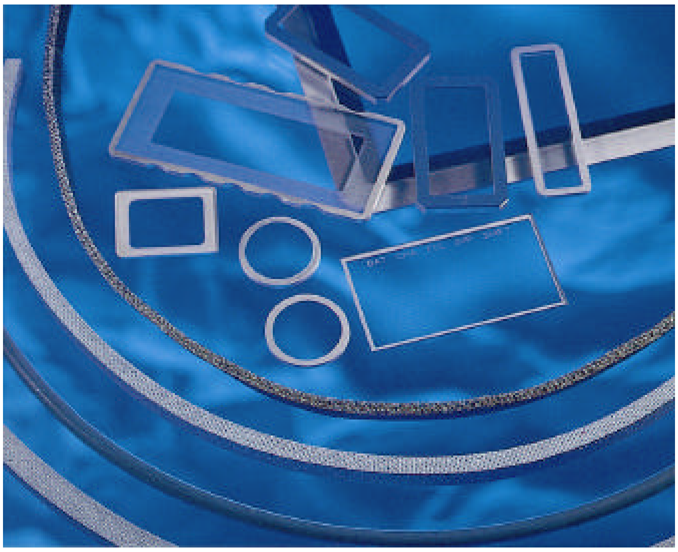
Abstract

This RFI shielded window design guide is intended to aid designers in understanding the trade-offs associated with the selection of specific materials against anticipated performance.

1.Introduction

One of the many requirements, which compromise the shielding integrity of equipment enclosures, is the need for large-area openings for access to electronics, ventilation, and displays. The displays may be panel meters, digital displays, oscilloscopes, status monitors, mechanical indicators or other readouts. The most critical displays to shield against electronic noise are the large area, high resolution monitors (CRT). Shielding of these large apertures is generally more difficult than those encountered for cover plates, doors, ventilation panels and small apertures, such as connectors, switches and other controls in which the majority of the opening is covered by a continuous homogeneous conductive (metal) plate. Therefore, when working with window designs, which do not have a continuous conductive cover, consideration must be given to shielding as related to relative apertures and viewing as related to optical characteristics of shielding screens and supporting substrates. These two factors are inter-related and need to be treated as a combined problem.



Shielding windows are presently manufactured in one of three ways:

(1) Laminating a conductive screen between optically clear plastic or glass sheets. (Teckshield – F)
(2) Casting a screen within a plastic sheet . (Tecknit Europe Allylcarbonate type and EMC-CAST.)
(3) Applying an optically clear conductive layer to a transparent substrate. (Teckfilm and ECTC window)

Until recently, the typical conductive screen was a knitted wire mesh made from Monel, tin-plated copper-clad iron core (Sn/Cu/Fe) or tungsten. Wire diameters were typically from 0.001-inch diameter (tungsten) to 0.0045-inch diameter (Sn/Cu/Fe or Monel wire).

Knitted densities range from 30 openings per inch for the 0.001-inch diameter tungsten wire (94% open area) to 10 openings per inch for the 0.0045-inch diameter wire (90% open area). These high open area meshes provide high optical transmission with average shielding effectiveness (greater than 60 dB) below 10 MHz when wire crossovers are adequately bonded.

More recently, high-density woven wire screens have been employed which have extended the useful high-frequency response beyond 10 GHz. These screens have made use of silver-plated, stainless steel wires; copper-plated, stainless steel wires; and copper wires. In all cases these screens make direct contact to a peripheral wire mesh gasket, window frame or enclosure structure. Woven meshes have ranged from 80 mesh (wires to the inch) to 150 mesh and wire diameters from 0.001-inch diameter to 0.0045-inch diameter. Typical performance for a 100 mesh screen will provide almost 60% open area with shielding effectiveness of up to 60 dB beyond 1 GHz. Higher mesh densities and larger wire diameters usually result in higher shielding effectiveness with lower optical performance.

Optically clear conductive coatings are produced by depositing an electrically conductive transparent coating (ECTC) directly onto the surface of various optical substrates. Typically, these coatings can provide better than 50 dB shielding effectiveness below 100 MHZ with an optical transmission of better than 70% over the visible light spectrum. Increased shielding effectiveness may be achieved by increasing the thickness of the deposited coating material (decreasing resistance) at the expense of loss in optical transmission and increase in optical reflection.

In the following sections, various aspects of shielding window design will be reviewed as related to shielding performance, optical performance, optical designs and methods for mounting windows to enclosures.

2.Shielding Performance

A great deal of information has been written and published on total shielding effectiveness (SE) as an aid in reducing electromagnetic interference (electrical noise). Electromagnetic compatibility (EMC) may be achieved by reducing the electromagnetic interference (EMI) below the threshold level that disrupts the normal operation of an electronic system. An electronic system can be both an EMI emitter and become affected by EMI noise to the extent that the unit will not operated reliably. In Europe the EMC directive 89/336/EEC stipulates the allowable levels of radiated and conducted emissions and the necessary circuit immunity to these emissions to achieve electromagnetic compatibility (EMC). In the USA the present specifications covering these requirements for EMC consist of: MIL-STD-461A and B; FCC Part 15, Subpart J (originally Docket 20780); CISPR (international); NACSIM 5100 A (Tempest, secure data); and several special applications such as medical, radar, and SAE commercial specifications. Certain Specifications deal only with radiated noise or susceptibility. Others deal with both emitters and susceptibility, such as MIL-STD-461, for military equipment.

