Design Guidelines to EMI Shielding Windows

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INTRODUCTION

The DESIGN GUIDELINES TO SHIELDING WINDOWS is intended to aid designers in understanding the trade-offs associated with the selection of specific materials against anticipated performance.

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 read-outs. 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 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 and glass sheets; (2) Casting a screen within a plastic sheet; (3) applying an optically clear conductive layer to a transparent substrate. Until recently, the typical conductive screen was a knitted wire mesh made from Monel, tin-plated copper-clad iron core (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.

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.

High-density woven wire screens have been employed which have extended the useful high-frequency response beyond 10GHz. 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 large wire diameters usually result in higher shielding effectiveness with lower optical performance.

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.

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 emitter and a susceptor. An EMI emitter generates unwanted noise; a susceptor responds to unwanted noise. Military and governmental specifications stipulate the allowable levels of radiated and conducted emissions and the necessary circuit immunity to these emissions to achieve electromagnetic compatibility (EMC).

Shielding requirements for shielding windows can vary from moderate to severe. Any barrier placed between an emitter and a susceptor that diminishes the field strength of the interference is an EMI shield. The attenuation of the electromagnetic field is referred to as its shielding effective (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 functions of the barrier material properties: permeability, conductivity, and thickness, as well as the distance from the emitter to the shield. Figure 2-1 depicts the relationship between decibels, attenuation ratio, and percent attenuation.

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 80d dB to 120 dB. Above 120 dB, shielding effectiveness is difficult to achieve and difficult to confirm by measurement.

Figure 2-2 shows the range of shielding effectiveness for the three primary barrier materials used in shielding window: knitted wire mesh screens (Band I), transparent conductive coatings (Band II), and woven mesh screens (Band III). Shielding performance is the primary consideration in the design process and is, therefore, considered first.

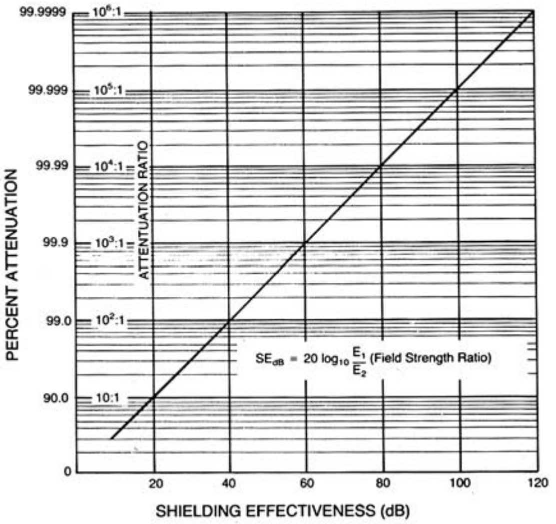
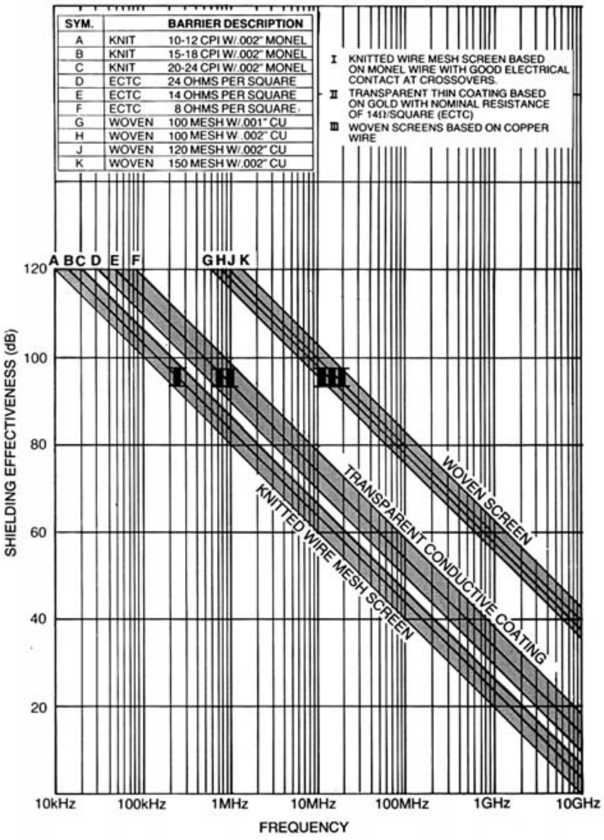


Figure 2. Shielding Effectiveness as a Function of Attenuation.



SYM.	BARRIER DESCRIPTION	
A	KNIT	10-12 CPI W/.002" MONEL
B	KNIT	15-18 CPI W/.002" MONEL
C	KNIT	20-24 CPI W/.002" MONEL
D	ECTC	24 OHMS PER SQUARE
E	ECTC	14 OHMS PER SQUARE
F	ECTC	8 OHMS PER SQUARE
G	WOVEN	100 MESH W/.001" CU
H	WOVEN	100 MESH W .002" CU
J	WOVEN	120 MESH W/.002" CU
K	WOVEN	150 MESH W/.002" CU

I KNITTED WIRE MESH SCREEN BASED ON MONEL WIRE WITH GOOD ELECTRICAL CONTACT AT CROSSOVERS.
II TRANSPARENT THIN COATING BASED ON GOLD WITH NOMINAL RESISTANCE OF 14Ω/SQUARE (ECTC)
III WOVEN SCREENS BASED ON COPPER WIRE

Figure 2-2. Barrier Shielding Performance for Shielding Windows.

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The shielding values presented in Figure 2-2 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:

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

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, which 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 2-2 shows that any of the three families of shielding materials would be suitable to provide 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 types 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, plus the optical substrate. Standard optical substrates should cause only a minor reduction in optical transmission should be less than 1% 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 to be referred to as percent open area. This characteristic is important in determining optical contrast which can affect operator fatigue in using devices such as video display monitors.

Table 2-1 summarizes the general shielding effectiveness ranges at specific frequencies for the three shielding materials shown in Figure 2-2. The three frequencies are 1 MHz (magnetic field), 10MHz (electric field), and 1 GHz (plane wave).

SUMMARY

Figure 2-1. Shielding Performance

Shielding Screen Material	**Shielding Range (dB)**		
	Magnetic 1 MHz	**Electric 10MHz**	**Plane 1GHz**
I Knitted Wire Mesh (Monel-Cross over Bond) 10-30 CPI	30-40	60-70	20-25
II Transparent Conductive Coating 8 to 24 OHM/Square	40-50	70-80	30-40
III Woven WireMesh (Copper Wire) 80-200 mesh	65-75	95-110	60-70

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 color filters. This section discusses the optical performance of the shielding screens.

Knitted mesh screens are produced on industrial knitting machines that were originally developed for the commercial, knitted fabric materials industry. The machines have been adapted to handle wire instead of yarn. In this process they produce a continuous tube of material called a "stocking." The diameter of the stockings varies from 3/8 inch to 30 inches. Various sizes are used to make electrically conductive metal gaskets and the conductive mesh screens for shielding windows. The irregular shapes formed in the knitting process (see Figure 3-1) aid in minimizing any obscuration of 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 call out 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.

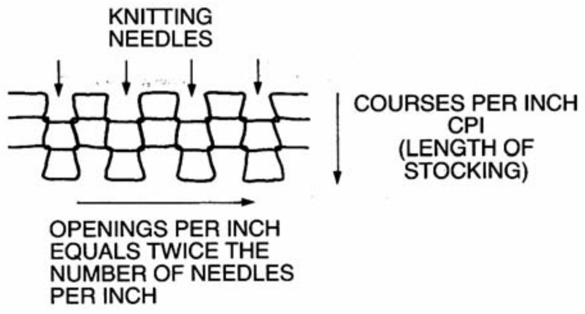

Figure 3. Knitted Mesh Screens.

Woven mesh using fine wires, generally much smaller than 0.005 inch diameter, provide a significant improvement in shielding effectiveness over other shielding widow materials, even at higher frequencies. These woven screens have 80 or more wires to the inch in both directions (Figure 3-2). 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.

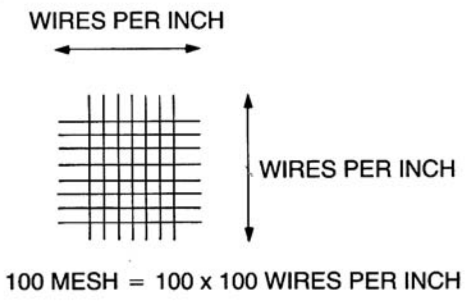

Figure 3-2. Woven Mesh Screens.

A third shielding material is the transparent conductive coating. This material exhibits good shielding properties at moderate optical transparency (reference Table 2-1 on shielding performance for knitted, woven and transparent conductive coatings). Since the shielding effectiveness is a function of the resistivity of the transparent coating which, in turn, is a function of the optical transmission, there are tradeoffs in performance (see Figure 3-3 and Table 3-1). 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.

