SHIELDING - COATING OPTIONS IN THE '80'S

Shielding Effectiveness

A common method of measuring the effectiveness of a shielding material is to establish the level of attenuation in decibels (dB) needed to provide protection to the system. The dB unit is a logarithmic measure of the degree of shielding.

The degree of attenuation, or shielding effectiveness, is not a constant for each of the various shielding materials, but is affected by the frequency of the incoming EMI signal. The shielding effectiveness is also determined by:

a. the electrical conductivity of the shield;
b. the thickness, uniformity and smoothness of the shield;
c. the frequency and impedance of the impinging field; and
d. the magnetic permeability of the material.

The electrical resistivity of the shielding material, measured in ohms/square varies with the different materials used, and with the thickness of the materials.

Figure 1 shows an example of a shielding effectiveness test set-up. In this set-up the shielding material to be evaluated is applied on a flat plastic panel, fixed in a compression holding fixture. Depending on the test procedure involved, electromagnetic radiation of a certain frequency range is generated by a transmitter and transmitted by an antenna through the flat panel to another room, where an antenna receives the attenuated radiation, which is measured by the receiver. The test procedure involved will prescribe which distance between transmitting antenna and receiving antenna should be used. In this type of measurement method, relative measurement can be easily made. It should be kept in mind that the size of aperture type and the spacing of antennas will have an effect on the measured attenuations.

To assist the industry, the ASTM D.9.12.14 (EMC subcommittee) is presently working to define procedures to help standardize this material measurement method. At present, the common wall and coaxial methods are both being outlined to enable comparison of relative shielding performance data for ASTM.

System shielding measurement methods differ from regulation (e.g., FCC vs. VDE) as well as within classifications of specific regulations (e.g., FCC, class 15, Type A vs. Type B).

The quality of EMI shielding material requirements varies greatly with application. However, a shielding effectiveness of 30-90 dB over a frequency range of 10 kHz to 1 GHz should solve all EMI problems (Table 1).

Level of Shielding Effectiveness	Quality of Shielding
0-10 dB	very little shielding
10-30 dB	minimum range for meaningful shielding
30-60 dB	good shielding—will solve all mild and moderate problems
60-90 dB	excellent shielding—will solve moderate to severe problems
90-120 dB	maximum possible with best shielding designs

Table 1. Quality of Shielding in Decibels

Once attenuation data is established on a specific shielding material at a given film thickness, the sheet resistance (ohm per square) is an easy quality control check and can be used as a guideline for shielding effectiveness. Ohm per square is determined with probes of a certain length over a distance equal to probe length.

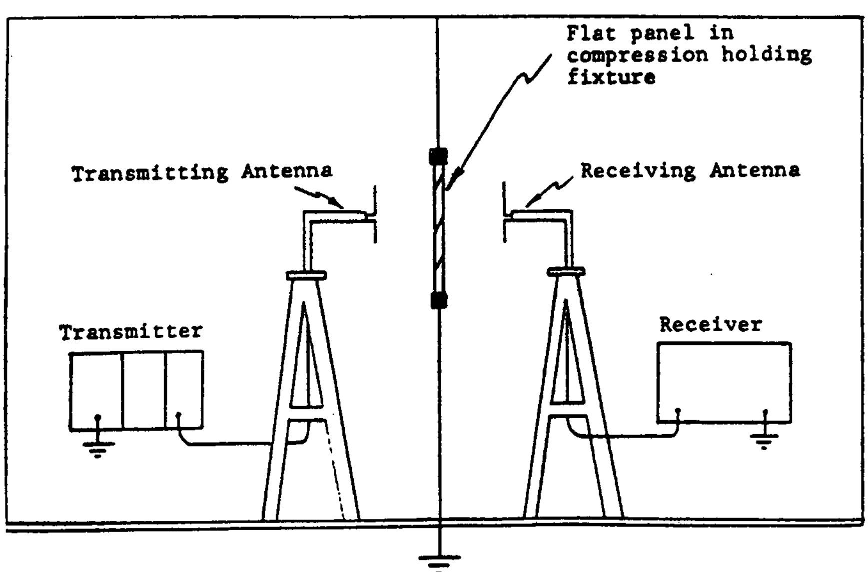

Figure 1. Sample Shielding Effectiveness Test Set-up.

