SHIELDING AIDS

A shielding aid can be defined as any product which aids in the containment of or protection against electromagnetic fields. This includes electric fields, electrostatic fields, magnetic fields and plane waves. This type of product can stretch your imagination. In addition to those listed in the Product Index are:

Conductive Cloth
Conductive Rubber
Conductive Monofilament
Conductive Lubricants
Conductive Textile Products
Conductive Silicone
Conductive Adhesive
Conductive Caulking
Conductive Closures
Conductive Gaskets
Conductive Closure Elements
Conductive Elastomers
Conductive Glass
Conductive Paint
Conductive Epoxy
Reflective Cloth
Shielded Windows
Shielded Glass
Cable Shielding Tape
Pressure Sensitive Tapes
Push Button Shielded Boots
Switch Shielded Boots
Connector Boots
Shrink Tubing
D-Strip Gaskets
O-Strip Gaskets
Hollow Strip Gaskets
Connector Gaskets
Waveguide Seal/Shield Gaskets
Zip-on Shielding
Hipernon Foils
Netic Co-Netic Foils
Foam-Foil
EMI/RFI Shielded Shaft Seals
Shielded Ventilating Panels
Shielded Air Filter Panels
Rack Mounted Shielded Enclosures

AND THERE ARE MANY OTHERS!

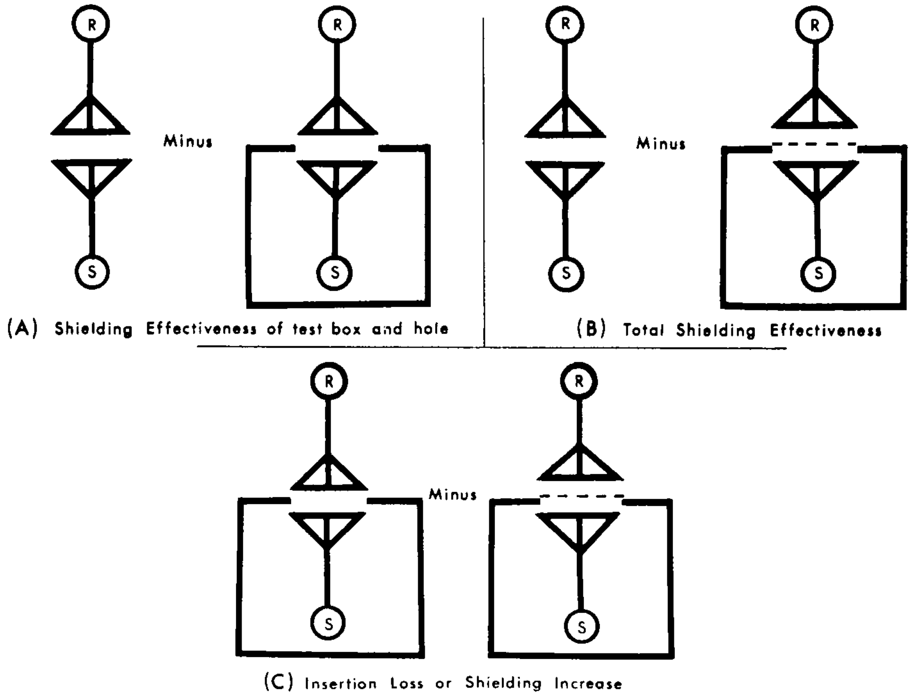
DEFINITIONS

A good design engineer should be familiar with the following definitions when selecting shielding products:

1. *SHIELDING INCREASE*–is the difference of an electromagnetic field amplitude emanating through a seam (as measured under fixed test conditions) with and without a gasket in the seam, with the force joining the seam remaining constant. The difference is expressed in decibels (dB) based on voltage measurements.
(Awithout gasket - Awith gasket) = Shielding Increase
2. *TOTAL SHIELDING EFFECTIVENESS*–is the difference of an electromagnetic field amplitude emanating from a source within an enclosure, and that from a source in free space. The difference is expressed in decibels (dB), based on voltage measurements.
(Afree space - Awithin enclosure) - Total Shielding Effectiveness
3. *FORCE*–The force used in testing during the use of a gasket should be expressed in pounds per linear inch of gasket or seam.
4. *GASKET EMI*––A material that is inserted between mating surfaces to provide isolation between two electromagnetic environments.
5. *INSERTION LOSS*–is the difference of an electromagnetic field amplitude emanating directly between two antennas, and that when a shielding aid or product is placed directly in the field separating the antennas. The difference is expressed in decibels (dB) based on voltage measurements.
(Adirect - Awith product = Insertion Loss)
6. *ATTENUATION*––Attenuation can be expressed as the difference between two levels of received energy under a defined set of circumstances. This difference is expressed in decibels (dB) as follows:

ATTENUATION

Figure 1 shows illustrations which may help you understand these definitions.