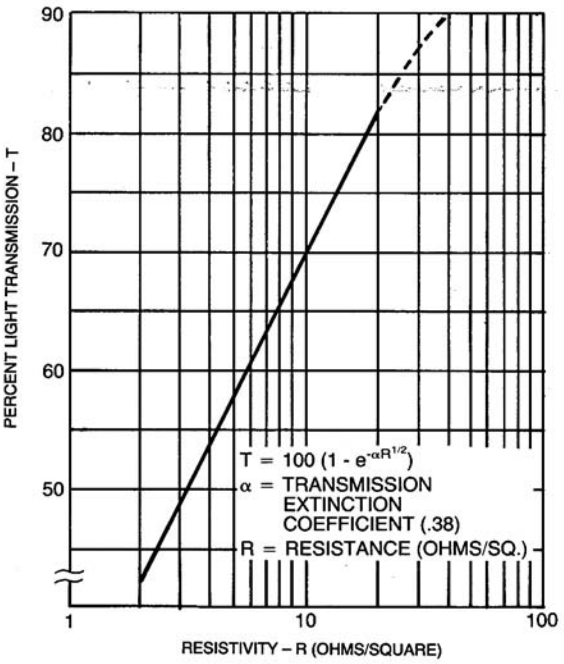

Figure 3-3. Light Transmission-Resistivity Relationship (Thin Gold Coating).

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Figure 3-4 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 circle (O) on the figure.

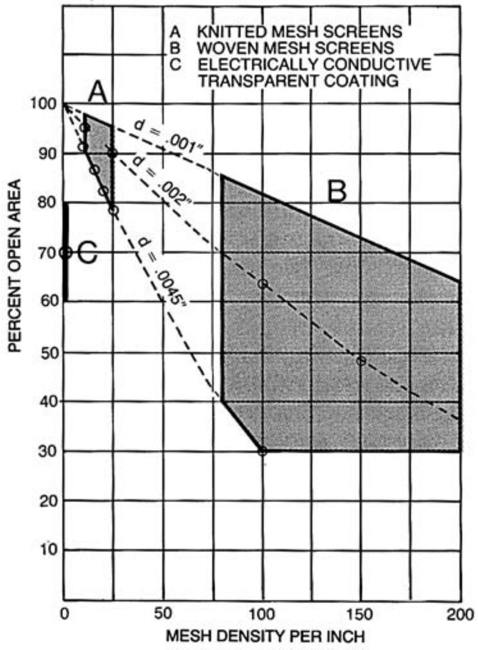

Figure 3-4. Percent Open Area of Mesh Screen.

Section A of Figure 3-4 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 3-4 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 3-4 (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 color CRT's employing a color mask on the faceplate. The color mask is used to delineate the specific phosphor color to be displayed. The masks have a color 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 color CRT, patterns of dark and 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 color 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 color 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 color monitors. The main limitations with the ECTC windows are high

Figure 3-1.

Shielding Screen Material	Shielding Range (dB)			Optical Open Area (%)		
	Magnetic 1 MHz	Electric 10MHz	Plane 1GHz	0.001" DIA.	0.002' DIA.	0.0045" DIA.
I Knitted Wire Mesh (Monel-Cross over Bond) 10-30 CPI	30-40	60-70	20-25	95-98%	90-96%	79-91%
II Transparent Conductive Coating (Molecular 8 to 24 OHM/Square Structure)	40-50	70-80	30-40	60-80%	NA	NA
III Woven WireMesh (Copper Wire) 80-200 mesh	65-75	95-110	60-70	64-86%	36-70%	30-41%

cost, their tendency to be easily scratched, a noticeable color tint for some coatings and a lower shielding effectiveness than the woven mesh screens.

The TECKNIT EMI Shielding Design Guide is an excellent reference in determining the required shielding for specific specifications (MIL-STD-461, FCC, VDE and others) against equipment circuits and EMI generators. Tables 3-1 summarize the performance capabilities of shielding windows from both shielding and optical aspects.

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.

Properties of the glass conform to ASTM-C-1036 and mirror to mirror select quality. Edges are cut and trimmed to remove any sharp surfaces. Edges may be ground, ground and polished, beveled, or mitered on special order as specified by customer drawings or specifications. Standard glass window thickness is 0.205 inch with a tolerance of plus or minus 0.020 inch. Other thickness may be furnished in the ranges and tolerances shown in Table 4-1. Maximum outside dimensions (length by width) are 18 inches by 14 inches with a standard tolerance of plus or minus 0.031 inch. Major defects such as gaseous inclusions, which are permitted by Federal Specifications, are culled before laminating. Glass, in effect, when specified for shielding windows will exceed the requirements as stipulated in federal Specifications. Plate glass is specified to assure virtually parallel and flat surfaces. See **TECKSHIELD-F Data Sheet** for laminated glass windows.

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.

A **thermoplastic** material softens when heated and hardens on cooling. Since this action is reversible it is possible for the material to be molded and remolded without appreciable change in the material properties. The significant difference in **thermosetting** materials is the irreversible heating action. These latter materials, once softened by heating, remain in the shape formed during the original heating cycle. Hence, the desired or final shape of the windows to be made must be incorporated into the mold of the part. Furthermore, with thermosetting plastics, the desired color) other than clear) depends on the thorough blending of the proper mixture of the coloring agent with the plastic material before molding.

THERMOPLASTICS-Cellulose Derivatives: The principal cellulose derivatives are the nitrate, acetate, acetate butyrate, and ethyl cellulose. The cellulose plastics have a comparatively poor surface hardness and poor abrasive resistance. They are readily hygroscopic (absorb water) with a resultant change in dimensions. Most do not possess the high optical qualities of glass or some of the other plastic substrate materials. Softening occurs at about 60*C for these thermoplastic materials and, therefore must be used in applications which will not exceed their softening temperature. **Cellulose acetate butyrate** (CAB) is probably the best of the cellulose family of plastics. It is especially suited to molding and possesses lower water absorption than other cellulose derivates and therefore, betters dimensional stability than cellulose acetate.

THERMOPLASTICS-Synthetic Resins: The principal thermoplastic resin materials consist of polycarbonates, polystyrenes and methyl methacrylates (acrylic). In general these resins are characterized by higher resistance to chemicals and lower water absorption than the cellulose derivatives. They generally have optical characteristics very close to glass with a much lower tendency toward scratching, but are still very much softer than glass. Polycarbonate is about 10 times easier to scratch or mar than the methyl methacrylates (acrylic).

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 125*C. 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.

Polystyrene material is relatively hard and rigid, naturally colorless and quite transparent. The softening range is about 20*C higher than the cellulose plastics, but lower than that for acrylic resins. Most other properties for this material are excellent except for poor resistance to most organic solvents.

Methyl methacrylate (acrylic) material has high luster, high transparency, and good surface hardness, is comparatively inert chemically and is not toxic. Essentially, acrylic possesses almost all the desirable qualities of glass except for scratch resistance. Com pared to other plastics, methyl methacrylate is harder than most but still readily scratched by dust particles.

Methyl methacrylate is a very stable compound and retains to a high degree its mechanical properties under adverse environmental conditions. Impact resistance when compared to some plastics is poor, although when compared to glass it is much superior.

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THERMOSETTING RESINS – ACP, CR-39 (PPG industries): ACP (Allyl Cast Plastic) is known as Columbia Resin (CR-39). It is a transparent solid, cured from the clear, colorless, 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 attach by chemicals. The continuous use temperature is 100*C.

In summary, the three most likely candidates for optical substrate materials in shielding window application are glass, acrylic and CR-39, in that order. Table 4-2 summarizes the performance characteristics of these materials.

TABLE 4-1
STANDARD SIZES AND TOLERANCES

MATERIAL	MAXIMUM SIZE	TOLERANCE	THICKNESS (Overall)	REMARKS
Plate Glass (woven mesh)	**Standard** 32″ x 56″ 32″ x 32″ **Special** 14″ x 14″	±0.031″	Standard[1] 0.270 ± 0.020 inch 0.205 ± 0.020 inch **Special** 0.145 ± 0.020 inch	Glass per ASTM-C-1036
Plastic (woven mesh)	**Standard** 24″ x 24″ **Special** 32″ x 32″ 32″ x 56″	±0.031″	**Standard** (acrylic) 0.145 ± 0.020 inch **Special** (acrylic) 0.205 ± 0.020 inch 0.270 ± 0.020 inch	Acrylic per L-P-391
Plastic (knitted mesh & ECTC)[4]	18″ x 22″	±0.031″	**Standard** (cast)[2] 0.125±0.010 inch **Standard** (edge laminated)[3] 0.135±0.015 inch **Special** (Cast) 0.060±0.010 inch	Smooth or matte finish, Polycarbonate CR-39, Acrylics

[1] **TECKSHIELD-F** Specification Reference, Appendix A-1
[2] **EMC-CAST** Specification Reference, Appendix A-2
[3] **EMC-LAMINATED** Specification Reference, Appendix A-3
[4] **EMC-ECTC** Specification Reference, Appendix A-4
[5] Contact factory for larger edge bonded windows.

