BASIC SHIELDING AIDS

The choice of material for shielding purposes depends primarily on the type and degree of shielding performance desired. Table 1 gives the conductivity and permeability of various metals used for shields and enclosures. Shielding effectiveness can be calculated by the equations presented in previous issues of *ITEM*. In some cases shielding effectiveness provided by a shield must be 60 dB or better.

ELECTRICAL BONDS

Good bonding technique is needed to obtain a seam that is electromagnetically tight. Electromagnetic interference leakage problems primarily stem from improperly bonded seams. Slits which result in gaps and degrade the shielding effectiveness are most commonly produced by poor spot welds or poorly spaced fasteners such as screws or rivets.

Several configurations for seams between two metallic members within an aerospace system are shown in Figure 1. The preferred seam is a continuous weld around the periphery of the mating surfaces. The type of weld is not critical, provided the weld is continuous.

An acceptable alternative technique is the overlap seam shown in "D" of Figure 1. In an overlap seam, all nonconductive materials must be removed from the mating surfaces before the surfaces are crimped, and the crimping must be performed under sufficient pressure to ensure positive contact between all mating surfaces. Figure 2 summarizes, in order of preference, techniques for implementing permanent or semipermanent seams.

Regardless of the type of seam used, the RF impedance of the seam must not differ appreciably from that of the materials being joined. If the RF impedance of the seam is relatively high, RF voltages can develop across the seam from skin currents, permitting RF energy to enter the shielded enclosure. It is sometimes necessary to use continuous welding of seams to ensure shielding effectiveness.

Seams that are properly bonded will provide a low impedance to RF current flowing across the seam. Wherever possible, mating surfaces of metallic members within an aerospace system should be bonded together by welding, brazing, sweating, swaging, soldering, or metal-forming. To assure adequate and properly implemented bonding techniques, observe the following recommendations:

a. All mating surfaces must be cleaned before bonding.

b. All protective coatings having a conductivity less than that of the metals being bonded must be removed from the contact areas of the two mating surfaces before the bond connection is made. (The conductivity of coatings, such as anodizing materials, should be verified with the manufacturer whenever it is questionable.)

c. When protective coatings are necessary, design them so that they can be easily removed from mating surfaces. Since the mating of bare metal to bare metal is essential for a satisfactory bond, a conflict may arise between the bonding and finish specifications. It is preferable to remove the finish where compromising of the bonding effectiveness would occur.

d. Generally, protective metal platings such as cadmium, tin, or silver need not be removed. Coatings having poor conductivity destroy the effectiveness of a bond to produce a low impedance RF path.

e. Mating surfaces should be bonded immediately after protective coatings are removed to avoid oxidation.