(A) Shielding Effectiveness of test box and hole

(B) Total Shielding Effectiveness

(C) Insertion Loss or Shielding Increase

Basic Considerations

When designing to attenuate fields, it is best to first define the nature of the field. For instance, electrostatic or electric field materials such as aluminum, copper, or monel, will have little or no effect on attenuating magnetic fields. For magnetic fields, the product must have permeability or other magnetic properties such as the Co-Netic material shown in the PERFECTION MICA COMPANY Catalog Sheet on Page 89.

Tape materials and foils can be used to help shield cables chassis and cabinets. Again, the selection should be based upon the type of shielding and amount of shielding (attenuation) desired. Most tapes have adhesive backings which are conductive and pressure sensitive. Thus, when they are overlapped on a cable, more complete shielding is obtained. The tape is also placed over seams and holes to reduce case leakage. To be effective, the surface upon which the tape is placed must be conductive (free of paint, dust, film and oxides, etc.) as must be the adhesive. The performance obtained will probably be more a function of these conductivities than the thickness of the foil materials, except for magnetic fields.

When shielding against magnetic fields, it may be desirable to have several isolated layers of thin material rather than one layer of thick material. This is true particularly at very low frequencies. For example a three layer container is shown on page 89.

Some shielding materials are available in sheet form enabling the user to cover entire areas or to punch out their own gasket forms. Foam/Foil, as offered by TAPECON, INC. (page 92), is available in sheets, as are the elastomers offered by METEX CORPORATION (page 91); TECKNIT (page 93); and CHOMERICS (page 87).

In addition to the tapes and foils, the following basic types of shielding aid materials are available:

1. *Woven Knitted Wire Mesh:* Can be aluminum, monel, copper, or other combinations of metals, closely woven in various densities.
2. *Conductive Elastomer:* Metal particles freely suspended in silicone or other non-conductive substances. These particles are mostly silver for high conductivity, but can be made of other metals. Can be in a fluid or solid form.
3. *Metal Impregnated:* Wire mesh, screening and other continuous metal parts impregnated in non-conductive substances such as silicone and others. The tips of the metal extend beyond the surface of the non-conductive substance.
4. *Conductive Glass:* Tin oxide, lead oxide and other conductive substances chemically deposited on the surface of glass. However, shielded see-through panels are more readily available as thinly woven mesh laminated by clear glass or plastic, as shown on page 93.
5. *Honeycomb Cells:* Metal honeycomb panels, consisting of many 5-sided cells electrically and mechanically bonded together.

There are other products such as conductive felt, conductive rubber, etc., but the five listed above, and the foils, are among the most common.

The woven or knitted mesh is available in many forms including: flat sheets, strips (on spools), either circular or rectangular, woven over a rubber or silicone core to provide a combination electrical and environmental seal, affixed to rubber and silicone for the same purpose, affixed to metal strips to provide a mechanical stop, as tape for wrapping harnesses, etc.

The conductive elastomers include a wide variety of products, including epoxy, shrinkable tubing, gasket strips similar to that of the woven mesh, switch covers or "fuzz buttons", connector gaskets, etc. The solid elastomer provides both an electrical and environmental seal.

The metal impreganted gasket material was the forerunner to the elastomers. It was most widely used as a connector gasket or in sheet form for easy punching without burrs. It still widely used when the conductive elastomer is more expensive and when a lesser performance can be tolerated.

The conductive or "leaded" glass is available, but the laminated wire mesh in clear plastic is more widely used. The treated glass has poorer attenuation characteristics at high frequencies (above 50 MHz). The see-through panel usually has a conductive strip around its periphery, such as a woven mesh gasket, for electrical grounding to the enclosure.

The Honeycomb panel has been available for a long time and is basically the most effective product for protecting large openings and air passages. Its major feature is that it provides shielding without significantly impeding air flow. It is now available with additional screens, etc., as an effective air filter.

