percentage increase required to satisfy βd = 3 is 64 percent. It is desirable, therefore, that βd should be kept as small as possible. This can be achieved by using stiff flanges or spacing bolts closer together.

Designing a Solid-O Conductive Elastomer Gasket-in-a-Groove

The *solid-O profile* is the most often specified conductive elastomer EMI gasket for several key reasons. Compared to other solid cross sections, it offers the widest deflection range to compensate for poorly toleranced mating surfaces and to provide reliable EMI shielding and pressure sealing. It can be installed in a relatively small space, and is the most easily installed and manufactured. It also tends to be less prone to damage, due to the absence of angles, corners or other cross section appendages.

The *"gasket-in-a-groove"* design offers five significant advantages over surface-mounted EMI gaskets:

1. Superior shielding, due to substantial metal-to-metal contact achieved when the mating surfaces are bolted together and "bottom out". (Flat die-cut gaskets prevent metal-to-metal contact between mating flange members, which reduces EMI shielding performance – especially in low frequency magnetic fields.)

2. Positive control over sealing performance. Controlling the size of the gasket and groove can ensure that required shielding and sealing are achieved with less careful assembly than is required for flat gaskets. In other words, the gasket-in-a-groove is more foolproof.

3. Built-in compression stop provided by the groove eliminates the risk of gasket damage due to excessive compression.

4. A gasket retention mechanism can be provided by the groove, eliminating the need for adhesives or mounting frames.

5. High current-handling characteristics of the metal-to-metal flange design improves the EMP and lightning protection offered by an enclosure.

This section presents the method for calculating groove and gasket dimensions which will permit the shielding system to function under worst-case tolerance conditions. Adherence to these general guidelines will result in optimum shielding and sealing for typical electronics "boxes". It should be understood that they may not be suitable for designing shielding for sheet metal cabinets, doors, rooms or other large, unconventional enclosures.

Important Notes: The guidelines presented here are intended to consider only "solid O" gasket cross sections. The calculations for hollow O, solid and hollow D, and custom gasket cross sections differ from these guidelines in several key areas.

Chomerics generally does not recommend bonding solid O gaskets in grooves. If for some reason your design requires gasket retention, contact Chomerics' Applications Engineering Department for specific recommendations, since the use of adhesives, dove-tailed grooves or "friction-fit" techniques require special design considerations not covered here.

Extreme design requirements or unusually demanding specifications are also beyond the scope of the guidelines presented here. Examples would include critical specifications for pressure sealing, exceptionally high levels of EMI shielding, exceptional resistance to corrosion, harsh chemicals, high temperatures, heavy vibration, or unusual mounting and assembly considerations.

Mechanical Considerations

Causes of Seal Failure

In order to produce a gasket-in-a-groove system which will not fail, the designer must consider three mechanical causes of seal failure:

gasket over-deflection and associated damage (see Figure 28d)

gasket under-deflection and loss of seal (see Figure 28f)

groove over-fill, which can destroy the gasket (see Figure 28e).

Designing to avoid these problems is made more complicated by the effects of:

worst-case tolerance conditions

deformation of the cover (cover bowing)

poor fit of mating surfaces.

The key to success involves selection of the appropriate gasket size and material, and careful design of the corresponding groove.

Deflection Limits

In nearly every solid-O application, Chomerics recommends a *minimum deflection of 10% of gasket diameter.* This includes adjustments for all worst-case tolerances of both the gasket and groove, cover bowing, and lack of conformity between mating surfaces. We recommend a *maximum gasket deflection of 25% of gasket diameter*, considering all gasket and groove tolerances.

Although sometimes modified to accommodate application peculiarities, these limits have been established to allow for stress relaxation, aging, compression set, elastic limits, thermal expansion, etc.

Maximum Groove Fill

Solid elastomer gaskets (as opposed to foam rubber gaskets) seal by changing shape to conform to mating surfaces. They *cannot* change volume. The recommended limit is *100% groove fill under worst-case tolerances of both gasket and groove.* The *largest* gasket cross sectional area must fit into the *smallest* cross sectional groove area.