Shielding requirements for shielding windows can vary from moderate to severe. Any barrier placed between a transmitter and a receiver (unit we are trying to protect) that diminishes the field strength of the interference is an EMI shield. The attenuation of the electromagnetic field is referred to as its shielding effectiveness (SE). The standard unit of measurement for shielding effectiveness is the decibel (dB). The decibel is expressed as the ratio of electromagnetic field strength on one side of a shielding barrier to the field strength on the opposite side.

The losses in field strength (absorption and reflection) from a shield are a function of the barrier material properties: permeability, conductivity, and thickness, as well as the distance from the emitter to the shield.

In most shielding applications, shielding effectiveness below 20 dB (10:1 reduction in EMI) is considered marginal due to long-term environmental effects on the mating surfaces of enclosures and shielding gaskets and barriers. Normally, acceptable shielding performance covers the range from 30 dB to 80 dB. Above average shielding ranges from 80 dB to 120 dB. Above 120 dB, shielding effectiveness is difficult to achieve and difficult to confirm by measurement.

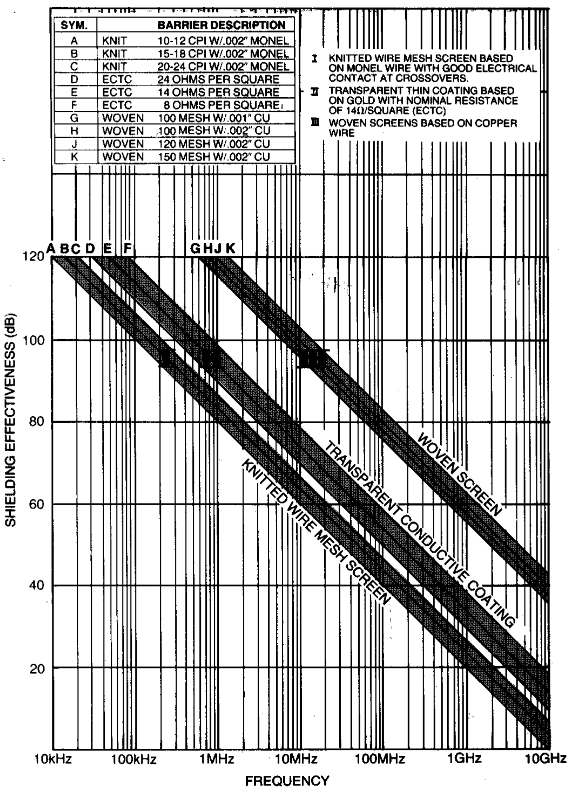


Figure 1

Figure 1 shows the range of shielding effectiveness for the three primary barrier materials used in shielding windows:

Knitted wire mesh screens (Band I),
Transparent conductive coatings (Band II),
Woven mesh screens (Band III).

Shielding performance is the primary consideration in the design process and is, therefore, considered first.

The shielding values presented in Figure 1 are considered to be conservative based on measurements in shielded room tests which generally show from 10 dB to 20 dB higher shielding effectiveness. The origin of the data is based on the theoretical relationship given by:

$$SE_{db} = 195-20 \log_{10}(df)$$

Where d is the mesh wire spacing in inches and f is the threat frequency in Hertz.

Since most EMI problems are broadband (cover a broad frequency range) the frequency of most concern is generally the highest frequency within that bandwidth envelope to which the equipment is responsive and which may be a threat to electromagnetic compatibility. Therefore, the highest threat frequency and the shielding requirements at that frequency are both needed to determine the type or types of windows that are suitable for that application.

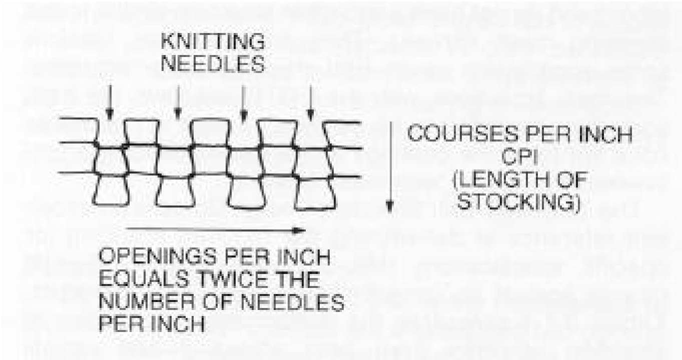
For example, assume the highest threat frequency is 10 MHz with a maximum required shielding of 60 dB at that frequency. Figure 1 shows that any of the three families of shielding materials would be suitable to provide adequate shielding. On the other hand, changing the maximum threat frequency from 10 MHz to 100 MHz would eliminate the knitted wire mesh screens and the transparent conductive coatings, leaving only the high-performance woven screens as a suitable solution.