Figure 1. Panel Seam Configurations

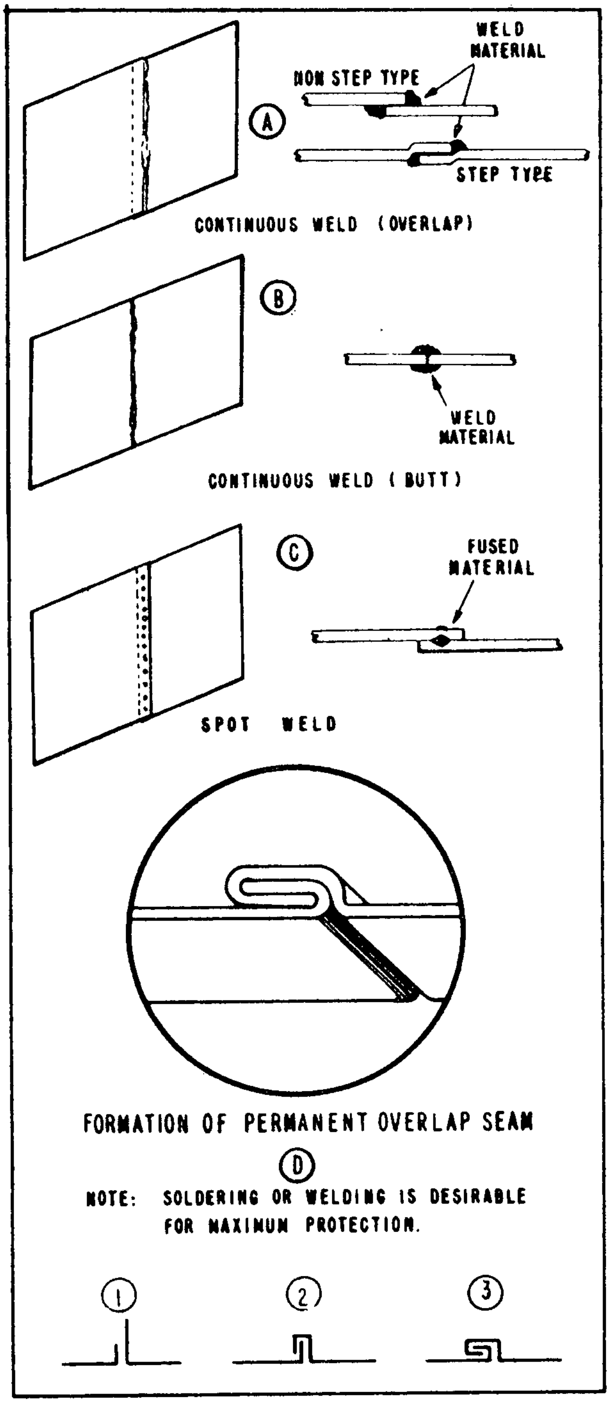


Figure 2. Types of Seams in Order of Preference

PREFERENCE	TYPE OF SEAM	REMARKS
1	Continuous weld	Best RF seam
2	Spot weld	Space weld joints less than 2 inches apart
3	Crimp seam	Use strong and lasting crimping pressure; pressure is maintained by spot welding

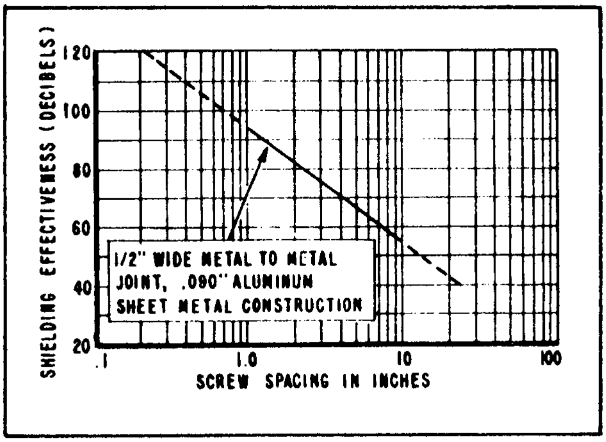
f. The nonreplaceable portion of a bonded joint that must be formed by dissimilar metals should be a metal lower in the electromotive force series than its mate. When two dissimilar metals must be bonded, select metals that are close to one another in the electromotive force series.

g. Bolted sections may be used for temporary bonds. However, bolted sections could be bonded to ensure consistent contact pressure over an extended period of time. Shield material must be rigid enough to prevent buckling between contact points.

h. When bolts or rivets are used to make a bond, they should be applied first at the middle of the seam and then progressively applied toward the ends of the seam to prevent the mating surfaces from buckling. Figure 3 is a plot of shielding effectiveness as a function of the spacing of the screws that fasten the two surfaces together. The shielding effectiveness of the joint depends on the number of screws per linear inch, the pressure of the contacting surface, and the cleanliness of the two mating surfaces.

i. When pressure bonds are made, the surfaces must be clean and dry before mating and then held together under high pressure to minimize the growth of oxidation due to moisture entering the joint, since the joint may not be 100% moisture-tight. The periphery of the exposed joint should then be sealed with a suitable protective compound and, whenever possible, one that is highly conductive to RF currents.

Figure 3. Shielding Effectiveness Versus Screw Spacing



When implementing bonding techniques, always remember that bonding straps do not provide a low impedance current path at RF frequencies. The important impedance exists at radio frequencies. There is little correlation between the DC resistance of a bond and its RF impedance. Even the measured RF impedance of bonds, such as jumpers, straps, or rivets, is not a reliable indication of the bonding effectiveness in the actual installation. Conductive epoxies and pastes do not always produce sufficient RF bonds. Even when proved effective in given instances, they have been known to degrade RF shielding effectiveness under conditions of strain, pressure, and the passage of time.