Analyzing Worst-Case Tolerances

Figures 28a-c illustrate the issues of concern, and identify the parameters which should be considered in developing an effective design.

Figures 28d and e illustrate two different cases which can result in gasket damage in the area of torqued bolts. In Figure 28d, the relationship between groove depth and gasket diameter is critical in avoiding over-deflection. In Figure 28e, sufficient groove volume must be provided for a given gasket volume to permit the gasket to deflect without over-filling the groove.

As shown in *Figure 28f*, cover deformation and groove sizing must be controlled to make sure the gasket is sufficiently deflected to seal the system.

Since a single gasket and groove are employed for the entire perimeter, the design must be optimized for each of the worst-case examples illustrated in Figures 28d-f.

Figure 28a
Exploded View of Electronic Enclosure

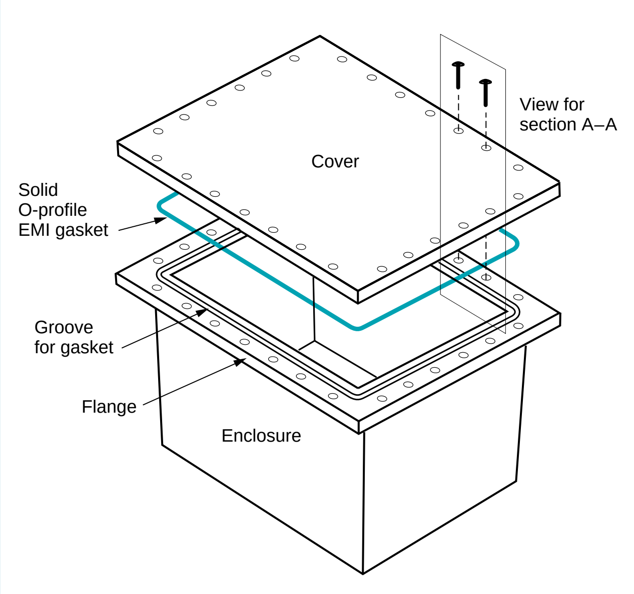


Figure 28b
Cut-away View of Assembly

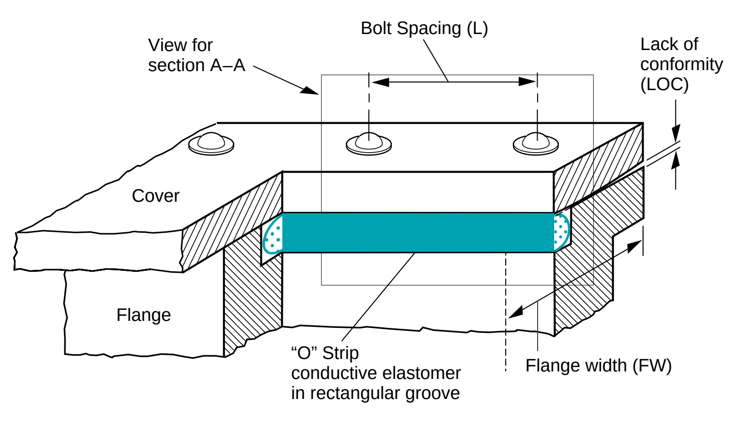


Figure 28c
Section A-A of Assembled Enclosure Flange and Gasket
(Sectioned midway through gasket and groove)