Knowing which type of windows are available, the next selection should be made on the basis of the optical transmission that is attainable from the screen materials or conductive coatings, and additionally the type of optical substrate. Standard optical substrates should cause only a minor reduction in optical transmission in the visual spectrum. The range of loss in optical transmission should be less than 1% and to up to 10% depending upon the reflection and absorption from coated and uncoated surfaces of the substrates. The following section will deal with the evaluation of the windows from an optical aspect of the specific materials. The optical characteristics will be referred to as percent open area. This characteristic is important in determining optical contrast that can affect operator fatigue in using devices such as video display monitors.

3.Optical Performance

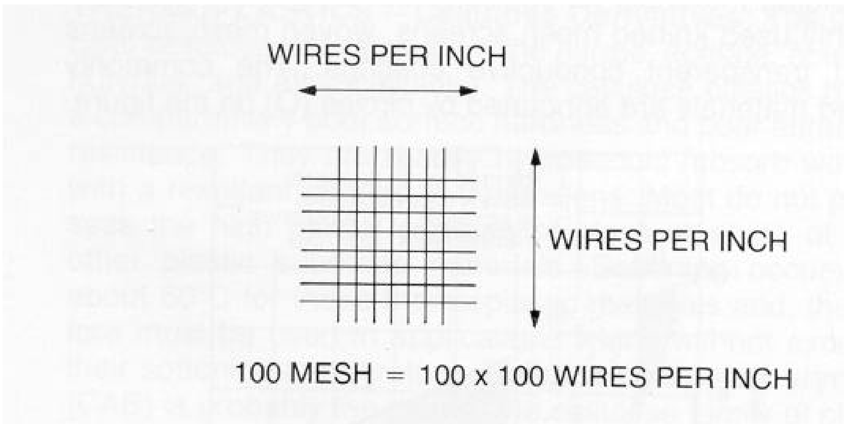
To deal with the material selection process an understanding of optical properties of shielding windows is imperative. These properties concern the optical transmission of the finished window, including optical substrate, shielding screen, laminating material, coatings, and characteristics of transmission colour filters. This section discusses the optical performance of the shielding screens.

Figure 2



Knitted mesh screens are produced on industrial knitting machines that were originally developed for the commercial, knitted fabric materials industry. The irregular shapes formed in the knitting process (see Figure 2) aid in minimizing any obstructions caused by the regular shapes as might be formed in typed or printed information. The density of the mesh is determined by the courses per inch along the length of the stocking, the wire material and the wire diameter. To maintain a square pattern of openings in both directions, it is necessary to specify the number of openings per inch around the stocking as well. This effectively determines the complete description of the knitted mesh screen. Knitted screens are generally limited to about 30 openings per inch when used as a screen for shielding windows.

Figure 3



Woven mesh uses fine wires, which are generally much smaller than 0.005-inch diameter, and provide a significant improvement in shielding effectiveness over other shielding window materials, even at higher frequencies. These woven screens have 80 or more wires to the inch in both directions (Figure 3). Typical mesh density is 100 mesh (100 by 100 wires per inch), 120 mesh (120 by 120 wires per inch) and 150 mesh (150 by 150 wires per inch). Typical wire diameters vary from 0.001 inch to 0.0025 inch depending upon plating and blackening. Blackening of the screen reduces reflections and improves image contrast.

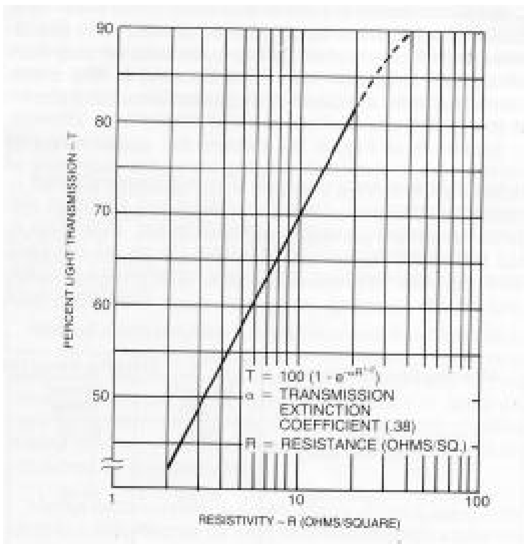


Figure 4

A third shielding material is the transparent conductive coating. This material exhibits good shielding properties at moderate optical transparency. There are trade-offs in performance since the shielding effectiveness is a function of the resistivity of the transparent coating, which, in turn, is a function of the optical transmission. (see Figure 4). An optimum relationship for this type of coating occurs at approximately 10 to 14 ohms per surface resistivity to obtain approximately 70% transmission and greater than 50 dB shielding at 100 MHz.

Figure 5

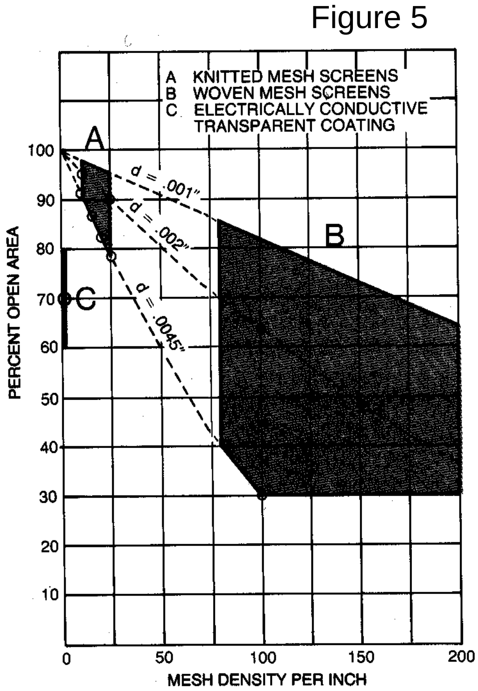


Figure 5 provides a ready reference for the optical transmission (percent open area) of the three types of shielding materials for windows covering the most commonly used knitted mesh screens, woven mesh screens and transparent conductive coatings. The commonly used materials are annotated by circles (O) on the figure.