RF GASKETS

Where continuous welding or overlap seams cannot be employed, RF gasket material may be used. Gasket material is inserted between the mating surfaces and a high pressure is maintained against the seam. It is essential to clean the mating surfaces thoroughly before the gasket material is inserted.

Figure 4. Acceptable Method of Making Permanent Seam Using RF Gasket

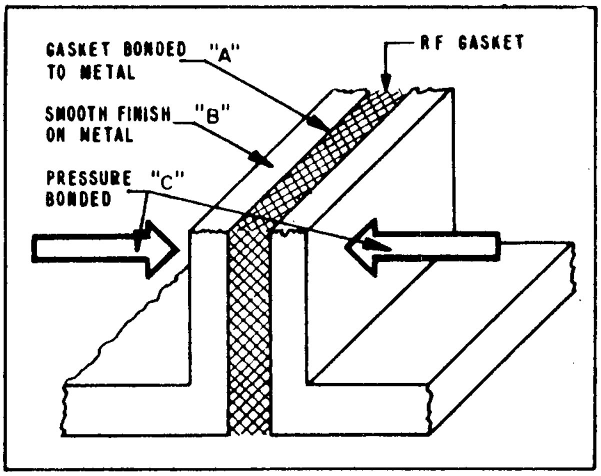


Figure 4 illustrates an acceptable method of making a construction seam using RF gasket material. The features to be observed in the figure are:

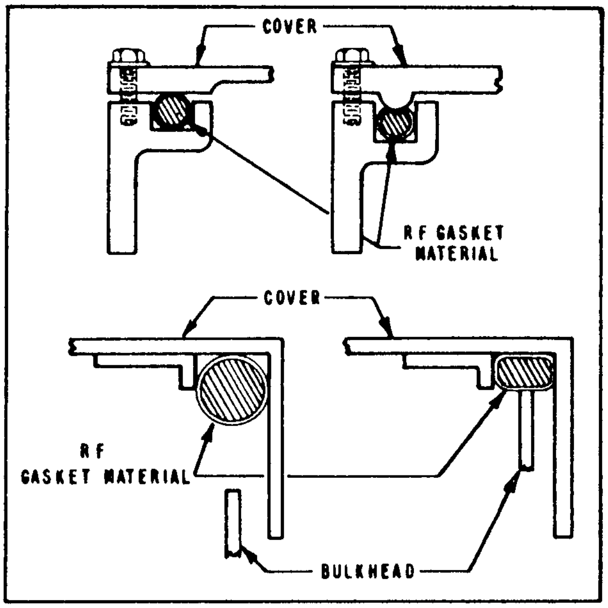
"A" – Gasket bonded to one metallic surface of the seam with conductive adhesive; surfaces cleansed of nonconductive material before application.

"B" – Metallic surface machined to smooth finish and all nonconductive materials removed.

"C" – Appropriate mechanical techniques (i.e., clamps, bolts, etc.) used to provide a high pressure on the RF gasket. The pressure must be nearly uniform along the entire length of the seam.

Figure 5 illustrates acceptable methods of making construction seams where sections must be removed and replaced for maintenance or loading and handling operations. Table 2 is a guide to RF gasket design and usage. Table 3 lists types of gasket material, in order of preference, based on overall effectiveness. Table 4 lists the three materials most frequently used for RF gaskets. They are ranked numerically for various properties, with 1 indicating the most desirable material in a group and 3 the least desirable.

Figure 5. Covers with Gaskets



In Table 4 the first comparison is on the basis of corrosion resistance, with the first column indicating intrinsic corrosion resistance and the second indicating corrosion resistance in the presence of aluminum. Monel definitely has the highest intrinsic corrosion resistance and aluminum the lowest. Since RF gaskets are frequently used against an aluminum structure, the question of compatibility arises. Although an aluminum gasket would naturally be more compatible with the aluminum structure, monel would still be the better choice because of its other properties.