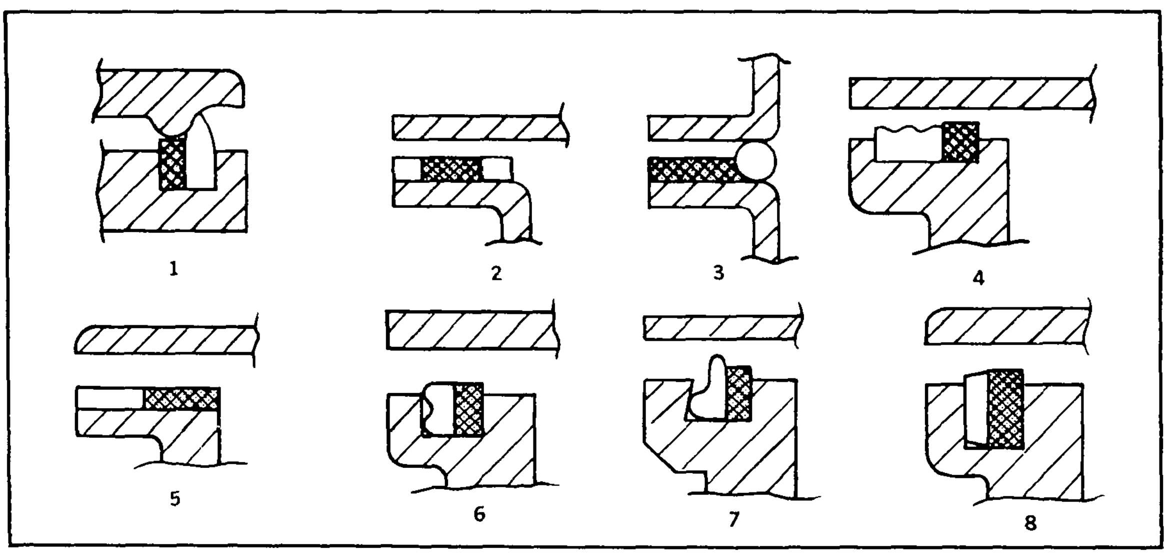


Fig. 2 Duosil offers unlimited seal/shield design possibilities.

Application Hints

Regardless of the type of gasket material used, it must be electrically grounded in order to be effective. When using conductive gasket material in seams and joints, overlapping surfaces must be provided. The surfaces making contact with the gasket should be highly conductive. Small areas of insulated surface can compromise the shielding of a box. Corners should be carefully treated to assure good contact with joining surfaces. Figure 2 shows some examples of gasket installation.

Solid mesh gaskets can take a set when over compressed, thus losing its resiliency. Optimum performance can be obtained by applying 20 psi of pressure uniformally over the entire gasket. The placement of a fastener in the corners usually precludes common leakage problems.

Some solid elastomer gaskets can tolerate more pressure than the woven mesh without setting. However, the elastomer can be cut through by knife edges. Figures 3 to 6 show some applications of the elastomer gaskets. A cross-section of a hollow strip gasket is provided by CHOMERICS on page 87.

Figure 7 provides a curve showing the typical shielding effectiveness obtained from conductive see-through panels with laminated wire mesh. There are several varying parameters which must be considered. The shielding effectiveness of any material will vary as a function of frequency. Generally, it is lower at the higher frequencies. The aperture of the hole can be significant. Figure 7 is for a 5-inch diameter opening. The hole itself has an aperture effect providing attenuation to signals whose wave length is significantly larger than the size of the hole. Where the depth of the material is within 1/10 of the hole aperture, the hole may begin to act as a wave guide. Less shielding effectiveness can be expected from the see-through panel as the hole size gets larger. Care must be given to the electrical bonding of the conductive seal around the edge of the panel. The see-through panel can not be expected to attenuate better than its seal.