TABLE 4-2
PROPERTIES OF WINDOW SUBSTRATES (TYPICAL VALUES FOR CLEAR COLORLESS MATERIAL)

PROPERTY	UNITS	PLATE GLASS	METHYL METHACRYLATE (ACRYLIC)[1]	POLYCARBONATE[1]	CR-39
OPTICAL					
Index of refraction	–	1.529	1.48-1.51	1.59	1.50-1.57
Transmission	%	90	21-23	85-89	89-91
Haze	%	0.9	0.6	0.5-2.0	0.4
MECHANICAL					
Flexure Strength	psi		12-14,000	12-13,000	5,000
Impact Strength (Izod Notch)	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	1.32
ELECTRICAL					
Dielectric Strength	volt/mil		450-530	380-425	290
Dielectric Constnat	@1MHz		2.7-3.2	3.0-3.1	3.5-3.8
Volume Resistivity	ohm-cm		10^{15}	8x10^{16}	4x10^{14}
THERMAL					
Thermal Conductivity	Btu-in/hr•ft^2•°F		1.44	1.35-1.41	1.45
Specific Heat	Btu/lb°F		0.35	0.3	0.3
Coeff. Therm. Expan.	in/in/°F	4.7X10^{-6}	45x10^{-6}	37.5x10^{-6}	60x10^{-6}
Continuous Use Temp.	°C/F	110/230	80/175	100/212	100/212
CHEMICAL/PHYSICAL					
Water Absorbtion	% (24hrs.)	—	0.3-0.4	0.15	0.2
Abrasion Resistance	ASTM 1044	0	14	100	—

[1] Connectors & Interconnections Handbook Volume 4, Materials, 1983.

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, matte finishes, optical color transmission filters, or special laminates such as polarizers.

Antiglare or glare reduction techniques consist of either an antireflection coating for glass windows or a matte finish for glass or plastic windows. Antireflection coatings utilize optical interference filters, while matte finishes are imprinted into the surface of the substrate and scatter incident light to reduce specular reflection (See Figure 5-1).

Color transmission filters transmit only specific color 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.

ANTIREFLECTION COATINGS

Antireflection interference coatings are applied to optical elements of shielding windows to reduce reflections. These coatings are applied by several deposition methods, such as high vacuum evaporation, sputtering thin film coating techniques. The techniques to reduce surface reflection from glass optical elements have been well known in the optical industry for many years. Virtually all lenses in modern cameras have a single or multilayer antireflection coating. The amount and the rate of material applied to the surface are controlled to obtain the required film thickness. These specialized coatings consist of several thin film layers of different materials to obtain a particular optical effect.

The basic laws of optics determine the reflection that occurs at a boundary between two transparent media of different index of refraction (n). The index of refraction is a measure of the speed of light in a medium. For vacuum, the index is 1.00 and for all practical purposes, it is 1.00 for air. Higher indices indicate a slower propagation speed for light in that media. The index for plate glass, such as used in shielding windows, is 1.525. This higher index means that the speed of light in plate glass is approximately two-thirds the speed of light in air. These indices are used to determine the percentage of incident light, which will be reflected at the boundary.

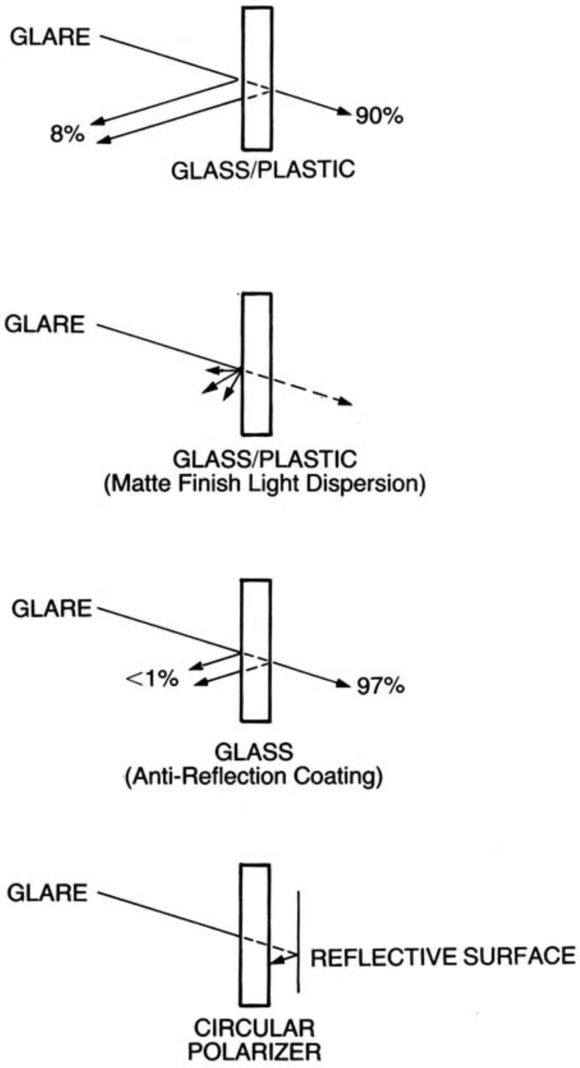

Figure 5-1. Glare Reduction Techniques.

The reflection (R) occurs at the boundary of interface between two different indices and can be calculated from the equation:

$$R=\frac{(n_g - n_a)^2}{(n_g - n_a)^2}$$

For ng: the index for glass is 1.52
For na: the index for air, 1.00

For the indices given above, the ratio of reflected to incident light is 0.04 or 4%. A similar reflection will occur wherever a boundary between two different indices exists, such as the boundary between glass and air at the second surface. The front and back surface reflections then may amount to a total of 8%

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of the incident light being reflected back to the viewer for plate glass with an index of 1.52. Figure 5-2 shows the relationship of reflection to indices from 1.0 to 2.0.

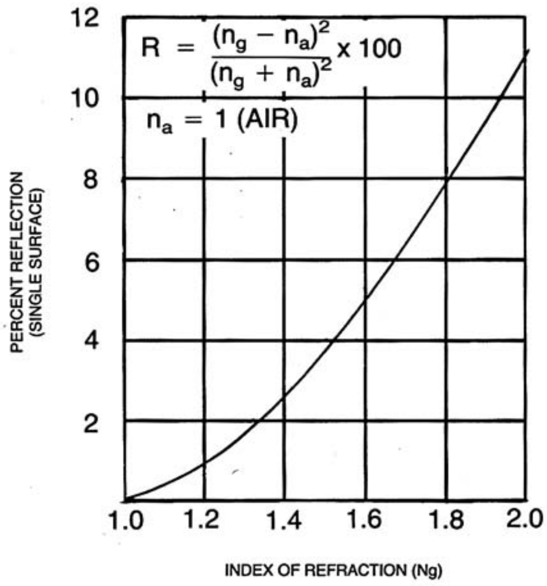


Figure 5-2. Percent Reflection Against Index of Refraction.

Figure 5-3 represents schematically an air/antireflection-coating glass interface. The light wavefront represented by two electromagnetic rays (A & B) impinge onto the front surface of the antireflection coating. Small portions (4%) of rays A & B are reflected while the larger portion of each enters the coating. Ray A reflects another small portion (4%) at the boundary between the antireflection coating and the glass substrate. The thickness of the coating is exactly ? of the wavelength of the reflected light to be absorbed. The reflected Ray A at the boundary between the antireflection coating at Point 2 arrives at Point 3 exactly out of phase with Ray B (out of phase occurs where Ray A is positive, Ray B is negative and of equal amplitude). At point 3 the out of phase condition results in destructive interference between rays A & B with a complete cancellation of the reflected wave fronts. The same cancellation occurs at the back surface when it is also subjected to the antireflection coating.

In reality, the number of materials that are available for antireflection coating are fairly limited, requiring a high index of refraction for the lass substrate and a low index for the coating. Under exact conditions, it was shown in the paragraph that the air-to-coating boundary reflection may

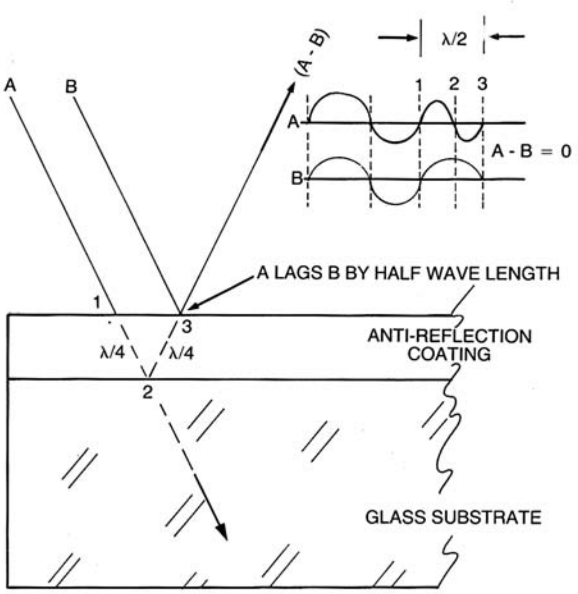


Figure 5-3. Air-Antireflection Coating-Glass interface

result in complete cancellation of the reflection from the coating-to-glass boundary, thus producing a near zero reflection value at some selected optical wave length. Unfortunately, in most applications, exact matching of indices and layer thickness seldom occurs. Even for only slightly mismatched conditions, the human eye is extremely sensitive to low light levels. To the untrained observer, a 1% to 2% reflectivity is still very apparent and often difficult to distinguish from an uncoated glass surface. To be effective for glare reduction application, the coating must reduce a single surface reflection significantly below 0.5% The transmission of TECKNIT high-efficiency optical coating is greater than 99% which is more than 7% higher than that for uncoated plate glass. Uncoated plate glass transmits approximately 90% of the incident light. Surface reflections account for 8% and absorption accounts for approximately 2%. To avoid the reflection of the second (back) glass-to-air boundary, the back surface must be coated with a similar coating.