Section A of Figure 5 encompasses the useful range of knitted materials. Wire diameters from 0.001 inch to 0.0045 inch bound the upper and lower limits while 10 to 25 CPI provide the limits of mesh densities. These boundaries provide the highest optical open area ranging from about 80% to greater than 95%. Bonding of wire crossovers has been assumed in all performance data shown in this guideline.

Section B of Figure 5 depicts the useful range of woven screen materials ranging from wire diameters of 0.001 inch to 0.0045 inch and mesh densities from 80 to 200 mesh. The circles indicate commonly used mesh materials that are generally readily available. Performance for 100 mesh screen with 0.0045 inch diameter copper wire provides approximately 30% optical transparency and 70 dB shielding, while 100 mesh with 0.002 inch diameter copper wire provides about twice the open area (64%) while reducing the shielding effectiveness by only 10 to 12 dB.

Section C of Figure 5 (vertical coordinate) shows the normal range of transparency for the transparent conductive coating. These electrically conductive transparent coatings (ECTC) have a distinct advantage over screen materials when used with three colour CRT's employing a colour mask on the faceplate. The colour mask is used to delineate the specific phosphor colour to be displayed. The masks have a colour repetition pattern or pitch that varies from an equivalent mesh density of about 60 mesh for broadcast monitors to 130 mesh for the very high resolution monitors. Whenever a repetitive pattern, such as a shielding mesh screen, is placed in front of a colour CRT, patterns of dark and light bars may appear across the viewing screen. These dark-light bars are known as moiré patterns. They occur as a result of the mesh screen having nearly the same pitch as the pattern of the CRT colour mask. Rotating the mesh will vary the number of bars. Changing the number of wires per inch (mesh density) will also alter the number of bars. Often there is an optimum mesh density, wire size and angular relationship to the fixed CRT colour mask pattern that will minimize or even eliminate the interference pattern.

These light and dark bars are the result of the patterns of two objects, either aligning up exactly with each other to produce light areas or misaligning completely and blocking all transmitted light to produce dark bars. Sometimes, it is difficult to attain a perfect match between the CRT mask and the screen mesh. ECTC windows on the other hand do not have a repetitive structure similar to the shielding mesh screens. They are, therefore, ideal in some applications as an EMI shield for colour monitors. The main limitations with the ECTC windows are high cost, their tendency to be easily scratched, a noticeable colour tint for some coatings and a lower shielding effectiveness than the woven mesh screens.

4.Optically Clear Window Substrates

Glass and clear plastic optical substrate materials are the most common for covering large area apertures for viewing windows. This section discusses the basic properties of these materials for shielding applications requiring both flat and curved windows.

Glass Substrates

Glass substrate materials provide the hardest surface for resistance to scratches and marring. Once fully laminated, these windows closely match the properties of safety glass, with the added protection of an embedded screen mesh.

Plastic Substrates

Not all clear plastics are of use in the manufacture of shielding windows. Plastics are divided into two general classes: thermoplastic and thermosetting resins.

Thermoplastic Synthetic resin - Polycarbonate material is virtually unbreakable and can withstand impacts greater than 200 ft.-lbs for a one-eighth inch thick sheet. Softening temperature is about 125ºC. The poorer than desirable scratch performance makes polycarbonate a poor candidate for viewing windows that require periodic cleaning, such as may be needed with cathode ray tubes (CRT). Some aromatic solvents (hydrocarbon) cause surface stress cracking in this material.

Thermosetting Resins – ACP, CR-39 (PPG Industries): ACP (Allyl Cast Plastics) is known as Columbia Resin (CR-39) or Allyl carbonate. It is a transparent solid, cured from the clear, colourless, water-insoluble liquid monomer through the aid of a catalyst. It is strong, relatively insoluble and inert. It is normally free of internal haze, has a low water absorption and moderate coefficient of thermal conductivity. Refractive Index is almost identical to that of crown glass, and yet, the density is about one-half. The resin material is superior to acrylic and other plastics with respect to softening under heat, crazing, resistance to abrasion and attack by chemicals. The continuous use temperature is 100ºC. Additionally, this type of EMI shielded window has excellent resistance to acids, alkalis and to all solvent including aliphatic and aromic hydrocarbons.

5.Contrast Enhancement

The optical performance of substrate materials may be substantially improved by increasing the optical contrast of the displayed image through glare reduction and optical filtering. Additionally, special surface treatments for some plastics may increase the scratch and mar resistance of surfaces subject to frequent cleaning. Here special coatings can significantly reduce the harsh effects of dust and dirt scratches from cleaning materials, which cause unwanted light scattering and image distortion or obscuration.