A comparison of the metals on the basis of conductivity shows that the intrinsic conductivity of the material is not the most important factor. Since surface corrosion films can form and these can greatly reduce the actual conductivity of an RF gasket, the material should be ranked according to its conductivity with surface films.

The mechanical properties of metals concerning tensile strength, springiness, and hardness are ranked as shown in Table 4. Aluminum comes out a poor third, and monel and silverplated brass rank close together. On the basis of these factors, it is recommended that monel be used for gasketing.

NONSOLID SHIELD

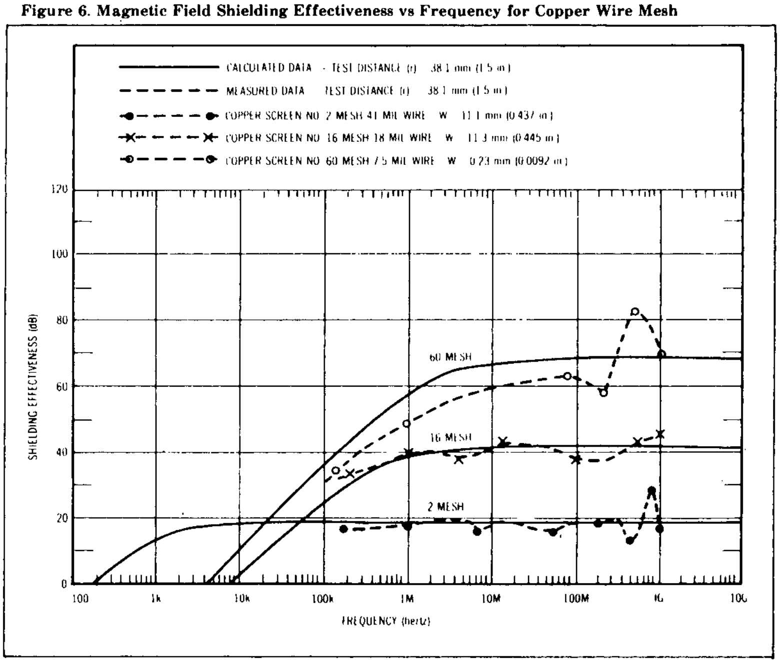
There are many applications in which the shield cannot be made of a solid material due to system design requirements. Screens and perforated materials must be employed if an enclosure must be transparent (e.g., a meter face) or ventilated.

Since there is no precise means of calculating the shielding effectiveness (SE) of woven materials, refer to the literature for the attenuation characteristics of the various materials and configurations. Often, the exact situation may not be treated sufficiently; therefore, the designer will be required to perform measurements to validate the shielding effectiveness and the configuration intended for use in the aerospace system.

In general, the SE of woven materials for radiated fields decreases with increasing frequency, and the SE increases with the density of the weave. In the induction field where the magnetic component is large, the SE increases with frequency, with the density of the woven material, and with the permeability of the material.

Figure 6 shows the magnetic field shielding effectiveness for three sizes of copper mesh. Because of the variation in commercial meshes and screens, verify use by testing.

Figure 6. Magnetic Field Shielding Effectiveness vs Frequency for Copper Wire Mesh



PERMANENT APERTURES

Permanent apertures are those holes or discontinuities in an aerospace system housing which cannot be shielded by a metal cover. Openings for ventilation or control shafts, apertures for panel-mounted meters, exposed connector pins, and exhaust nozzles are common examples.

Where shielding, ventilation, and strength are required and weight is not a critical condition, honeycomb panels may be used. The SE of honeycomb panels is based on, and predicted by, the attenuation properties of waveguides operated below cut-off. It is a function of the size and length of the waveguide and the number of waveguides in the panel. Figure 7 indicates the SE of a honeycomb panel constructed of steel with 3.1 mm (⅛ in.) hexagonal openings 12.7 mm (½ in.) long. Acceptable methods of shielding apertures for meters or other panel-mounted readout devices are illustrated in Figure 8.