Electrostatic Discharge

A conductive coating applied on the inside or outside of the electronic equipment enclosure will, if properly grounded, prevent build-up of electrostatic charges and, consequently, ESD. However, if the conductive material is too conductive, the electrostatic charges, transferred for instance by human contact, will bleed off very quickly and pass directly to the ground as if travelling through a wire. This current can arc directly to the equipment and can radiate EMI to the electronics of the equipment, causing malfunctioning. To reduce the impact of this problem a higher resistance coating must be used which will spread out the discharge path and dissipate the impact (See Figure 2).

European companies which export electronic equipment that is enclosed in plastic and uses shielding materials, have to comply with Underwriters Laboratories specification UL 746C. UL 746C defines a level of performance for ductile and brittle coatings. The main concern is loss of adhesion or flaking off into the electronic components, causing short circuits.

Solid Metal Coatings

Two techniques which are commercially used to apply solid metal coatings on plastic enclosures are vacuum metalizing and zinc arc/flame spray. Vacuum metalizing is the deposition of a metallic film by evaporation in a high vacuum atmosphere. Aluminum is the most common evaporant. The resulting metal film is very uniform in thickness at about 4 to 5 μm. Prior to metalizing, a base coat is sprayed and cured to provide adhesion of the aluminum to the substrate. Masking is often required to protect the topside or decorative side of the plastic enclosure from being coated with metal.

Masks may be metal, or made of inexpensive, vacuum formed plastic. Vacuum metalizing equipment is very expensive; a 1.75 meter diameter vacuum metalizer costs approximately $100,000 to $150,000. The advantages and disadvantages have been listed in Table 3.

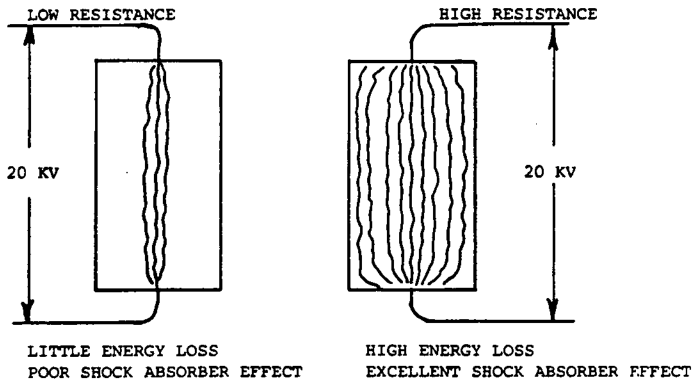

Figure 2. Arc Concentration & Spread as a Function of Coating Conductivity.

Metallic enclosures of electronic equipment can be sensitive to ESD. In cases where the construction material should be protected against corrosion, pretreatments such as phosphating and anodizing are applied, followed by a top coat. In this case, the surface is converted to an insulating layer, generating possible ESD problems. A large computer manufacturer has been faced with this problem, and has issued a specification to apply graphite-based coatings to solve the problem.

Physical Testing of Shielding Materials

Besides attenuation/conductivity testing, it is equally important that the shielding materials remain stable in their operating environment (heat, cold, humidity, etc.).

The American Society of Plastics Industry (SPI), Structural Foam Division, Physical Test Committee, has, together with suppliers of shielding materials and manufacturers of electronic equipment, developed a preliminary specification which incorporates environmental tests to measure adhesion and conductive properties. In Table 2, the most important tests have been listed.

1. Thermal cycling, 10 cycles
   30 minutes $-40°C$
   5 minutes room temperature
   30 minutes 70°C

2. Thermal conditioning 70°C
   after 3 days
   after 14 days
   after 30 days

3. Humidity
   95% RH at 70°C
   after 3 days
   after 14 days
   after 30 days

Table 2. Environmental Tests

Advantages	Disadvantages
—Can be put on any plastic	—Size of vacuum chamber limiting factor
—Excellent attenuation properties	— Base coat required
—Film thickness of metal can be controlled	—High capital cost
— Not limited to simple designs	—Aluminum layer is susceptible to corrosion in a humid atmosphere, causing a loss of conductivity

Table 3. Vacuum Metalizing

Zinc arc and/or flame spray is one of the most controversial shielding processes in use today. In both techniques, a molten metal, usually zinc, is deposited onto the prepared (mostly sandblasted) plastic substrate. With the arc spray pistol, two metal wires are fed through an electric arc which melts the ends, causing a layer of metal to be sprayed onto the part by a hand-held pistol. Flame spray involves a metal powder that is melted by contact with super-heated inert gas in a special spray gun and atomized onto the part.