The eight percent (8%) reflection of incident light from the glass surface may be frequently as intense as the optical energy generated by many displays. Cathode ray tubes (CRT) monitors, radar scopes for traffic controllers, digital LED and LCD and electroluminescence are examples of fairly low brightness displays. In some applications where the ambient light is very high (outdoors), the intensity of the reflected light may exceed the light energy from most data displays.

Under these conditions, it is often easier to see the reflected image of the scene behind the viewer than the display itself that has been completely of almost completely washed-out (zero contrast) by ambient light. In these cases, the use of light dispersion (scattering surfaces as are provided by matte finishes. Circular polarizers are useful for eliminating reflections internal within the display that can be reflected back toward the viewer reducing image contrast.

MATTE FINISH

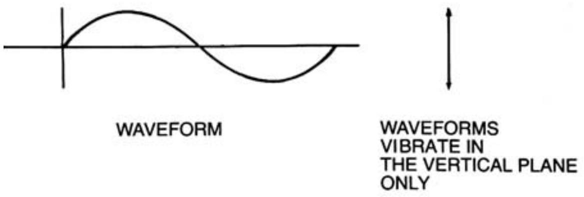
Matte finishes are used as an antireflection surface treatment to effect a dispersion of specular reflectance. These finishes for either glass (an etch finish) or plastic (mold or cast finish) are available as an alternate to thee antireflection coating (HEOC for glass). Matte front surface finishes 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 display, LED, LCD, and electroluminescent and monochrome or multicolor displays.

At or near normal incidence where ambient light strikes the window straight on, light reflected is a function of the indices as discussed earlier. As the angle of incidence increases s measured from the normal (perpendicular) to the window surface, an abrupt increase in reflection occurs bout 45∞ incident angle. These near grazing angles are often coincident with the positioning of overhead lighting. Reflections under these conditions are best treated with a shading hood or by using matte finish which dispense the reflected energy (reference Figure 5-1).

POLARIZERS

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

Electromagnetic radiation is generally conceived of on the basis of field theory. An electric and magnetic field are said to exist at right angles to each other. In any random waveform, the orientation of either field would be random in relation to some fixed axis. Therefore, in a bundle of optical waveforms or rays, there would be (statistically) a complete random orientation of the fields (the electric field, for example) as shown in Figure 5-4b. These waveforms would be unpolarized; that is, there would be no preferential orientation of either field. A polarized wave, then, is one in which the fields are specially oriented in one direction, Figure 5-4A.



(A) PLANE POLARIZED WAVEFORM

(B) UNPOLARIZED WAVEFORM

Figure 5-4. Polarized and Unpolarized Waveforms

A linear polarizer selectively transmits an unpolarized waveform by resolving the field components that are aligned with the polarizing axis of the polarizer. In this manner, the polarized waveform consists of a single orientation of the electric field. When viewed through another linear polarizer (called an analyzer) with its polarization axis at right angles (90º) to the polarized waveform, the light will be completely blocked. When the axis is aligned at other than a right angle to the polarized waveform, the wave is transmitted as a function of the angle (COSINE$^2\Theta$) between the axes of the polarizer and the analyzer. For example, where the axes are aligned at 45º, about 50% of the polarized light will pass through the analyzer.

Linear polarizers are used to control light output. These polarizers attenuate reflected light glare form smooth objects where the reflected light has been polarized in a known plane, such as horizontally. To minimize the reflected light, the linear polarizer acting as an analyzer is oriented with its polarizing axis perpendicular to the reflecting surface.

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

Design Guidelines to EMI Shielding Windows cont.

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The problem then becomes one of discriminating between light which enters the display from the window side and light generated within the display. Generally, the acceptance angle of the light entering the display will be fairly narrow (Figure 5-5). The farther away the display is located in relation to the window, the narrower the acceptance angle of the interfering light and, therefore, less chance that light will be retro-reflected back to the viewer. Light, which originates outside the acceptance angle will not contribute to the loss in contrast with the image being emitted at the display (CRT, LED, annunciators - those displays that generate their own illumination). Additionally, orientation of the reflecting object within the display plays an important part in determining what light from the window will be reflected back out the window toward the viewer.

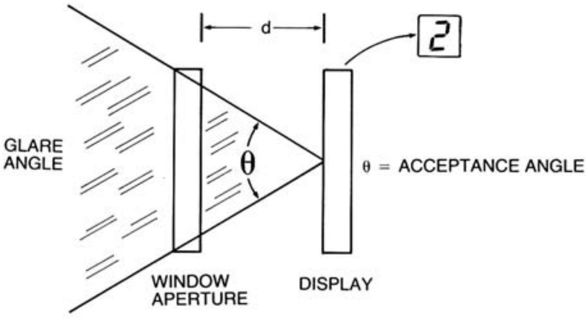

Figure 5-5. Glare Acceptance Angle.

CIRCULAR POLARIZER – HOW IT WORKS

A circular polarizer consists of linear polarizer in series with a 1/4 wave-retarding element. It is important that the linear polarizer precedes and is oriented (aligned) correctly to the ? wave-retarding element.

With reference to Figure 5-6, light passing through the linear polarizer is polarized along its polarizing axis and enters the 1/4 wave retarder. The 1/4 wave retarder separates the polarized rays into two equal rays that pass through the retarder at different speeds (by virtue of two different indices of refraction). The thickness of the retarder determines the phase relationship of the two light rays and is selected to produce a 90º phase shift (1/4 wavelength). After passing through the 1/4 wavelength retarder, the phase relationship of the rays remains constant. Upon striking a highly reflective surface (specular), the phase orientation of the two rays reverses with the phase lagging ray preceding the previously phase leading ray by 1/4 wavelength.

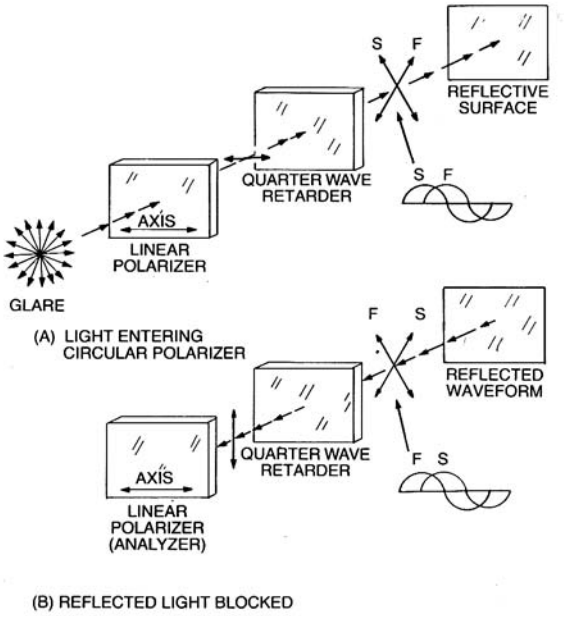

Figure 5-6. Circular Polarizer.

On reentry through the 1/4 wave element, the retarder phase aligns the two rays and orients the resultant wave at right angles to its original polarization. The 90º rotated polarized wave emerging from the 1/4 wave retarder is then completely blocked by the linear polarizer (the first element of the circular polarizer).

Circular polarizers can not be used with LCD display. LCD displays use linear polarizers in their normal operation to effect selective filtering of the external illumination. This type of display would partially or completely block the incident light from the circular polarizer, effectively defeating the purpose of the various elements of the LCD.

OPTICAL COLOR TRANSMISSION FILTERS

Optical filters generally are classified according to their spectral properties such as short wave cut-off, long wave cut-off, bandpass, 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. Bandpass 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 equipment, such as laser beam. Neutral density filters reduce the average illumination across the visual spectrum.

In shielding window applications, transmission filters are used to provide various hue 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.

Light transmitted through the filter material experiences a first surface reflection, absorption within the bulk of the material and losses due to the second surface reflection. The transmitted light (T) is a fraction of the incident light and the optical density of the filter is given by:

$$D = \log_{10} \frac{1}{T}$$

Where there are several transmission factors involved (multiple values of T), thee factors should be included and multiplied together. For example, if the transmission factor for a color filter at the peak wavelength is Tp and the optical substrate transmission factor is Ts, the density expression would be:

$$D_T = \log_{10} \frac{1}{T_P T_S}$$

Standard colors are available for plastics which broadly cover four hue classes (red, yellow, green, blue) and neutral gray. Table 5-1 tabulates suggested filters, which most nearly match the spectral band for each of the emitters.