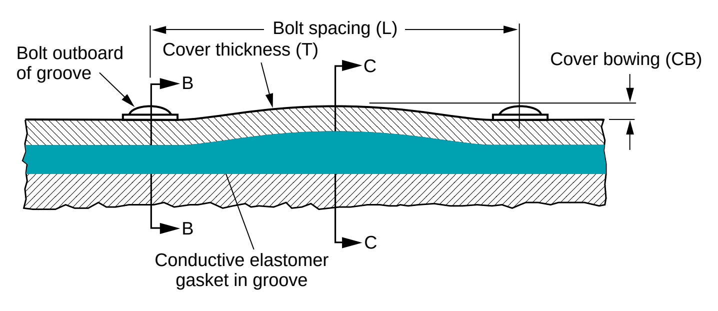
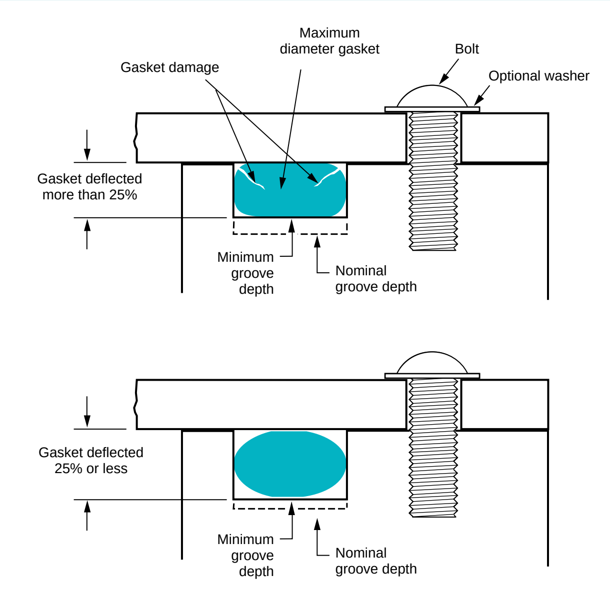


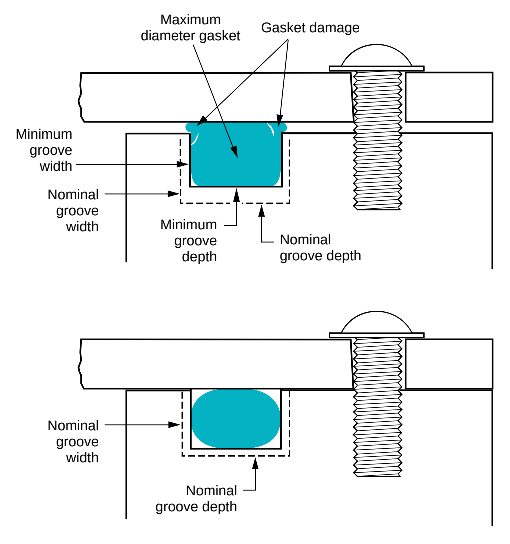
Figure 28d Section B-B from Figure 28c – Worst Case Maximum Deflection *(Maximum gasket diameter, minimum groove depth)*



Problem: Gasket too tall for minimum groove depth (deflection beyond elastic limit). Results in gasket damage or fracture.

Solution: Over-deflection avoided with smaller maximum gasket diameter and/or deeper minimum groove depth.

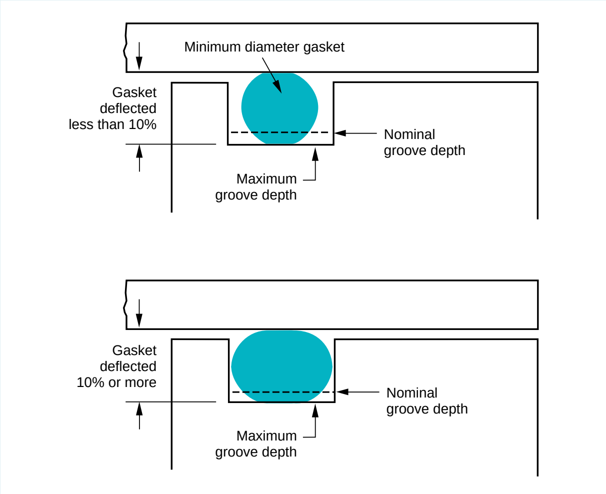
Figure 28e Section B-B from Figure 28c – Worst Case Maximum Groove Fill *(Maximum gasket diameter in minimum groove depth and width)*



Problem: Minimum groove dimension cannot accommodate maximum gasket diameter, resulting in gasket damage.

