI gasket which must be considered before it is incorporated into an enclosure. These properties are compression (or deflection), compression set, shielding effectiveness and environmental seal. Compression, the reduction in volume of a gasket under pressure, is usually applied to sponge materials or products that are formed with hollow cores. Deflection, the reduction of a dimension due to pressure without necessarily resulting in a change in volume, is applicable to all materials including solid elastomers. Compression set is the permanent loss of the original height of a gasket after being compressed. It is important therefore to understand the various types of joints in order to determine which gasket properties are most important to a particular design.

Types of Joints: There are traditionally three types of joints classified by usage:

Type I Permanently mounted cover plates or assemblies. Generally compression set is not of concern in these applications even though high pressures may be encountered. The best gasket for this application is a knitted wire mesh gasket pressed to the desired gasket shape.

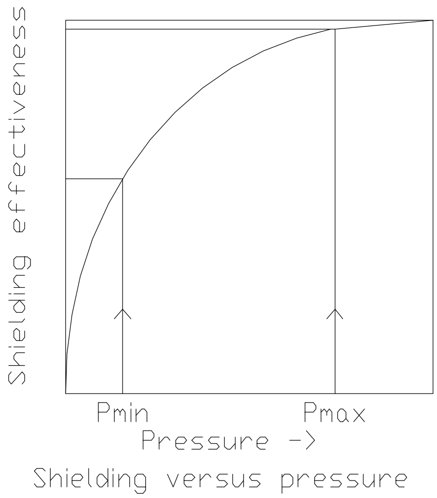
Type II Access cover plate with high joint unevenness which is opened frequently but always closes on the same portion of the gasket. A hinged door is an example of a Type II joint. Most of the elastomeric gaskets are suitable for this type of application where the closure pressures are under 100 psi. In the lowest closure pressures, the hollow-shaped elastomers are most suitable.

Type III Removable cover plate with a symmetrical mounting pattern which is replaceable but not necessarily in the original orientation. Gaskets for this type of application are removable and reusable. Gasket materials which exhibit low closure force and low compression set would be suitable in most applications.

Other Gasket Design issues:

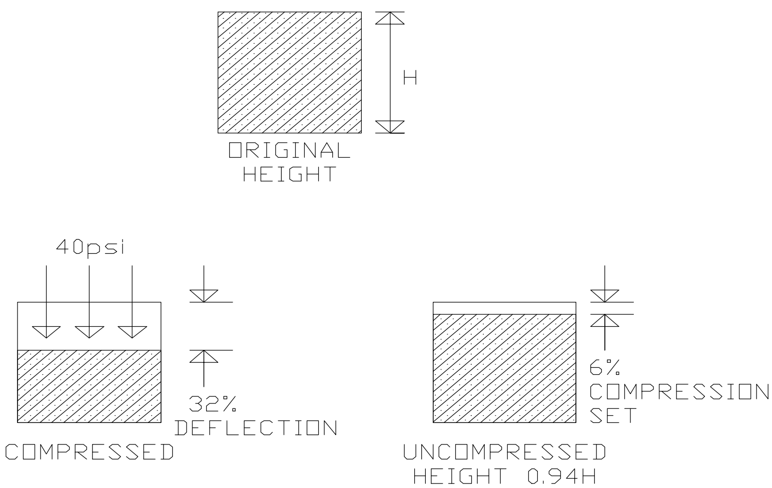
Minimum gasket width should not be less than one half of the thickness (height).	Minimum distance from bolt hole (or compression stop) to nearest edge of sealing gasket should not be less than the thickness of the gasket material. When bolt holes must be closer, use U-shaped slots.

Minimum hole diameter not less than gasket thickness.	Tolerances should be conservative whenever possible.



Closure Pressure

Shielding effectiveness and closure pressure have a general relationship as shown in Figure left. The minimum closure force (Pmin) is the recommended applied force to establish good shielding effectiveness and to minimize the effects of minor pressure difference. The maximum recommended closure force (Pmax) is based on two criteria: (1) maximum compression set of 10% and/or (2) avoidance of possible irreversible damage to the gasket material when pressure exceeds the recommended maximum. Higher closure pressures may be applied to most knitted wire mesh gaskets when used in Type I joints, but the gaskets should be replaced when cover plates are removed, i.e., whenever the seam is opened.