Figure 5-7 provides spectral transmission curves for the more commonly used filters.

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 coating not only provides scratch and mar resistance, but is also resistant to moisture and cleaning solvents. The coatings re 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.

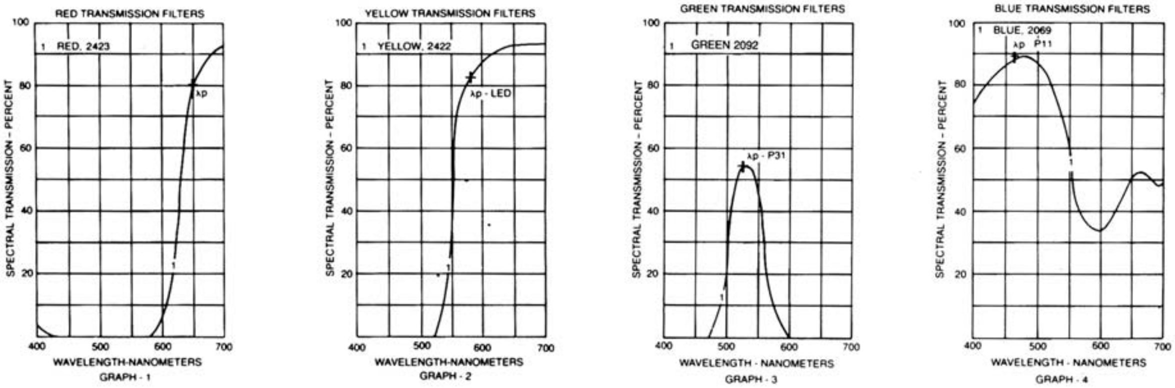

Figure 5-7. Standard Spectral Transmision Filters.

TABLE 5-1
RECOMMENDED TRANSMITTING FILTERS FOR TYPICAL LED EMITTERS

EMITTER	FILTER NUMBER	PEAK WAVELENGTH (λp in nm)	PERCENT TRANSMISSION at λp	PERCENT TOTAL LUMINOUS TRANSMISSION
LED				
Red	2423	650	80	10
Yellow	2422	580	82	60
Green	2092	530	53	21

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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 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 I 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 6-1) 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 hock and vibration.

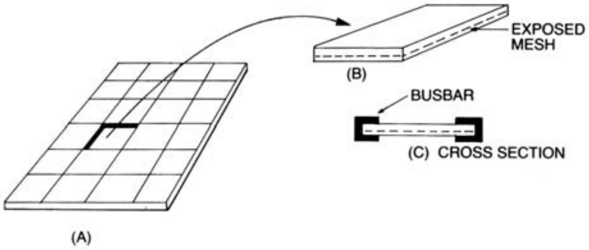

Figure 6-1. Busbar Termination.

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.

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 6-1. Contact is made to the screen by means of a conductive busbar of either a highly conductive coating such as an organic-type paint which 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 vulcanization) 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 flexure.

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 performance shielding window as may be required for NASCIM 5100A (Tempest) applications. There are three recommended edge terminations for woven mesh screens in applications requiring the maximum performance over any extended period. The three methods are listed in order of performance.

1. Bond, Direct Contact, Self Gasketing: Shielding effectiveness tests have shown that the most consistent results and highest performance are

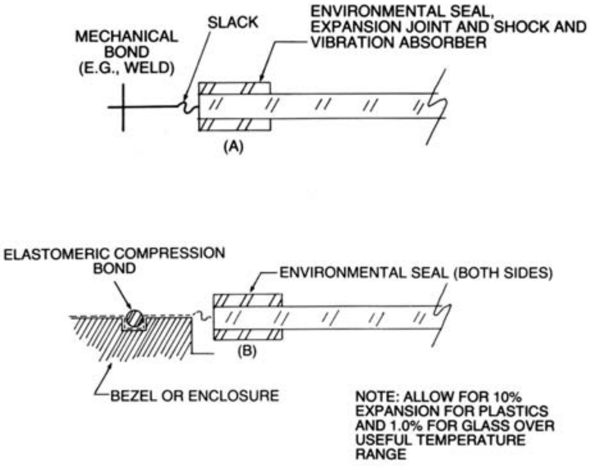

Figure 6-2. Bond Direct Contact.

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. A nearly identical assembly may be attained by a mechanical clamping of the screen as shown in Figure 6-2. For both glass and plastic windows, the use of elastomer gaskets (neoprene or silicone) as moisture barriers and for shock mounting is recommended.

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 6-3). The use of elastomer moisture barrier and shock mounts to protect the window and screen from possible adverse environment is recommended.

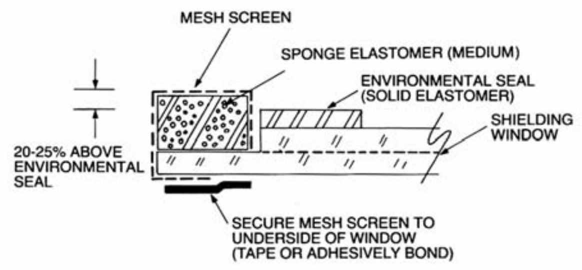

Figure 6-3. Wrap Around Screen, Direct Contact (Most Commonoly Used Configuration).

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 6-4). A conductive metallic or elastomer gasket I 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 (see Tecknit DUOGASKET). 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.

Many combinations of gaskets are possible. The three 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.

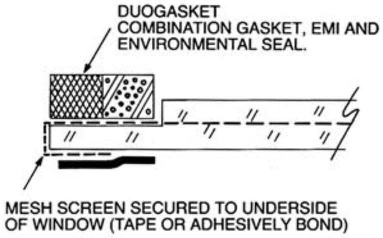

Figure 6-4. Interfacial Gasket, Indirect Contact with Mesh Screens (Most Economical)

SURFACE PREPARATION

The primary function of an EMC gasket is to provide impedance that matches or exceeds the conductivity 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 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 nonuniform 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.

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4. Flange width should allow at least five 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.

CORROSION

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

Corrosion occurs between dissimilar metals in the presence of an electrolyte. Dissimilar metals in contact 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 6-1, electrochemical compatibility grouping, lists groups of common materials used as structural, barrier and gasketing materials. The rate of corrosion (erosion of the less noble metal, anodic) depends upon the electrochemical potential difference between the dissimilar metals and the strength of the electrolyte.

Table 6-1. Grouping of Metals by Electrochemical Compatibility.

(ANODIC)

Group I	Group II	Group III	Group IV
Magnesium	Aluminum	Cadmium Plating	Brass
Magnesium	Aluminum Alloys	Carbon Steel	Stainless Steel
Alloys	Beryllium	Iron	Copper & Copper
Aluminum	Zinc & Zinc Plsling	Nickel & Nickel Plating	Alloys
Aluminum	Chromium Plating	Tin & Tin Plating	Nickel / Copper
Alloys	Cadmium Plating	Tin / Lead Solder	Alloys
Beryllium	Carbon Steel	Lead	Monel
Zinc & Zinc	Iron	Brass	Silver
Plating	Nickel & Nickel Plating	Stainless Steel	Graphite
Chromium	Tin & Tin Plating	Copper & Copper Alloys	Rhodium
Plating	Tin / Lead Solder	Nickel/Copper Alloys	Palladium
	Lead	Monel	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, which 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, aluminum and copper are not compatible in most environmental situations since they are not contained within one single group (aluminum is in groups I and II, while copper is in groups III and IV. To make these materials compatible, either one or both, preferable the latter, would have to be tin plated.

MOUNTING WINDOWS

Twist drills that are commonly used for metals may normally be used on most plastics. Since, when machining plastics, a scraping action produces better results than a cutting action; drills may be repointed to provide zero rake angle. Moderate speed and light pressures produce best results and minimize temperature changes at the cutting edge, which may result in galling or seizing.

Plastic windows may be provided with holes, which are often used for mounting and access holes for screwdriver adjustments for “zeroing” or “scaling” digital readouts. These holes should be drilled prior to the application of surface coating or finishes whenever possible to prevent scratching or marring the surfaces of the window. Holes or notches are not recommended for glass windows.