Wherever high ambient lighting conditions are present, loss in display contrast may occur from window reflections unless these reflections are controlled by means of antireflection coatings, matter finishes, optical colour transmission filters, or special laminates such as polarizers.

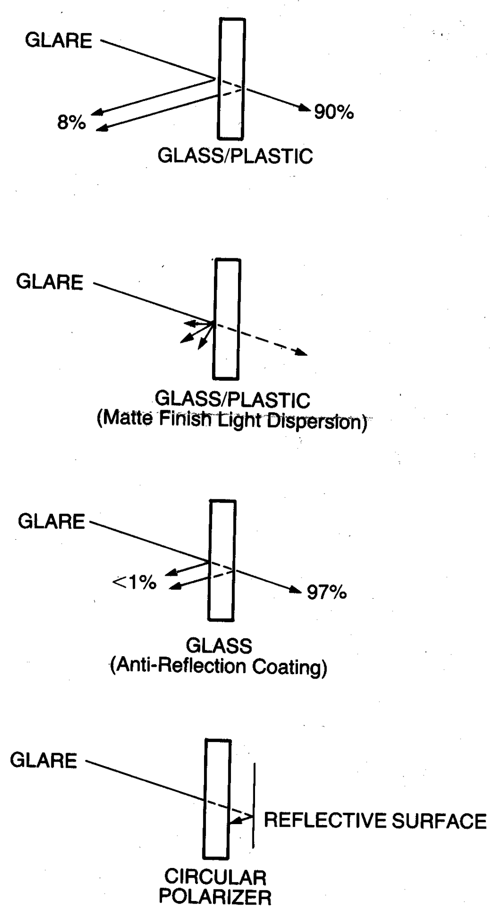


Figure 6

Antiglare or glare reduction techniques consist of either an anti-reflection coating for glass windows or a matt finish for glass or plastic windows. Anti-reflection coatings utilize optical interference filters, while matt finishes are imprinted into the surface of the substrate and scatter incident light to reduce specular reflection (See Figure 6).

Colour transmission filters transmit only specific colour hues within a comparatively narrow spectral band reducing the amount of optical energy, which does not contribute to the display image. Polarizers selectively block the passage of unwanted wide band spectral energy such as is reflected from the internal surface of a display.

6.Matt Finish

Matt finishes are used as an antireflection surface treatment to effect a dispersion of specular reflectance. These finishes for either glass (an etch finish) or plastic (mould or cast finish) are available as an alternate to the anti-reflection coating (HEOC for glass). Matt front surface finishes are used in applications where the shielding windows may be used in close proximity to the display, such as flat (or nearly flat) CRT, plasma displays, LED, LCD, and electro luminescent and monochrome or multicolour displays.

7.Polarizers

Polarizers provide a third method of discrimination between optical signals and optical noise. There are two basic types of polarizers, linear and circular.

A linear polarizer selectively transmits an unpolarized waveform by resolving the field components that are aligned with the polarizing axis of the polarizer. Linear polarizers are used to control light output. These polarizers attenuate reflected light glare from smooth objects where the reflected light has been polarized in a known plane, such as horizontally.

Circular polarizers provide an important additional advantage. When viewing objects through a window, the objects on the inside of the enclosure are generally orientated at various angles to the window surface, such that the light that reflects from those objects may be polarized in several planes.

8.Optical Colour Transmission Filters

Optical filters generally are classified according to their spectral properties such as short wave cut-off, long wave cut-off, band pass, rejection, or neutral density.

Short wave cut-off filters are used to block the ultraviolet while long wave cut-off filters may be used to eliminate infrared heating. Band pass filters are principally used to increase the signal-to-noise ratio (contrast) of displays (or detectors). Rejection filters are usually employed to eliminate specific spectral wavelength(s)or to minimize their intensity, which might be harmful to the operation of an equipment, such as a laser beam. Neutral density filters reduce the average illumination across the visual spectrum.

In shielding window applications, transmission filters are used to provide various hues and shades of transmitted light. To assist the designer in selecting the proper filter for specific applications, it becomes important to be able to calculate the effect of material thickness and combinations of elements that tend to alter the transmitted light and the overall density of the filter.

9.Abrasion Resistant Coatings

The surfaces of most plastics are relatively soft in comparison to glass. As a result, the front surface of shielding windows are subjected to possible scratching and marring when periodically cleaned to remove dust, dirt and grease in normal handling during operation of the equipment. These soft surfaces can be treated with specially formulated coatings for use on thermoplastic and thermosetting plastics.

Abrasion resistant coatings not only provide scratch and mar resistance, but also are resistant to moisture and cleaning solvents. The coatings are clear and non-yellowing and are resistant to ultraviolet light. They can be applied to methyl methacrylate (acrylic), polycarbonate or CR-39. Polycarbonates are not recommended for normal shielding window applications unless protected with an abrasion resistant coating.