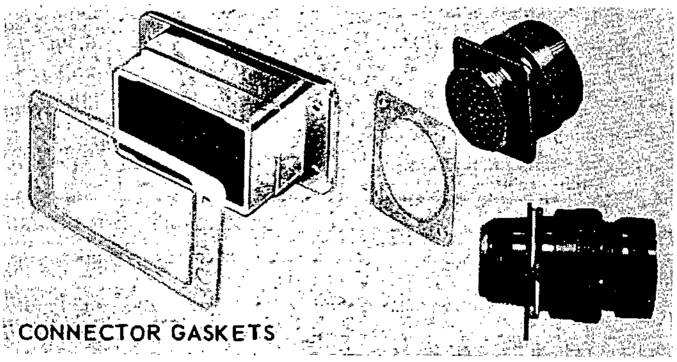


FIG. 3

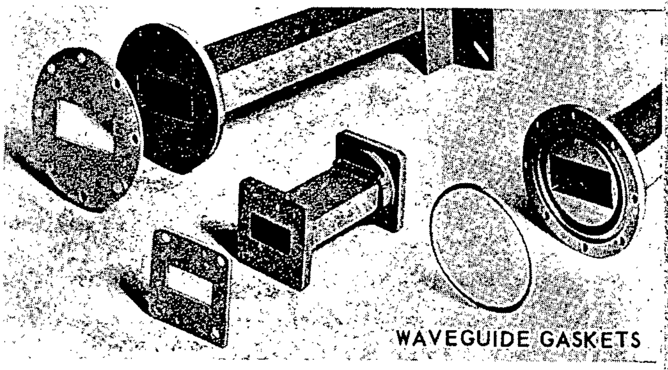


FIG. 4

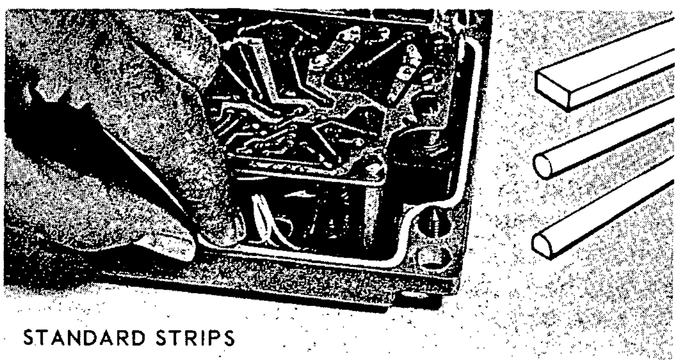


FIG. 5

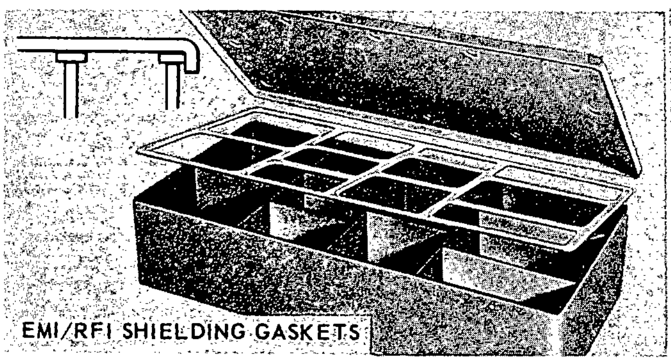


FIG. 6

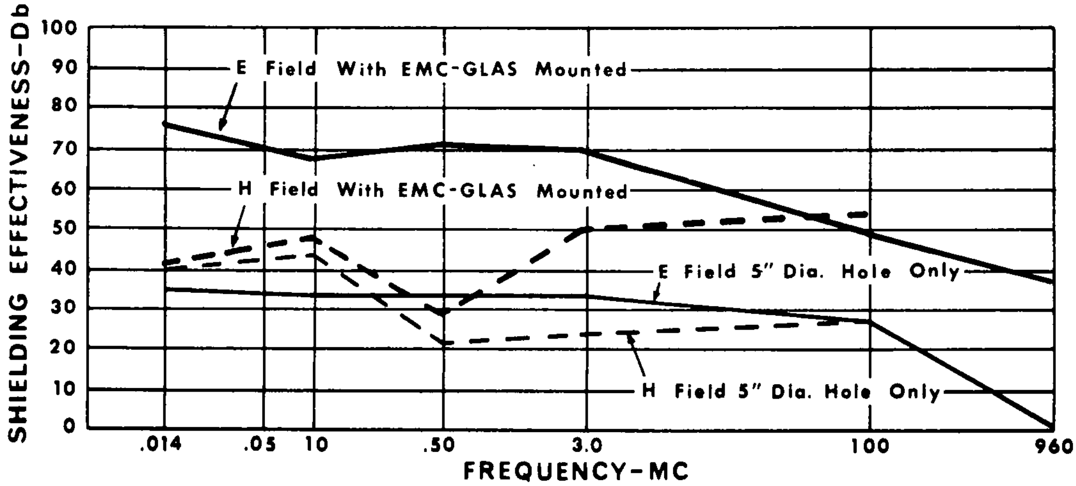


FIG. 7 Shielding Effectiveness VS. Frequency for 5" Dia. Test Opening

——— Total Shielding Effectiveness "E" Field with EMC-GLASS

– – – Total Shielding Effectiveness "h" Field with EMC-GLASS

——— Shielding Effectiveness of Opening "E" Field

– – – Shielding Effectiveness of Opening "H" Field

Honeycomb Theory

At low frequencies metallic honeycomb must be evaluated as an enclosure material. The analysis applied to determine high frequency performance will not hold at low frequencies because the material appears electrically as a "sheet" and not as a series of parallel waveguides.