Common mounting methods include pressure-clips to secure windows under pressure during curing and clamping bars for larger plastic or glass windows. Bolt spacing © for windows, especially those with resilient gasketing, should follow the basic equation as given by:

$$C = \left[\frac{480\ (a/b)\ E\ t3\ \Delta H}{13\ P\ \text{min} + 2\ P\ \text{max}}\right]^{1/4} \text{inches}$$

Where: a=width of clamping bar
b=width of resilent gasket
E=modulus of elasticity of cover plate
t=thickness of clamping bar
$\Delta H=H1-H2$ (difference between max/min gasket deflection)
P min=minimum pressure (at minimum deflection)
P max=maximum pressure (at maximum deflection)

The bolt spacing equation can be simplified by making some assumptions:

1. The bar width (a) will always be equal or greater than the gasket width (b); therefore, the ratio a/b will usually be greater than one (1). The worst case, which requires the minimum bolt spacing (C), occurs when a/b equals one. Should the bar be twice the width of the gasket, the bolt spacing could be increased by about 20%.
2. The maximum closing pressure, as a rule of thumb, should not exceed the minimum pressure by more than a 3:1 ratio.
3. The minimum closing pressure with a solid elastomer moisture seal should not be less than 50 PSI (P min.).
4. Modulus of elasticity for most metals (clamping bar) is greater than 10 PSI.
5. Assume a maximum deflection of 0.010 inch (ΔH).

Then, maximum bolt spacing, C, becomes:

$$C = 15(t)^{3/4}$$

Example: Aluminum clamping bar 1/8 inch thick (t) would require a center-to-center bolt spacing of 3-1/8 or less.

SPECIFYING SHIELDING WINDOWS

Sections 1 through 6 have provided methods by which the designer can establish minimum system need from shielding and optical clarity requirements.

Table 3-1 summarizes the shielding range in dB and open area in percent (%) of three types of shielding screen materials.

Table 4-1 tabulates maximum sizes, thickness and tolerances for standard glass and plastic optical substrates.

Table 4-2 tabulates optical, mechanical, electrical, thermal and chemical/physical properties of standard optical substrate materials: plate glass, methyl methacrylate (acrylic), polycarbonate, and CR-39.

Table 5-1 tabulates standard color transmission filters for plastic substrates.

Table 7-1 summarizes standard features of the **TECKNIT TECKSHIELD-F, and EMC-ECTC** windows.

Table 7-1 provides a suggested work sheet, which will aid **TECKNIT** Application Engineers in handling request for designing or ordering flat shielding windows. For curved shielding windows fully laminated or edges bonded, contact factory. Usually by consulting with the factory before the design stage can result in cost savings and performance enhancement for curved shielding windows.

Table 7-1

	TECKSHIELD-F (Fully Laminated)	**EMC-ECTC**
Maximum Size	32″ x 54″ (813mm x 1372mm)	
Shielding Material	Woven Mesh or Knitted Mesh	Transparent Conductive Coating
Shielding Effectiveness (1GHz)	>60 dB	>30 dB
Anti-Glare Finish (On Request)	Yes	Yes
Anti-Reflection Coating (On Request)	Yes (HEOC)	Yes (One Side Only) (HEOC)
Color Transmission Filters (On Request)	Yes (Ref. Table 5-1)	Yes (Ref. Table 5-1)
Abrasive Resistant Coating	Yes (On Acrylic and Polycarbonate)	Yes
Circular Polarizers	Yes (Fully Laminated)	Yes (Edge Bond)

Design Guidelines to EMI Shielding Windows cont.

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ENGINEERING SPECIFICATIONS ES-71-01, TECKSHIELD WINDOWS – FLAT GLASS

I OPTICAL QUALITY

The finished window will meet the optical quality criteria with respect to any imperfections and defects as detailed below:

A. Minor Imperfections

1. **Definition** – Any one of the following conditions, exceeding 0.0001 square inches but not exceeding 0.0025 square inch area per defect and not exceeding 0.2 inch in its longest dimension, in the viewing area:
   - **a.** embedded Particles
   - **b.** air bubbles
   - **c.** scratches
   - **d.** wire screen defects
2. **Accept/Reject Criteria**
   The window shall not have more than one such “imperfection” per 40 sq. in. of viewing area.

B. Major Defects

3. **Definition** – Any condition as described in Section A, but exceeding 0.0025 square inch in area or exceeding 0.2 inch in its longest dimension per defect in the viewing area.
4. **Accept/Reject Criteria**
   Any “Major Defect” shall be cause for rejection.

II ANTI REFLECTION COATING (HEOC)

The multi-layer low-reflection coating will meet the minimum acceptable requirements for optical contrast enhancement when used for TECKNIT EMI shielding windows.

A. Coated Area: Unless otherwise specified, glass elements shall be coated over their entire effective aperture, except for an allowable uncoated area with a maximum width of 0.060 inch around edges.

B. Specular Reflectance: When applied to substrate materials having indices of refraction of 1.5 ± 0.04, the specular reflectance from a coated surface shall average less than 0.85% for an angle of incidence of 10º over the wavelength range of 450 to 650 nanometers.

C. Coating Quality: The coating shall be uniform in quality and condition, clean, smooth, and free from foreign materials, and from physical imperfections and optical imperfections as follows:

1. The coating shall show no evidence of flaking, peeling or blistering.
2. The coating shall not contain blemishes, such as discoloration, stains, smears and streaks or show evidence of a cloudy or hazy appearance.
3. The coating shall show no evidence of scratches, digs, or pinholes within a central area, which covers 60% of the overall viewing area.

D. Abrasion Resistance: There shall be no visible damage to the coated surface when rubbed 15 times with a standard rubber-pumice eraser under a force of 2 to 2-1/2 pounds.

E. Humidity: Continuous exposure to 100% relative humidity at a temperature of 80º C.

F. Operating and Storage Temperature Range: -55º to + 80ºC continuous.

ECTC™ Windows

ELECTRICALLY CONDUCTIVE TRANSPARENT COATING

U.S. Customary
[SI Metric]

GENERAL DESCRIPTION

ECTC WINDOWS are custom designed optical display panels produced by depositing a very thin electrically conductive transparent coating directly onto the surface of various optical substrate materials to provide high EMI shielding performance coupled with good light transmission properties.

APPLICATION INFORMATION

Applications of ECTC WINDOWS are found in equipment requiring visual displays where the viewing panel must also serve to reduce the radiated electromagnetic energy entering or leaving the device.

SUBSTRATE MATERIALS

Most transparent plastic and glass sheet material are suitable for ECTC coating. However, even those optical substrate materials with high quality surfaces, have minute surface imperfections which become more apparent after coating. In most applications these blemishes will not degrade the appearance of the finished window or the shielding performance.

CONDUCTIVE COATING

Standard ECTC coating has a nominal resistivity of 14.0 ohms per square and a light transmission of about 70 percent in the visible spectrum. Applying ECTC coatings to both surfaces of the optical substrate, increases shielding effectiveness by 6 to 10 dB, while reducing the optical transmission from 70 percent to about 50 percent.

ECTC coatings are easily damaged by abrasion since “finger printing” from oils present in normal skin moisture are difficult to remove. In normal usage, the coating is applied to the inner surface of the window substrate which permits cleaning of the front surface with a commercial window cleaner. NOTE: Inspection, handling and installation personnel should use clean, lint-free cotton gloves when handling ECTC Windows.

SPECIFICATIONS

MATERIAL DESCRIPTION

- **Optical Substrate**
  Acrylic: Acrylic sheet per Federal Specification L-P-391, Type 1, Grade C, clear (ASTM-D-4802).
  Glass: Glass sheet per Specification ASTM-C-1036, clear.
  Commercial Grade Polycarbonate
- **Conductive Coating:**
  TECKNIT ECTC vacuum deposited thin metal film.
  Indium Tin Oxide coatings available upon request.
- **Busbar Termination:** TECKNIT Silver Acrylic conductive coating.
- **Mounting Frame (when specified):** Aluminum alloy

PERFORMANCE CHARACTERISTICS

- **Coating**
  Surface Resistivity: 14 ohms/square nominal (±4 ohms/square).
- **Temperature Range**
  Acrylic: -67°F to 150°F [-55°C to 65°C].
  Glass: -67°F to 167°F [-55°C to 85°C].

MATERIAL	H-FIELD	E-FIELD	PLANE WAVE
ECTC	100 kHz	10 MHz	1 GHz
	20 dB	90 dB	30 dB

Tested in accordance with TECKNIT Test Method TSETS-01, which is based upon modified MIL-STD- 285. Typical values are based on a 5" square window.

BUSBAR TERMINATION AND INTERFACE GASKETING

The edges of ECTC WINDOWS are terminated with a border of highly conductive, silver busbar material. This conductive band serves two purposes:

1. Provides a uniform current distribution. The busbar material has a very low surface resistivity when compared to the ECTC coating.

2. Provides a more durable low impedance bearing surface than the ECTC coating alone. An interface gasket joins the ECTC window coating to the enclosure panel.

The most widely used interface gasket is TECKNIT CONSIL, silver-filled silicone rubber gaskets. These gaskets provide both environmental and electromagnetic sealing without damage to the busbar or coating.

FRAMING AND MOUNTING

Standard ECTC Windows can be mounted directly to the equipment panel or enclosure without an interface gasket using TECKNIT conductive epoxy. When using standard interface gasketing, TECKNIT standard framing is available.