Although arc/flame spray does provide good conductivity with a hard coating, there are many drawbacks that must be considered. Special, expensive equipment is required ($10,000—$20,000). Also, with improper use, flame/arc spray may distort or warp the plastic enclosure, as already experienced by many customers. In addition, the coating may separate from the substrate due to the difference in thermal coefficient of expansion. In Table 4, the advantages and disadvantages have been listed.

Advantages	Disadvantages
—Good conductivity	—Special expensive equipment required.
—Hard, dense coating	—In most cases sandblasting of plastic enclosure is required.
—Effective over a wide frequency	—May distort or warp thermoplastic enclosure.
	—Separation from substrate due to diference in thermal coefficient of expansion.

Table 4. Zinc Arc/Flame Spray

EMI shielding/ESD protection obtained by spraying the plastic enclosures with electrically conductive coatings offers great flexibility of approach. Low cost conventional spray equipment is used, and prototypes can be hand-painted to speed testing. Spray application is fast and the coating can cover all areas; drying is also rapid. Usually it is the inside housing surface that is sprayed, but external applications can be as effective. Surface preparation is the same for the decorative outer-finish; a primer coat is usually not required, and a top coat is necessary only when oxidation is a problem.

Coatings employ graphite, copper, nickel, silver or other conductive pigments in various organic binders and solvents. Several water-based systems are also available for application on solvent-sensitive plastics and in areas where solvents are prohibited. When properly selected, resin-bonded conductive coatings give excellent adhesion to any of the plstics — solid or foamed thermoplastics, urethanes, or glass/polyester composites.

Silver coatings, which were initially used widely, exhibit excellent conductivity and good adhesion. However, due to the rather high silver prices, they have become too expensive for certain applications. This has necessitated the formulation of systems using cheaper metals. The copper-filled coatings met this criteria. However, copper is not considered to be as environmentally stable, as it has a tendency to oxidize upon exposure, therefore negatively affecting its shielding properties.

Graphite coatings have also been developed as shielding materials. However, these coatings are not as effective as metal-filled coatings. Graphite coatings are satisfactory in many cases for use as low cost coating for ESD applications. Nickel-based coatings have been widely recognized as the most applicable of metal-filled coatings. Normally air drying types are used and application at a coating thickness of approximately 50 to 75 μm, giving attenuation values from 30 to 65 dB, depending on frequency. The cost effectiveness, ease of application and the good attenuation values make nickel coatings very attractive for shielding plastic enclosures of electronic data processing equipment. In Table 5, the advantages and disadvantages of electrically conductive coatings have been listed.

	Advantages	Disadvantages
Silver	excellent conductivity, conventional spray equipment, and ease of application	expensive
Nickel	good conductivity, conventional spray equipment, ease of application, and good resistance to oxidation	
Graphite	conventional spray equipment, and ease of application	not very effective shielding suited for ESD protection
Copper	conventional spray equipment, and ease of application	copper oxidation reduces conductivity

Table 5. Resin-Bonded Conductive Coatings

Mention has been made of applying a conductive coating to the external surfaces of a plastic housing rather than inside and then overcoating with conventional decorative finishes. At first look, the idea is excellent, as masking costs can be significantly reduced as can extra handling in each painting operation. The approach can work well.

However, a word of caution should be noted. Not all nickel acrylic or nickel urethane systems can be top coated without careful consideration given to the complete package compatibility. Incompatible coating use will produce problems in the intercoat adhesion of finish quality areas (which can be overcome by working with the shielding and decorative coating suppliers). Electrical properties can be affected by top coating if two systems are not compatible. Also, thought must be given to the method of connecting the conductive coating to ground if it is to be top coated.

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