Solution: Groove over-fill avoided with smaller maximum gasket diameter and/or greater minimum groove depth and/or width.

Figure 28f Section C-C from Figure 28c – Worst Case Minimum Deflection *(Minimum gasket diameter in maximum depth groove, aggravated by cover bowing and lack of conformity between mating surfaces)*



Problem: Gasket will not be deflected the recommended 10% minimum. Combined effects of tolerances, cover bowing, and lack of conformity can result in complete loss of cover-to-gasket contact over time, and consequent seal failure.

Solution: Under-deflection avoided with larger minimum gasket diameter and/or shallower maximum groove depth.

Calculating the Dimensions and Tolerances for the Groove and EMI Gasket

Figure 29 diagrams the calculation and decision sequence required to determine the dimensions for a properly designed solid-O gasket/ groove system. Because the relationship between groove depth and gasket diameter is central to seal performance, *groove depth is selected as the key variable to determine first.*

Start by making an educated guess as to reasonable values for groove and gasket sizes and tolerances, based on desired nominal gasket deflection of 18%. For example, if 0.025 in. of gasket deflection is desired, start with a nominal gasket diameter of 0.139 in. This is calculated by dividing the desired total gasket deflection by 0.18 to estimate the required gasket size. (Total Gasket Deflection ÷ 0.18 = Approx. Nominal Gasket Size.) This relationship is an alternate form of Formula 1. Final groove dimensions can only be determined after completing all of the calculations called for in Figure 29, and arriving at values which remain within the recommended limits for gasket deflection and groove fill.