10.Assembly and Mounting

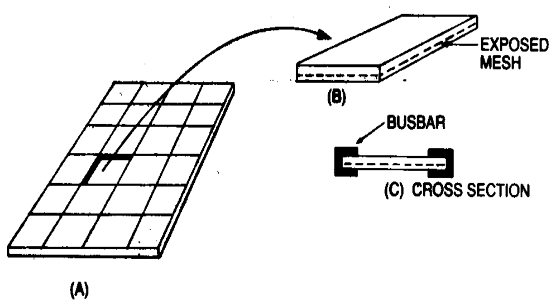
The edge of shielding windows is prepared for mounting to the enclosure by applying an interface gasket, which conducts induced currents from the shielding mesh screen or conductive surfaces to the ground plane of the system.

There are essentially two basic barrier terminations for shielding windows: (1) conductive busbar: (2) conductive gasketing. The conductive busbar is used to contact the shielding screen or conductive coating. The busbar terminates the edge of the window opening by contacting the screen mesh while providing a flat surface on one or both sides of the window (Figure 7) to make electrical contact to the enclosure bezel. Conductive gasketing is often used in combination with conductive busbars to provide a resilient interface for aid in absorbing shock and vibration.

10.1 Conductive Busbar

A conductive busbar is an electrical conductor that can be used as a common electrical connection around the perimeter of the shielding window to the conductive shielding barrier of knitted wire mesh screen, transparent conductive coating (ECTC) or woven mesh screen.

Figure 7



Generally, the more economical way to manufacture small shielding windows is to either laminate or cast knitted wire mesh screen or woven mesh screen into large area sheets and/or to dissect the sheets into several smaller area windows. The windows that are cut to size from the larger sheets have the mesh screen emerging at the four edges of the window as shown in Figure 7. Contact is made to the screen by means of a conductive busbar of either a highly conductive coating such as an organic-type paint that is highly filled with conductive silver particles or a deposited metal film.

Silver is the preferred filler for paint to attain maximum conductivity. The liquid carrier for the paint is an acrylic base, which produces a hard, firm busbar and is compatible with most optical substrate materials. The busbar then provides a comparatively large contact area to which an electrochemically compatible, conductive, resilient gasket may be attached for shock mount and moisture barrier.

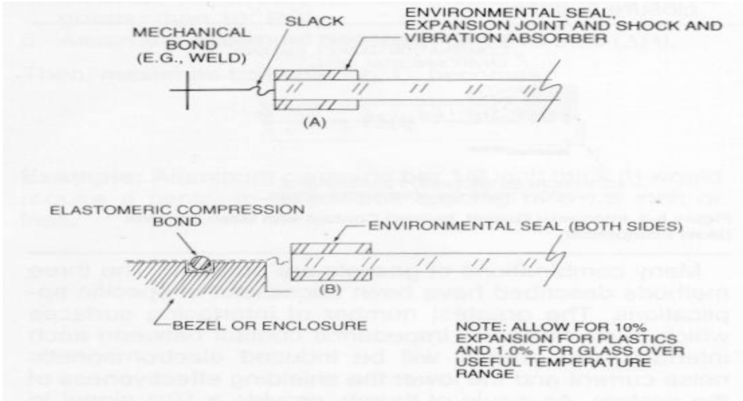
An alternate mounting method for these types of windows, employing a peripheral busbar, is to bond the window directly to the enclosure using a conductive RTV (room temperature vulcanisation) adhesive or a conductive epoxy. This latter mounting technique provides a comparatively rigid mounting and should be backed up by several mounting clips or fasteners to ensure proper bonding and to reduce possible seam fixture.

10.2 Conductive Gasketing

The termination of the shielding mesh screen to attain maximum performance from the shielding window is as important in the material and methods selection as in the shielding screen itself. Improper screen termination may severely reduce the shielding effectiveness of a high performance shielding window as may be required for NACSIM 5100A (Tempest) applications. There are four recommended edge terminations for woven mesh screens in applications requiring the maximum performance over any extended period. The four methods are discussed now:

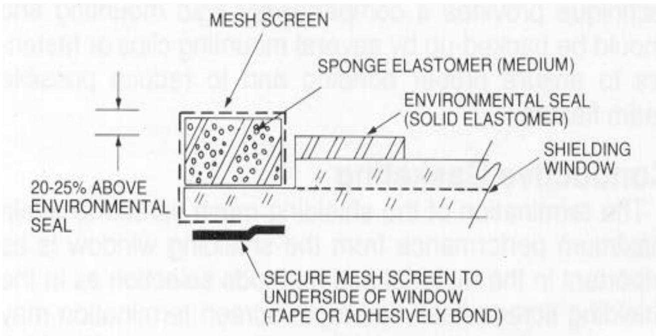
1. Bond, Direct Contact, Self Gasketing: Shielding effectiveness tests have shown that the most consistent results and highest performance are attained when the shielding screen is bonded permanently to the enclosure by spot welding, brazing or soldering, depending upon the material used for the screen. Generally, this method is not cost effective.