Compression Set

Selection of a gasket material for a seam which must be opened and closed is to a large extent determined by the compression set characteristics of the gasket material. Most resilient gasket materials will recover most of their original height after a sufficient length of time when subjected to moderate closing forces. The difference between the original height and the height after the compression force is removed is compression set. As the deflection pressure is increased, the compression set increases (See Figure 7-4).

General Compression/Deflection Curves
Compression/deflection curves can be used to determine the following gasket characteristics:

1. Gasket height needed to compensate for joint unevenness.
2. Gasket closing pressure needed to assure good shielding.
3. Gasket compression set as a function of applied pressure.

The data presented is representative of the general characteristics of the materials depicted. Variation in the values presented can be expected as a result of manufacturing tolerances, density of material, variation in hardness (durometer) and variations in cross sections. On the following example curves on figure 7-5 the knitted wire mesh gasket shows a minimum recommended closing pressure of 138 kPa (20 psi) and a maximum recommended closing pressure of 414 kPa (60 psi). Below 138 kPa (20 psi), a significant fall off in shielding effectiveness can be expected while above 414 kPa (60 psi) high compression set may result. Using these minimum (Pmin) and maximum (Pmax) pressure values and extending them to the compression/deflection curve, minimum and maximum compression values (percentage of original gasket height H) can be determined. In the case of the knitted wire mesh, the minimum recommended deflection is 80% of the original height (or 0.8H), and the maximum recommended deflection is 60% (or 0.6H).

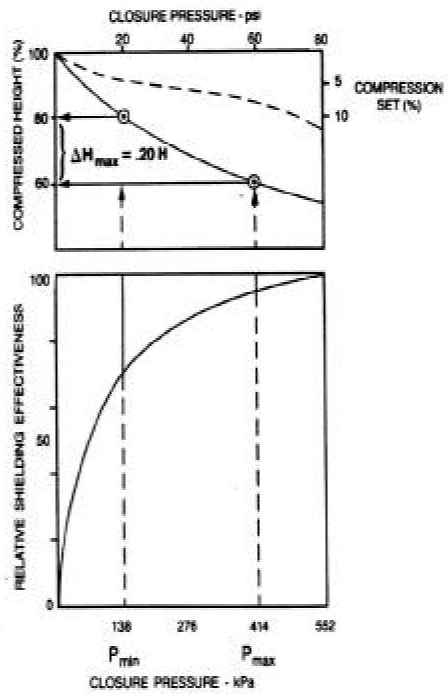


Figure 7-5, Knitted Wire Mesh Gasket

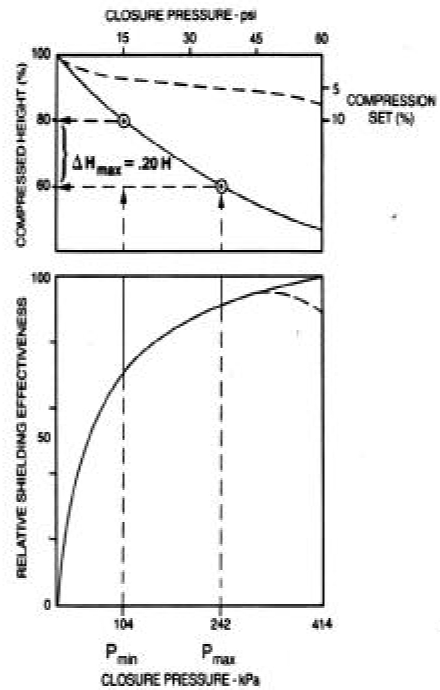


Figure 7-7, Oriented Wires in Sponge Elastomer (ELASTOFOAM)

The difference in gasket height then is:

ªH = 0.8H - 0.6H = 0.2H

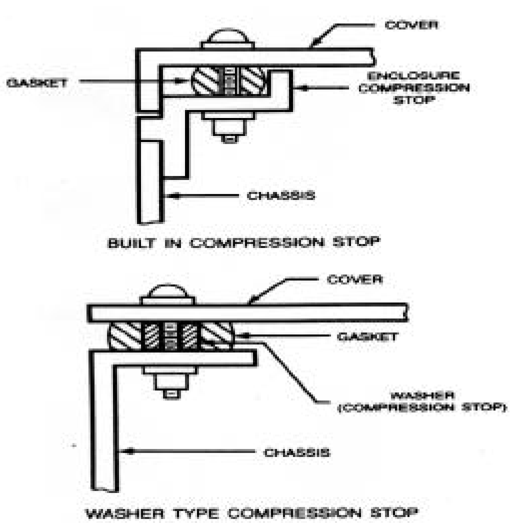
Using this value with the known or anticipated joint unevenness, the minimum gasket height can be calculated. For purposes of this example, assume joint unevenness ªh is 0.06".