STANDARD OPTICAL SUBSTRATE MATERIAL

Table 1. STANDARD THICKNESS (T)

MATERIALS	THICKNESS (T) in. [mm]	TOLERANCE in. [mm]
Acrylic	.062 [1.52]	±.016 [0.41]
	.125 [3.18]	±.020 [0.51]
Glass	.090 [2.29]	±.020 [0.51]
	.125 [3.18]	±.020 [0.51]

STANDARD WINDOW CONFIGURATION

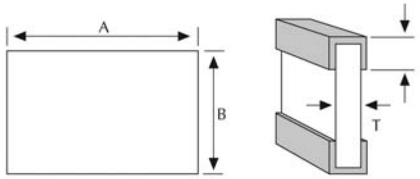
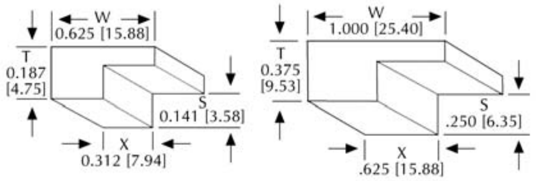


Figure 1. Window Dimensioning.

*Continuous Busbar around periphery (TECKNIT Silver Acrylic Conductive Coating).

STANDARD FRAME STYLES



ACRYLIC (Style 107)   GLASS (Style 135)

Figure 2. Frame Cross Section

STANDARD FRAME DIMENSIONING

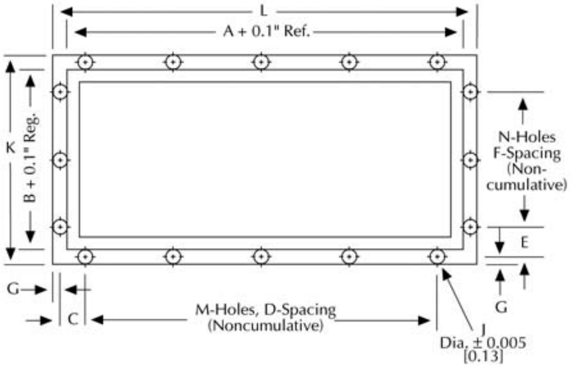


Figure 3. Overall Frame Style

STANDARD TOLERANCES

Table 2. SYMBOL	WINDOW DIMENSION	TOLERANCE
A,B	18 in. [up to 457 mm]	±.031 [0.79]
	FRAME	
C,D,E,F,G	12 in. [up to 305 mm]	±.015 [0.38]
	12-18 in. [305 to 457 mm]	±.020 [0.50]
K,L	12 in. [up to 102 mm]	±.015 [0.38]
	4-24 in. [102.1 to 610 mm]	±.031 [0.79]
	FRAME CROSS SECTION	
W,X	0-.750 in. [up to 19 mm]	±.010 [0.25]
	.750 -1.250 in. [19.1 to 31.8 mm]	±.012 [0.30]
S,T	.750 in. [up to 19 mm]	±.006 [0.15]

ORDERING INFORMATION

ECTC Windows are custom designed to customer specifications and drawings. Customer drawings should provide dimensional data as suggested in Figure 3 such as overall size, viewing area, window size and thickness (dimensions AxB), type of edge termination and interface gasket, type frame by style number and special options. For assistance, contact your TECKNIT representative or factory engineer.

Teckfilm™

TRANSPARENT CONDUCTIVE COATING ON POLYESTER FILM

U.S. Customary
[SI Metric]

GENERAL DESCRIPTION

TECKFILM is a highly conductive coating deposited on a transparent polyester film. It is available in rolls 30" wide. Usable width is 28". The conductive coating is overcoated with a ceramic type film which serves to increase visible light transmission and to provide a protective barrier that exhibits electrical conductivity through the layer.

CONSIL®-II silver filled silicone elastomer material is recommended between the TECKFILM and conductive mating surface as an interface gasket and an environmental seal between the enclosure and TECKFILM window panel assembly.

APPLICATION INFORMATION

TECKFILM is designed for electric and planewave shielding, grounding and static discharge applications. TECKFILM is used as a transparent, shielding panel for visual displays in instrumentation equipment, control panels, computer processing, printers, peripheral equipment and large electrode displays as a grounding shield.

MOUNTING TECHNIQUES

Various methods of mounting are as follows:

1. Affixed to conductive mating surface with clamps or bonded with TECKNIT Two-Part RTV Silver Silicone Adhesive Sealant (Part No. 72-00036).

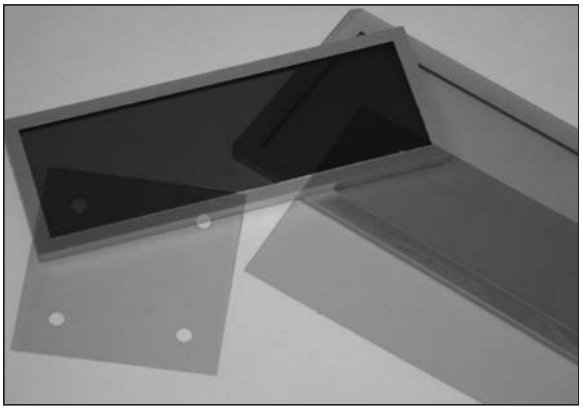
2. Mounted between a substrate and conductive mounting surface with or without the aid of edge bonding to the substrate.

NOTE: TECKFILM conductive surface can be marred if handled excessively.

EMI SHIELDING PERFORMANCE

TECKNIT TECKFILM Shielding Effectiveness has been tested in accordane with TECKNIT Test Method TSETS-01 which is based upon modified MIL-STD- 285. Typical shielding effectiveness values are based on a 5" square window.

MATERIAL	H-FIELD 100 kHz	E-FIELD 10 MHz	PLANE WAVE 1 GHz
TECKFILM	20 dB	90 dB	30 dB



SPECIFICATIONS

MATERIAL DESCRIPTION

- **Substrate:** Polyester film .005 in. [0.13mm] thick, clear and colorless.
- **Conductive Coating:** Vacuum deposited thin metal film with protective ceramic coating.
- **Standard Bulk Material Part Number:** 70-00117

PERFORMANCE CHARACTERISTICS

- **Substrate and Coating**
  Surface Resistivity: 14 ohms/square (nominal) (±4 ohms/square).
  Visible Light Transmission: 70 to 80%.
  Temperature Range: -76°F to 300°F [-60°C to 150°C].

ORDERING INFORMATION

Fabricated and rule die cut window shapes up to 28" wide can be supplied. Contact your TECKNIT area representative or factory engineer for assistance.

Teckshield®-F

HIGH PERFORMANCE EMC WINDOWS

GENERAL DESCRIPTION

TECKSHIELD-F high-performance fully laminated flat windows are specially designed to provide optimum optical transmission and EMI shielding in severe interference environments. TECKSHIELD-F windows have proven to be effective in TEMPEST qualified Visual Display Units, as well as in printers and enclosures requiring large viewing apertures. A special low-resistance mesh is laminated between two layers of glass or acrylic. The edge termination between the window mesh and the enclosure is designed to provide uniform mesh-to-enclosure continuity around the entire perimeter of the shielding aperture.

FEATURES

- Full lamination provides rugged construction, prevents moisture intrusion or entrapment between optical layers, enhances optical contrast by elimination of two optical media-to- air interfaces.
- High shielding performance of large viewing apertures at a broad range of frequencies.
- Minimum optical distortion of viewed display.
- Design options include color filters and polarizers for contrast enhancement, which permit flexibility in matching optical and shielding requirements to specific applications.

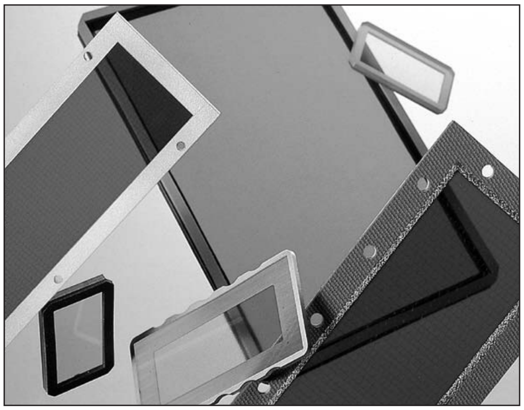
APPLICATION INFORMATION

TECKSHIELD-F high-performance flat windows are designed for enclosures requiring superior shielding against EMI radiation or susceptibility. They provide maximum EMI protection and high optical clarity for teleprinters, digital, graphic, and other flat displays. TECKSHIELD-F windows can also be economically matched to most visual display units to minimize image distortion and to maximize shielding effectiveness.

EMI SHIELDING PERFORMANCE

MESH SCREEN	H-FIELD 100 KHZ	E-FIELD 10 MHZ	PLANE WAVE 1 GHZ	PLANE WAVE 10 GHZ
100 OPI	55 dB	120 dB	60 dB	40 dB
145 OPI	55 dB	120 dB	80 dB	45 dB

Tested in accordance with TECKNIT Test Method TSETS-01, which is based upon modified MIL-STD-285. Typical Shielding Effectiveness values are based on a 5" square window.