Figure 7. Shielding Effectiveness of Hexagonal Honeycomb Made of Steel

FREQUENCY	SHIELDING EFFECTIVENESS
(MHz)	(dB)
0.1	45
50	51
100	57
400	56
2200	47

Where the use of waveguide materials is impractical or otherwise undesirable, as in large ventilating holes, substantial attenuation of radiated electromagnetic energy can be obtained by covering the aperture with a wire screen or mesh. Number 22, 15-mil copper wire screen will provide about 50-dB attenuation to electric and magnetic fields at frequencies between 1 MHz and 1 GHz. Figure 9 shows an acceptable technique for mounting a wire screen over an aperture. A similar mounting technique can be used in installing circular and rectangular waveguide materials.

One method of minimizing the degradation of SE is to design small apertures to act as effective waveguide attenuators. Figure 10 illustrates how a necessary hole can be designed into a circular waveguide with a nonmetallic control shaft that passes through the panel. The cut-off frequency for a waveguide is the lowest frequency at which propagation occurs without attenuation. Below cut-off, the attenuation is a function of guide length and frequency. An aperture in a shielding enclosure designed as a waveguide operating below cut-off for the dominant mode or lowest propagating frequency can achieve theoretical shielding efficiencies in the range form 80dB to 100dB. The depth of the aperture determines the amount of attenuation realized and the diameter of individual openings determines the cut-off frequency.

TEMPORARY APERTURES

Temporary apertures include access panels or removable metallic sections within aerospace systems. These panels or sections cannot perform a shielding function when opened or removed. If it is necessary for apertures to be opened in RF fields, design the interior circuits, components, and cables to preclude interference.