Figure 8



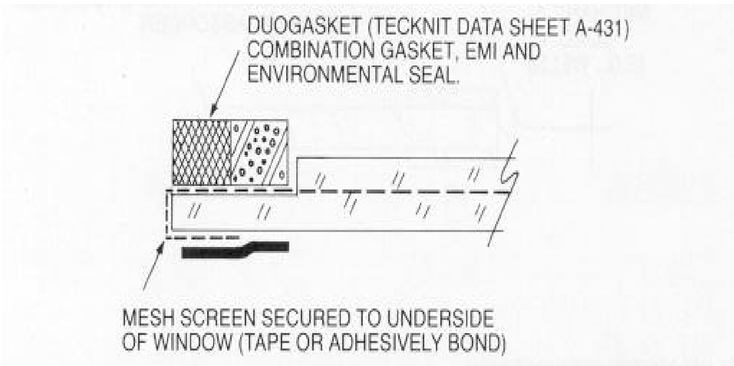
A nearly identical method of assembly may be attained by a mechanical clamping of the screen as shown in Figure 8. For both glass and plastic windows, the use of elastomer gaskets (neoprene or silicone) as moisture barriers and for shock mounting is recommended.

Figure 9



2. Wrap-Around, Direct Contact, Self Gasketing: The mesh screen is wrapped over a sponge or hollow core elastomer gasket and secured to the underside of the window (Figure 9). The use of elastomer moisture barrier and shock mounts to protect the window and screen from possible adverse environment is recommended.

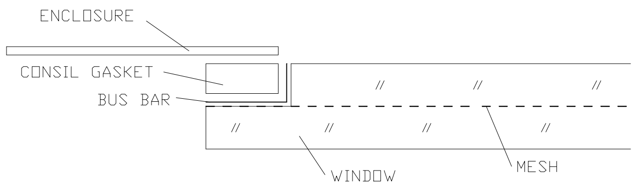
Figure 10



3. Interfacial Gasket, Indirect Contact, Conductive Gasketing: The mesh screen is extended along the flat of the step formed in the lamination process and secured to the underside of the window (Figure 10). A conductive metallic or elastomer gasket is mounted and bonded to the surface of the step. The gasket should be resilient and compatible with the screen and enclosure materials. Contact resistance must be kept low by means of a low impedance bond, such as a conductive RTV or conductive epoxy. A recommended gasket for this type of application, providing both EMC and moisture barrier, is a knitted mesh bonded to a silicone sponge. The knitted mesh strip should utilize tin-plated phosphor-bronze (TPPB). TPPB provides highest shielding and environmental compatibility between the shielding screen and the enclosure surface.

4.Silver Busbar, indirect contact and conductive gasketing

This method is typically employed on Tecknit Europe's Allyl carbonate cast windows. The window is machined to size using an accurate CNC milling machine. These milling machines allow a highly precise window to be cut to very precise tolerances. A shoulder shape is cut which removes the substrate material to leave the exposed mesh. A silver bus bar is then added to provide a highly conductive surface that is connected to the EMI screen mesh. A conductive elastomer gasket (A Tecknit Consil product) is then used to ensure a uniform electrical connection between the bus bar and the enclosure. See figure 10a above.



Many combinations of gaskets are possible. The four methods described have been successful in specific applications. The greatest number of interfacing surfaces which must make low impedance contact between each interface, the greater will be induced electromagnetic noise current and the lower the shielding effectiveness of the system. As a rule of thumb, provide a 10:1 signal to noise ratio margin (about 20 dB more shielding) than may be actually required when all the mating surfaces are freshly cleaned and properly protected.

10.3 Surface Preparation

The primary function of an EMC gasket is to provide an impedance that matches or exceeds the conductivity of the enclosure and minimizes the coupling efficiency of the seam itself from becoming a re-radiator. Normally, the reflection and absorption functions of a conductive shielding gasket are to a large extent masked by metal covers, metal enclosures and by sufficient fasteners to securely hold the cover plates in place. However, with shielding windows, the solid metal cover has been replaced by a quasi-continuous open mesh which at best is equivalent to a very thin barrier. At high frequencies (about 100MHz) the screen does not respond as a solid barrier. Special attention must be paid to the method by which the induced EMI currents in the mesh screen are returned to the system ground. Any significant difference in seam impedance, including that introduced by the gasket materials, may produce non-uniform current flow resulting in the generation of EMI voltages. Such induced voltages can then become sources of EMI radiated energy. To minimize these effects, the seam design and preparation is important and the following features should be incorporated into any new design:

1. Mating surfaces should be as flat and parallel as practically possible.

2. Mating surfaces must be conductive and protected from oxidation by plating with a hard conductive finish that is galvanically compatible with each other and with interfacial gaskets (tin, nickel, cadmium).

3. Protective coatings having less than half the conductivity of the mating surfaces should be avoided.

4. Flange width should allow at least five (5) times the maximum expected separation between mating conductive surfaces.

5. Mating surfaces should be cleaned to remove dirt and oxide films just prior to assembly of the shielding window to the enclosure and bezel.

6. Bonded surfaces should be held under pressure during adhesive curing to minimize surface oxidation and to maximize conductivity after cure.

11.Corrosion

Corrosion is one of the major factors that influences specific design considerations. Generally, the light weight structural materials, aluminium and magnesium, are most highly active electrochemically when in contact with the more conductive materials used for shielding. Selecting suitable shielding materials and finishes that inhibit oxidation and corrosion and are compatible with enclosure materials becomes a major trade off in the designing of shielding windows.