ªh = h1 - h2 = 0.06"

For minimum gasket height, the maximum compression Difference (ªH) must equal the maximum joint unevenness (ªh), ªH = ªh. Substituting for ªH (0.2H) and for ªh (0.06").

$$0.2H = 0.06'' \text{ so} \qquad H_{min} = \frac{0.06''}{0.2} = 0.30''$$

This value is the minimum gasket height which will accommodate the required pressure range, shielding effectiveness, compression set and joint unevenness when using a knitted wire mesh gasket. Any gasket with a height greater than 0.30" should be suitable for the depicted example.



Compression Stops

In order to avoid damage to the gasket or excessive bowing of the cover plate from gasket over compression, discs or washer type compression stops can be provided as an integral part of the gasket assembly. Compression stops are stamped out from standard gauge sheet or cut to thickness from rod or tubing. Materials commonly used are aluminum and stainless steel. For sponge elastomers, compression stops should be cut to a maximum of 80% of the elastomer thickness and a minimum of 65%. For solid elastomers, the compression stops should be 90% to 95% of the gasket height.

Another form of compression stop is to confine the gasket by means of a groove such that the cover plate flange mates with enclosure flange, thereby effecting a compression stop.

Fastener Spacing

Fasteners are normally required between cover plate and enclosure to provide enough closing force along the seam length to insure adequate contact pressure and to compensate for joint unevenness. Fastener spacing, cover plate thickness, minimum-maximum pressures, gasket compressibility and material characteristics are important parameters in the cover plate design.

Maximum gasket deflection occurs at the fastener locations where the maximum compressive force is applied. Frequently the closure forces required to compress a resilient gasket is sufficient to cause bowing of the cover plate. The amount of bowing depends on several interrelated factors. The bowing can be severe enough that insufficient pressure is applied at the mid action of the gasket resulting in little or no shielding or even the development of a slit gap. These effects can be minimized by proper spacing, proper cover plate thickness and proper selection of gasket materials. The basic equation for bolt spacing (reference Figure 7-13) is given as:

$$C = \left\{ \frac{480\ (a/b)\ E\ t^3\ {}^{a}H}{13\ P_{min} + 2P_{max}} \right\} \quad \text{exp } 1/4$$

where

a=width of cover plate flange at seam	b=width of gasket
C =bolt spacing	E=modulus of elasticity of cover plate
ªH=H1 -H2	H=gasket height
Pmin / Pmax=minimum/maximum gasket pressure	t=thickness of cover plate
HI =minimum gasket deflection	H2 =maximum gasket deflection

The equation can be tremendously simplified by making two assumptions which can be shown to have only slight affect on the result or which can be used to provide a close approximation for bolt spacing. These assumptions are:

1 .Width of gasket equals width of cover plate flange (a=b).

This condition is the limiting condition since the cover plate flange dimension (a) is always equal to or greater than the gasket width (b). For a gasket width equal to one half of the flange width, the bolt spacing correction is less than 1.19 times the value obtained for a=b or (a/b=1). The actual correction factor is the fourth root of the a/b ratio or (a/b)exp1/4. Using (a=b) actually provides a safety factor over any other relationship between (a) and (b).

2. Maximum pressure (Pmax) equals three times the minimum pressure (Pmin). For almost all resilient gaskets, Pmax is usually greater than twice Pmin. Using the ratio Pmax/Pmin = 3, bolt spacing is reduced by less than 7% for Pmax to Pmin ratio of 6. Actual correction factors for other values of Pmax to Pmin ratios and Pmin are given in the following table:

Pmax/ Pmin correction		Pmin correction	
Pmax/Pmin	Correction factor	Pmin correction	correction factor
2	1.02	10	1.19
3	1.00	20	1.00
4	.98	30	0.90
5	.95	40	0.84
6	0.94	50	0.80

Incorporating these two assumptions into the basic equation, the bolt spacing is:

$C = 2.242\ [E t^3 {}^{\wedge}H/P_{min}]$ exp 1/4 where a/b = 1 and Pmax/Pmin =3 and for Pmin = 20 psi, typical elastomeric gaskets:

C = 59.62 [t³^H] exp 1/4 , aluminium plate (E=10 exp7 psi)

C = 78.46 [t³^H] exp 1/4 , steel plate (E=3 x10 exp7 psi)