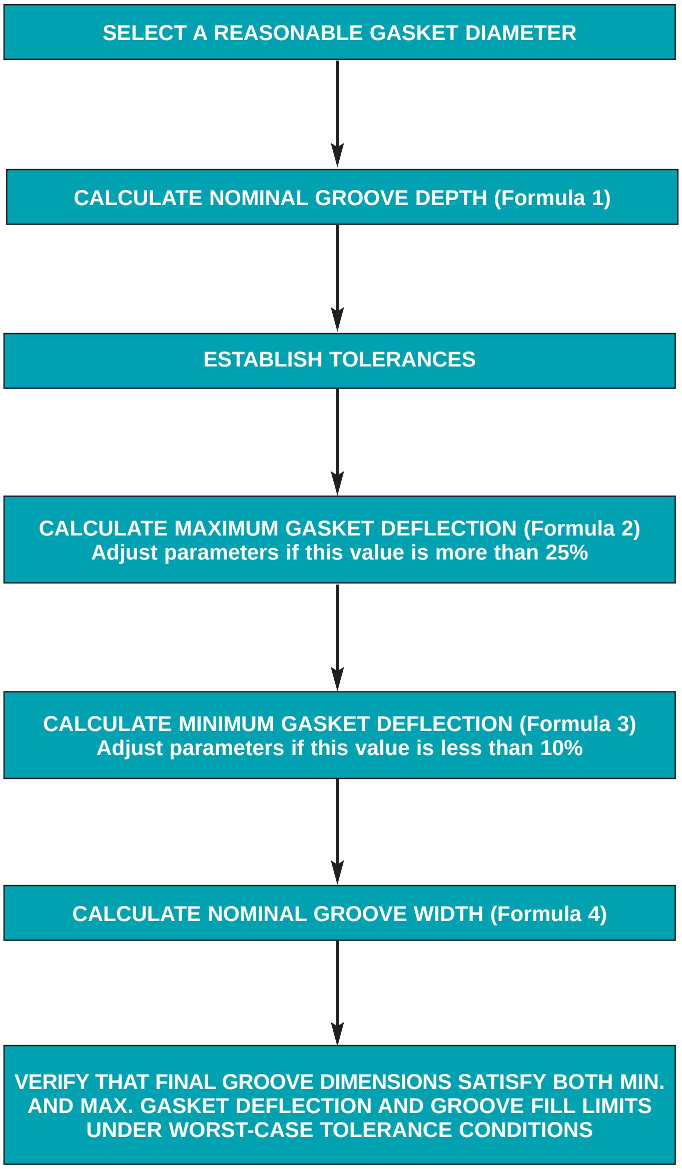


Figure 29 Procedure for Calculating Gasket and Groove Dimensions

Formulas *(see definition of terms at right)*

1. Nominal Groove Depth

$GrD_{nom} = 0.82\ GaD_{nom}$

2. Maximum Gasket Deflection

(Worst Case, expressed as a % of gasket diameter)

$$GaDf_{max} = 100 \left[\frac{(GaD_{nom} + GaT) - (GrD_{nom} - GrDT)}{(GaD_{nom} + GaT)} \right]$$

3. Minimum Gasket Deflection

(Worst Case, expressed as a % of gasket diameter)

a. $$GaDf_{min} = 100 \left[\frac{(GaD_{nom} - GaT) - (GrD_{nom} + GrDT) - CB - LOC}{(GaD_{nom} - GaT)} \right]$$

where

b. $$CB = \frac{GDF \times L^4_{max}}{FW_{min} \times T^3_{min} \times E \times 32}$$

(***Note:*** Formula must be adjusted when using metric units)

and

c. LOC = 0.001 in. for machined surfaces with surface roughness of 32-64 μin. RMS.

(For discussion, see Terms.)

4. Nominal Groove Width

a. $GaA_{max} = 0.7854^{*}\ (GaD_{nom} + GaT)^2$

b. $$GrW_{min} = \frac{GaA_{max}}{GrD_{min}}$$

c. $GrW_{nom} = GrW_{min} + GrWT$

****Note:*** $0.7854 = \frac{\pi}{4}$

Terms

All values may be calculated in inches or mm unless otherwise indicated.

GaA_{max} – Maximum gasket cross section area (in^2 or mm^2)

GaD_{nom} – Nominal gasket diameter

GaT – Gasket tolerance (difference between max. and nom. or min. and nom.)

GrW_{min} – Minimum groove width

GrWT – Groove width tolerance

GrW_{nom} – Nominal groove width

GrD_{min} – Minimum groove depth

GrD_{nom} – Nominal groove depth

GrDT – Groove depth tolerance (difference between max. and nom. or min. and nom.)

$GaDf_{max}$ – Maximum gasket deflection (%)

$GaDf_{min}$ – Minimum gasket deflection (%)

L_{max} – Maximum bolt spacing

FW_{min} – Minimum flange width

T_{min} – Minimum cover thickness

GDF – Gasket deflection force (ppi or Newtons per meter).

Note: For the purpose of this guide, the GDF value should represent the worst-case minimum gasket deflection arising from cover bowing. For example, the GDF is taken at 10% deflection for the calculation in Formula 3b.

E – Young's modulus. (For aluminum, use 1 x 10^7 psi, or 7 x 10^5 kg/cm^2.)

CB – Cover bowing, generally calculated by modeling the elastic deformation of the cover as a uniformly loaded beam with two fixed supports. (The moment of inertia of the cover is modeled as a rectangular beam, the "height" of which is taken to be equal to the cover thickness, while "width" is considered equal to flange width. The moment of inertia can be adjusted for cover configurations other than flat. Refer to an engineering handbook for the necessary revisions to Formula 3b.) An assumption is made that one side of a cover/flange interface is infinitely stiff, typically the flange. If this is not essentially true, elastic deformation of each is computed as though the other were infinitely stiff, and the two values combined.

LOC – Lack of conformity, the measure of the mismatch between two mating surfaces when bolted together, expressed in inches. Experience has shown that machined surfaces with a surface roughness of 32-64 μin. RMS exhibit an LOC of 0.001 in. It is left to the engineer's judgment to determine LOC for other surfaces. LOC can be determined empirically from measurements made of actual hardware. In this guide, LOC applies only to the surfaces which form the EMI shielding interface.