Corrosion occurs between dissimilar metals in the presence of an electrolyte. Dissimilar metals in contact with each other whilst in the presence of an electrolyte cause galvanic corrosion. A single metal under stress in the presence of an electrolyte may result in stress corrosion due to impurities embedded within the conductor. Table 11.1, electrochemical compatibility grouping, lists groups of common materials used as structural, barrier and gasketing materials. The rate of corrosion (erosion of the less noble metals anodic) depends upon the electrochemical potential difference between the dissimilar metals and the strength of the electrolyte.

Table 11-1. Grouping of Metals by Electrochemical Compatibility

(ANODIC)

Group I	Group II	Group III	Group IV
Magnesium Magnesium Alloys Aluminium Aluminium Alloys Beryllium Zinc & Zinc Plating Chromium Plating	Aluminium Aluminium Alloys Beryllium Zinc & Zinc Plating Chromium Plating Cadmium Plating Carbon Steel Iron Nickel & Nickel Plating Tin & Tin Plating Tin/Lead Solder Lead	Cadmium Plating Carbon Steel Iron Nickel & Nickel Plating Tin & Tin Plating Tin/Lead Solder Lead Brass Stainless Steel Copper & Copper Alloys Nickel/Copper Alloys Monel	Brass Stainless Steel Copper & Copper Alloys Nickel /Copper Alloys Monel Silver Graphite Rhodium Palladium Titanium Platinum Gold

(CATHODIC)

Selection of materials from a common group provides the least chance for corrosion due to galvanic action when materials are in contact for extended periods of time in a normal office environment. The materials are arranged in their decreasing order of galvanic activity within each group and from left to right. Materials at the top of a group or in groups to the left, erode under galvanic action. Dissimilar metals that are in different groups may be accommodated by plating one or both with a material that is common to both the enclosure and the mating surface. For example, aluminium and copper are not compatible in most environmental situations since they are not contained within one single group (aluminium is in groups I and II, while copper is in groups III and IV.) To make these materials compatible, either one or both, preferably the latter, would have to be tin plated.

Summary of Tecknit EMI shielding Window Products:

	Teckshield F	Allyl carbonate	ECTC window	Teckfilm
Maximum size	813x 1372mm (32" x 54")	440x440mm (17.3" x 17.3")	457x 457mm (18" x 18")	
Shielding Material	Woven mesh	Woven mesh	Conductive coating	Conductive coating
Useful Temp range (Celcius)	-55 to 70C	-60 to 100C	-55 to 85C	-60 to 150C
Substrates available	Polycarbonate Glass	Allyl carbonate	Acrylic Glass	Polyestor
Light transmission %	60% open area	93%	70% typical	70 – 80%
SE at 10MHz	120dB @100opi	120dB @ 100opi	90dB	90dB
Anti- glare finish	Optional	Optional	Optional	-
Anti- reflection	Optional	Optional	Optional	-
Colour filter	Optional	Optional	Optional	-
Abrasive resistant coating	Optional (but acrylic only)	Optional	Optional	-
Cicular polorizer	Yes (fully laminated)	No	Yes (Edge bond)	-

Summary of EMI Window Specifications

1.Decide up on the EMI Shielding level, in dB, and open area in %

Shielding screen material	Shielding range dB			Optical Open area %		
	1 MHz	10MHz	1GHz	0.001”	0.002”	0.0045”
knitted mesh	30-40	60-70	20-25	95-98%	90-96%	79-91%
Transparent conductive coating	40-50	70-80	30-40	60-80%	NA	NA
Woven wire mesh	65-75	95-110	60-70	64-86%	36-70%	30-41%

2.Determine Substrate type

Property	UNITS	PLATE GLASS	ACRYLIC	POLY - CARBONATE	ALLYL- CARBONATE
Optical					
Index of refraction	-	1.525	1.48-1.51	1.59	1.50-1.57
Transmission	%	90	91-92	85-89	89-91
Haze	%	0.9	0.6	0.5-2.0	0.4
Mechanical					
Flexure Strength	Psi		12-14000	12-13000	5000
Impact strength *	ft-lb.in		0.4	12-16	0.2-0.4
Hardness	Rockwell		M80-M90	M68-M74	M95-M100
Specific Gravity	-	2.52	1.20	1.20	1.20
Electrical					
Dielectric strength	Volt/mil		450-530	380-425	290
Dielectric Constant	@1MHz		2.7-3.2	3.0-3.1	3.5-3.8
Volume resistivity	ohm-cm		10^{15}	$8x10^{16}$	4×10^{14}
Thermal					
Thermal conductivity	#		1.44	1.35-1.41	1.45
Specific Heat	Btu/lb.ºF		0.35	0.3	0.3
Coeff.Therm.Expansion	In/in.ºF	$4.7x10^{-6}$	$45x10^{-6}$	$37.5x10^{-6}$	$60x10^{-6}$
Continuous use temp.	ºC/ºF		80/212	100/212	100/212
Chemical / Physical					
Water absorption	% (24hrs)	-	0.3-0.4	0.15	0.2
Abrasion Resistance	ASTM 1044	0	14	100	-

* Izod notch   # Btu-in/ hr.ft^2.ºF

3.Determine Window finish, from:

Matt finish
Polarizer type (circular or linear)
Optical colour transmission
Abrasion resistant coating
Assembly and mounting method
Corrosion

References: Tecknit Design Guidelines to EMI shielded windows, P. Grant, 1984.