For low frequency magnetic fields, practically no Attenuation is provided by reflection loss. All Attenuation results from the absorption loss which is given by the general equation:

$$A = 8.686\sqrt{\pi \mu f \sigma} \quad \text{dB}$$

where d is the sheet thickness (assuming a solid metal sheet), μ is the permeability, f is frequency and σ is the conductivity of the shield. At low frequencies, f is naturally low. Conductivity (σ) is similar for all metals and is not as vastly different as permeability (μ). Thus selection of a permeable metal honeycomb material as opposed to a nonpermeable metal honeycomb results in much greater attenuation.

The attenuation of a metallic honeycomb panel for electric fields and plane waves can be predicted from waveguide theory. Electromagnetic energy which is guided between two infinite parallel planes will not be attenuated if the distance between the parallel planes is greater than the "cutoff wavelength". Electromagnetic energy having wavelengths larger than the cutoff wavelength will be attenuated.

The cutoff wavelength, λ_c, for electromagnetic energy being guided between two parallel planes, is equal to twice the distance between the planes, or, in the case of honeycomb, twice the cell width (w).

Hence, for a honeycomb cell the cutoff wavelength is:

(2) $$\lambda_c = 2w \qquad \text{(meters)}$$

The general expression for attenuation (a) of impressed RF energy through a waveguide, with a wave length, λ, greater than λ_c is:

(3) $$a = \frac{2\pi}{\lambda}\sqrt{\left(\frac{\lambda}{\lambda_c}\right)^2 - 1} \qquad \text{(nepers/meter)}$$

As λ increases, this expression approaches:

(4) $$a_T = \frac{2\pi}{\lambda_c} \qquad \text{(nepers/meter)}$$

For a cell (panel) thickness, T, the Attenuation becomes:

(5) $$a_T = \frac{2\pi}{\lambda_c}T \qquad \text{(nepers)}$$

Substituting λ_c = 2w from (2) above:

(6) $$a_T = \frac{2\pi}{2w}T \qquad \text{(nepers)}$$

Converting from nepers to decibels, when one neper equals 8.686 dB:

(6a) $$a_T = 27.3\frac{T}{w} \qquad \text{(decibels)}$$

Thus for $\frac{T}{w} = 4$, $a_T = 109$ dB

Since equation (3) becomes a = 0 when $\lambda = \lambda_c$, equation (6) also becomes $a_T = 0$. Therefore, the upper frequency limit for honeycomb is not the frequency at the cutoff wavelength in equation (2). However, if $\lambda = 2\lambda_c$ in equation (2), then

$$a = \frac{2\pi}{2\lambda_c}\sqrt{\left(\frac{2\lambda_c}{\lambda_c}\right) - 1}$$

$$= \frac{2\pi}{\lambda_c}\left(\frac{\sqrt{3}}{2}\right)$$

$$= \frac{2\pi}{\lambda_c}(.87) \qquad \text{(decibels)}$$

This is .87, the value of a_T in equation (4). Thus a_T at twice the cutoff wavelength (1/2 cutoff frequency) will be .87 of its final value as given in (4), (5), (6) and (6a). This is why the frequency whose wavelength is $2\lambda_c$ (or 4W) is considered the upper frequency limit for honeycomb panels. These values are:

CELL WIDTH	UPPER FREQUENCY LIMIT
1/8 in.	24 GHz
3/16 in.	18 GHz
1/4 in.	12 GHz

Help Available

If you have a shielding problem, call a technical representative from one of the manufacturers whose products are shown in *ITEM*. Ask them about corrosion, maintainability, conductivity, and how best to apply their diversity of products. Ask for samples or buy sample kits. Note that the MAGNETIC SHIELD DIVISION OF PERFECTION MICA COMPANY has a brochure available on "Home Study Course on Magnetic Measurement", and METEX is offering an "EMI Shielding Handbook". CHOMERICS, TECKNIT, and TAPECON also can provide literature and data which can save you many engineering hours in solving your problems.

(NOTE: Graphs and photographs in this article were provided through the courtesy of TECHNICAL WIRE PRODUCTS, INC.)