Figure 8. Acceptable Methods of Shielding Panel-Mounted Meters

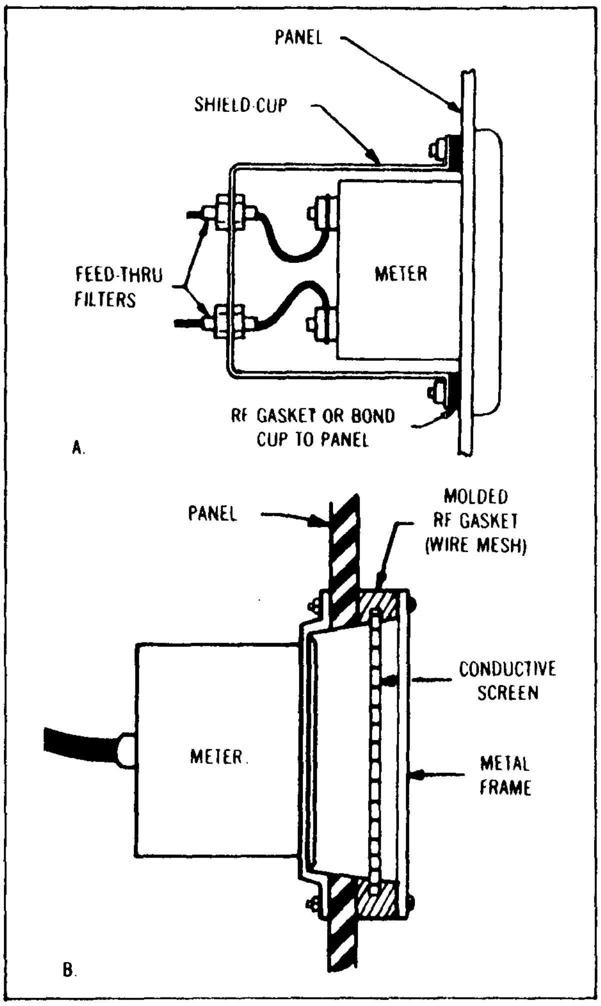


Figure 9. Method of Mounting Wire Screen Over a Large Aperture

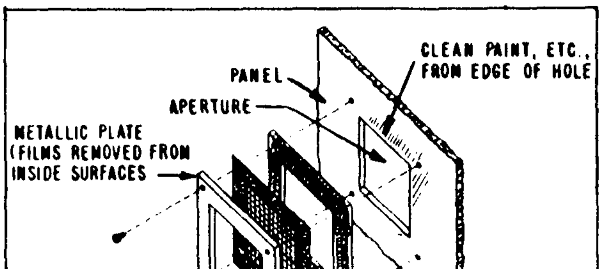
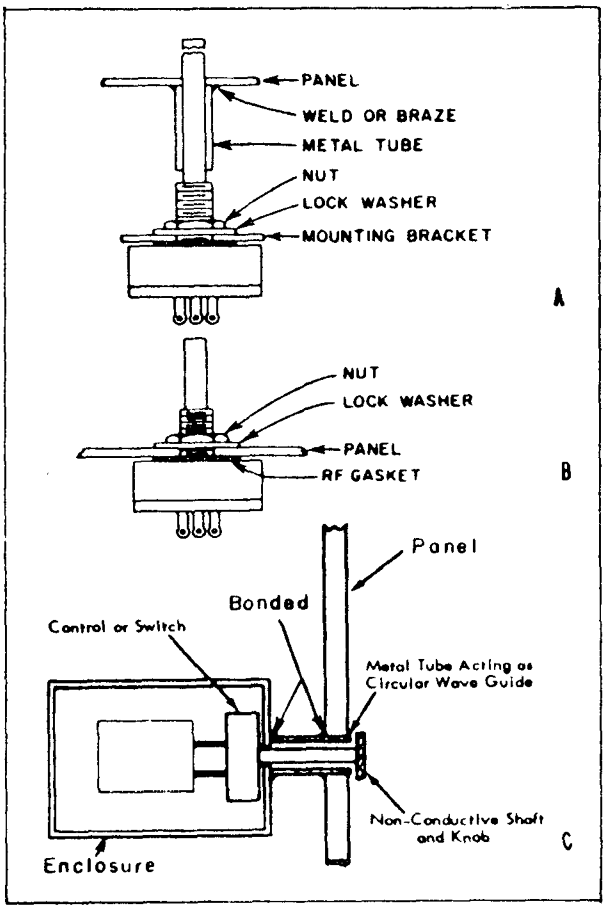


Figure 10. Acceptable Use of Circular Waveguide in a Permanent Aperture for Control Shaft



Design to maintain a continuous low RF impedance electrical bond between the door or panel and the equipment housing when the access doors and panels are closed. Metallic mesh or fingers between the mating surfaces achieve the best bond. When metallic fingers are used, 5 to 10 grams of pressure per finger should be applied to the mating surfaces.

If hinges are used on panels, a mesh such as conductive weather stripping on the hinged side of the panel is recommended. An alternative method for shielding at the hinged side of a panel is to use metal fingers. The shielding material must be electrically and mechanically bonded to the frame at close intervals to ensure proper shielding.

Figure 11 illustrates acceptable methods of applying shielding materials around the sides of hinged access panels. The mesh used in these applications should be a square cross section from 12.7 mm to 25.4 mm (½ in. to 1 in.) on a side. Also, appropriate mechanical locking devices must be used on access panels to maintain a minimum of 137.8-kPa (20-lbf/in.^{2}) pressure between the edges of the panel and the mesh or fingers.

The best arrangement of spring contact fingers around removable panels or doors is the installation of two sets of fingers at right angles to each other. One set is a wiping set. The other set is in compression. The combination makes good electrical contact when the door is closed. The pressure exerted by these springs is highly important and it should be carefully maintained. Cleanliness is also important.