SPECIFICATIONS

MATERIAL DESCRIPTION

- **Standard Optical Media**
  Glass: Per Specification ASTM-C-1036, Type 1, Class 1.
  Acrylic: Per Federal Specification L-P-391, Type 1, Grade C (ASTM-D-4802).
- **Optical Media Options**
  Acrylic Colors: See Table 2.
  Anti-Reflection Coatings:
  Non-Glare Coating (Matte Finish).
  High Efficiency Anti-Reflection Coating (Less than 0.6% Reflection).
- **Mesh Screen**
  100 OPI: Blackened Copper Mesh 0.0022" Wire Diameter, 60% Open Area.
  145 OPI: Blackened Copper Mesh 0.0022" Wire Diameter, 45% Open Area.
  Interface Gasket: Copper Mesh Wrap-Around Termination. See Figure 2.
  Duogasket: See Figure 3.
  Busbar Termination: Tecknit Silver Acrylic Conductive Coating (Fig. 5)

PERFORMANCE CHARACTERISTICS

- **Operating & Storage Temperature**
  Glass: -67°F to 176°F [-55°C to 80°C]
  Acrylic: -67°F to 140°F [-55°C to 60°C]

U.S. Customary
[SI Metric]

STANDARD WINDOW CONSTRUCTION

Standard TECKSHIELD-F fully laminated window construction consists of: (a) Standard mesh screen, blackened and laminated between (b) two layers of standard optical medium (clear and colorless see Fig. 1), and with (c) an interfacial gasket (copper mesh wrap around or Duogasket) to provide electrical continuity between the window mesh and equipment enclosure. The Duogasket consists of an environmental seal and an EMI gasket seal.

Standard window thicknesses are 0.205 in. [5.2 mm] for glass substrates and 0.145 in. [3.68 mm] for acrylic substrates.

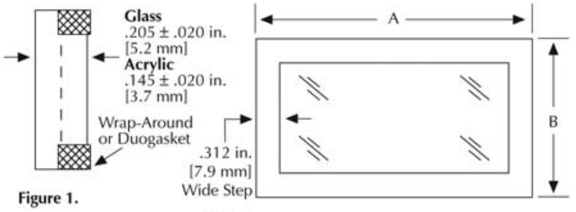
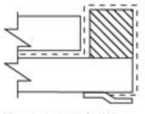
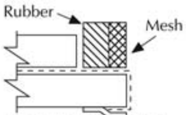


Figure 1.



Copper Mesh Wrap-Around Termination

Figure 2.



Duogasket Termination

Figure 3.

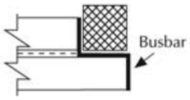


Figure 4.

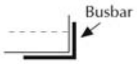


Figure 5.

FRAMING AND MOUNTING

Standard TECKSHIELD-F windows may be mounted directly to the equipment enclosure utilizing the recommended interface gasket termination shown in Figs. 2, 3, 4 and 5. When specifying a finished mounting frame for the standard window thickness shown in Fig. 1, provide a drawing of the frame as shown in Fig. 6 using the TECKNIT styles shown in Fig. 2-5.

In some instances, standard TECKSHIELD-F windows may be mounted directly to the equipment enclosure without an interface Duogasket by using TECKNIT conductive epoxy to establish an electrical bond to the enclosure. Additional mechanical clips may be required to locate and mechanically secure the window to the enclosure.

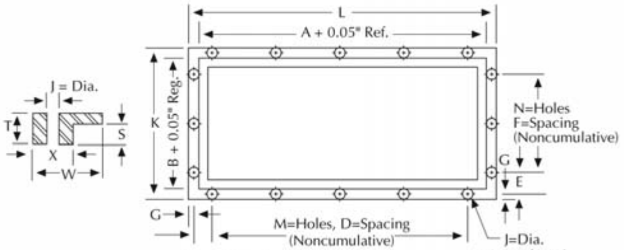


Figure 6. Typical Frame Design

STANDARD TOLERANCES

Table 1.

SYMBOL	WINDOW DIMENSION	TOLERANCE
A,B	18 in. [up to 457 mm]	±0.031 [0.79]
	FRAME DIMENSION	
C,D,E,F,G	up to 12 in. [305 mm] 12 to 18 in. [305-457 mm]	±0.015 [0.38] ±0.020 [0.50]
K,L	up to 4 in. [102 mm] 4 to 24 in. [102.1-610 mm]	±0.015 [0.38] ±0.031 [0.79]
	FRAME CROSS SECTION	
W,X	up to 0 - .750 in. [19 mm] .750 to1.250 in. [19.1-31.8 mm]	±0.010 [0.25] ±0.012 [0.30]
S,T	up to 0.750 in. [19 mm]	±0.006 [0.15]

ACRYLIC COLOR TRANSMISSION FILTERS

Table 2.

Red	Amber	Yellow	Green	Blue	Gray
2423	2422	2208	2092	2069	2514

ORDERING INFORMATION

TECKSHIELD-F high-performance windows are custom designed to customer specifications. Drawings should be provided that show dimensional data such as overall dimensions, mounting hole dimensions, desired viewing area, window and frame thickness (when required), type of edge terminations and interface gasket, type of frame or bezel and special options. For assistance contact your nearest TECKNIT area representative or factory location.

Teckshield®-F Polycarbonate Windows

FEATURES

- 80% open area-best light transmission of all Tecknit woven window meshes.
- Available as thin as .053" [1.35].
- -60°F to 158°F [-55°C to 70°C] operating temperature.
- All standard Tecknit EMI terminations available.

EMI SHIELDING PERFORMANCE

	H-FIELD 100 kHz	E-FIELD 10 MHz	PLANE WAVE 1 GHz	 10 GHz
80 OPI SS	35 dB	85dB	42 dB	30 dB
100 OPI SS	40 dB	105 dB	52 dB	35 dB

SPECIFICATIONS

MATERIAL DESCRIPTION

- **Mesh Screen:** Blackened 304 stainless steel, .001" dia., 80 or 100 openings per inch.
- **Standard Substrate:** Polycarbonate, clear & colorless.
- **Available Upon Request**
  UL-94VO-rated polycarbonate
  Abrasion resistant & anti-glare coatings

Teckshield®-F Allycarbonate Windows

ALLYCARBONATE EMI SHIELDED WINDOWS

PHYSICAL & OPTICAL PROPERTIES OF MONOMER CASTING MEDIUM

Temperature Range:
-60ºCto 100ºC
-60ºC to 130ºC (1 Hour Duration)

Rockwell Hardness (M):
97 ASTM Test Method (D 785)

Visible Transmission %:
93.3 ASTM Test Method (D1003)

Tecknit Allylcarbonate shielded windows are manufactured by casting a woven EMI shield mesh into a material that has optical properties similar to that of glass. The window offers a lightweight, cost effective alternative to traditional glass laminated shielded windows and is a more flexible material to machine, making it more suited to meet the changing design demands that are part of modern electronics.

Available Standard Shielding Mesh Types

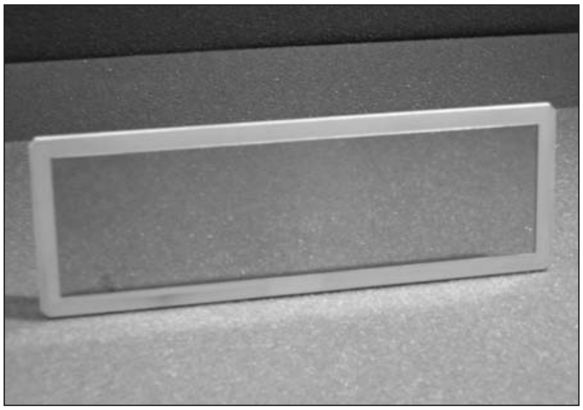
50 OPI - Blackened stainless steel woven screen 0.001 inch diameter wire
100 OPI - Blackened stainless steel woven screen 0.001 inch diameter wire
100 OPI - Blackened copper woven screen 0.002 inch diameter wire

Shielding Performance of Mesh Screens

	H-FIELD	E-FIELD	PLANE WAVE	
	100 kHz	10 MHz	1 GHz	10 GHz
50 OPI	16db	45db	56db	36db
100 OPI	40db	105db	52db	35db
100 OPI	55db	120db	60db	40db

Note: (OPI Number of openings per inch of woven screen)

Some examples of shielding screens also available as a non-standard are, 80 OPI and 150 OPI woven materials, however lead times for these products may vary. Please contact our Sales Office.



Allylcarbonace windows are ideally suited to applications where there is a requirement to shield displays or visual apertures. Windows are machined using computerised programming technology This offers a facility to accurately engrave data or drill mounting holes into the window itself.

The windows operate in a very broad temperature range and have a high resistance to abrasion and most acids and solvents. The window product is ideally suited to many applications and is now supplied throughout a broad range of companies in military and Commercial Industries.

FEATURES

- 80% open area-best light transmission of all Tecknit woven window meshes.
- Available as thin as .053" [1.35].
- -60°F to 158°F [-55°C to 70°C] operating temperature.
- All standard Tecknit EMI terminations available.
- Cast Material Supplied as a Standard
  .079" [2mm] to .236" [6mm] thick
  Clear or medium-grade matte finish