Figure 11. Acceptable Close Contact Strips for Temporary Apertures

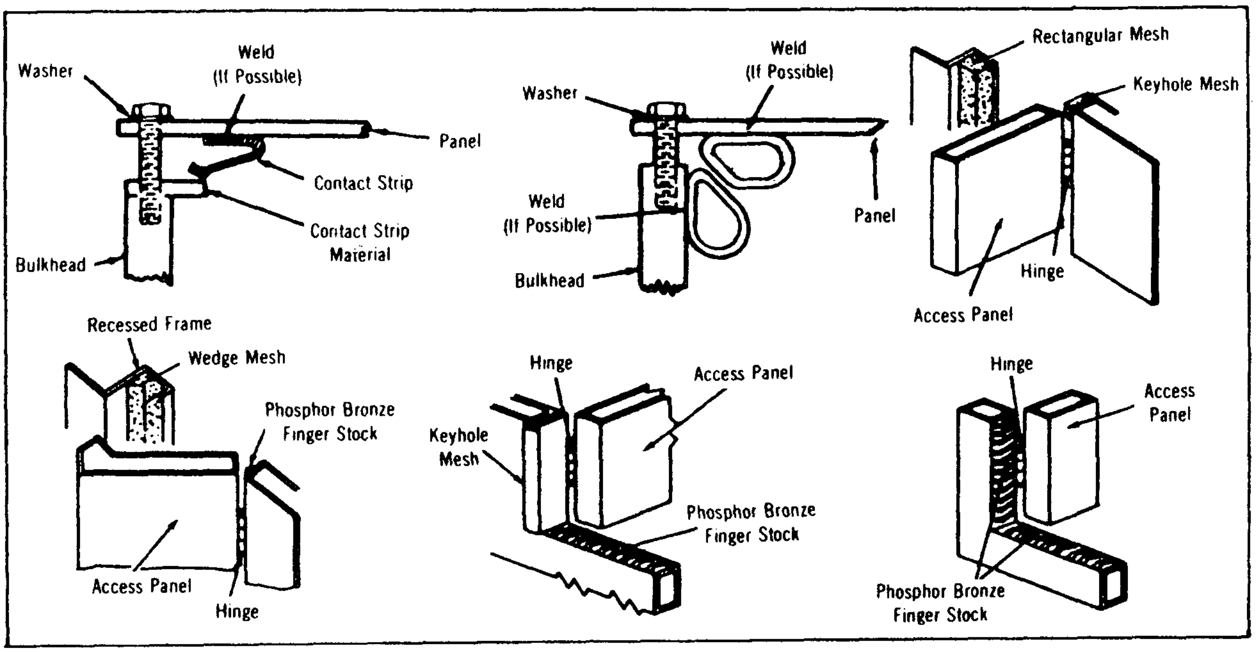


TABLE 1. Characteristics of Various Metals Used for Shields

METAL	σ RELATIVE CONDUCTIVITY	μ RELATIVE PERMEABILITY AT 150 kHz	PENETRATION LOSS DB/MIL AT 150 kHz
Silver	1.05	1	1.32
Copper-Annealed	1.00	1	1.29
Copper-Hard Drawn	0.97	1	1.26
Gold	0.70	1	1.08
Aluminum	0.61	1	1.01
Magnesium	0.38	1	0.79
Zinc	0.29	1	0.70
Brass	0.26	1	0.66
Cadmium	0.23	1	0.62
Nickel	0.20	1	0.58
Phosphor-Bronze	0.18	1	0.55
Iron	0.17	1,000	16.9
Tin	0.15	1	0.50
Steel, SAE 1045	0.10	1,000	12.9
Beryllium	0.10	1	0.41
Lead	0.08	1	0.36
Hypernick	0.06	80,000	88.5
Monel	0.04	1	0.26
Mu-Metal	0.03	80,000	63.2
Permalloy	0.03	80,000	63.2
Steel, Stainless	0.02	1,000	5.7

TABLE 2. RF Gasket Design and Usage

GASKET CONSIDERATION	DETERMINED BY
Material	Corrosion, mechanical wear, spring qualities, and RF properties
Form	Attachment methods, force available, other gasketing functions, joint unevenness, and space available
Thickness	Class of joint, joint unevenness, force available, and RF level

TABLE 3. Types of Gaskets in Order of Preference

PREFERENCE	TYPE SEAM	REMARKS
1	Metal mesh RF gasket	Subject to set; offers 54 dB attenuation at 20 psi; some evidence indicates attenuation highest at lower frequencies
2	Phosphor bronze spring fingers	Subject to breakage; offers approximately 60 dB attenuation
3	Conductive rubber	Satisfactory where nominal connection and small number of screws are required; some evidence indicates attenuation highest at higher frequencies

TABLE 4. Comparison of Three RF Gasket Materials

MATERIAL	CORROSION		CONDUCTIVITY		MECHANICAL		
	INTRINSIC	WITH ALUMINUM	INTRINSIC	WITH SURFACE FILM	TENSILE	SPRING	HARDNESS
Monel	1	2	3	1	1	2	1
Silverplated brass	2	3	2	2	2	1	2
Aluminum	3	1	1	3	3	3	3