CONDUCTIVE COATINGS AND ADHESIVES

The use of plastics in fabricating enclosures for electronic and electrical assemblies has increaed substantially recently. Plastic enclosures made from polyester-fiberglass, epoxy fiberglass engineering thermoplastics such as *Lexan®*, *Noryl®*, and *Valox®*, and are considerably less expensive and more desirable in performance than metal cabinets, particularly in such mass production applications as business machines, computer terminals, and automotive body parts. However, these plastics, being extremely good insulators, do not provide any resistance to the flow of electromagnetic radiation, and will not shield electronic assemblies inside from its effects. Similarly, they will not absorb the radiation that the devices themselves emit.

An additional problem resulting from the use of plastics in these applications is that of static electricity. While the metal cabinets formerly used provided effective protection against static build-up because of their natural conductivity, plastics will not do so. The tendency of plastics to accumulate static charge buildup, much like a capacitor, often results in wiping out of a computer memory, for example, when the build-up is abruptly discharged by grounding.

CONDUCTIVE COATINGS

Spray paints have offered a quick and inexpensive method of obtaining conductive coatings. They can be applied with conventional painting equipment and do not require special engineering know-how or extensive capital investment for facilities. Spray paints can be applied to complex and shaped surfaces and can be controlled as to how much electrical conductivity is functional or necessary. They offer good adhesion to most plastics, a durable film finish, and can be utilized as an undercoat for conventional aesthetic finishes.

Prior to the introduction of structural foam plastics for the replacement of metal enclosures, extensive research was conducted to establish a conductive paint that would be compatible with the plastic materials. The requirements were relatively simple: compatibility with all structural foam materials, good adhesiion to platics, durable finish; good wetting characteristics for metallic fillers, easy sprayability using conventional equipment, and quick air-dry time. Controlled surface resistivity and long-term stability at operating temperatures equal to those of the carrier paint were requirements of metallic fillers.

For electrostatic neutralization or dissipation, minimum resistivity of 50 ohms/square is needed, and a coating thickness of 0.5 to 4 mils is normally required to provide this level of resistivity. For grounding requirements, a resistance of 10 or less ohms /square is needed, usually requiring a coating thickness of 1 to 3 mils. In cases involving electromagnetic shielding, 1 ohm/square of thickness of 1 to 5 mils, depending upon the material used.

ELECTROMAGNETIC SHIELDING EFFECTIVENESS

Conductive paints have been in the field for over five years, and have been tested and approved by leaders in the electronic business machine industry. Extensive EMI/RFI shielding tests have been conducted, first comparing various processes or methods available to the plastics industry. Tests were conducted using Lexan® Structural Foam FL-900 boxes 10" x 10" x 10" (P. J. LeBlanc, Plastics Department, General Electric Company, Pittsfield, Ma.). Although there must have been a "box resonance" at the 50 MHz frequency, it does show the comparison of shielding increase of a steel enclosure with carbon coated, flame sprayed, silver painted, and vacuum metallized enclosures. Surface resistivities were not measured, although no added shielding increase was noted when both the inside and outside of the enclosure were coated with conductive (silver) paint.

Another EMI/RFI test was conducted using three basic surface resistivity values:

1 ohm-square
10 ohms-square
100 ohms-square

The testing was conducted by Honeywell, Inc., and the procedure was designed to meet MIL-Standard 285. These tests of silver and non-metallic paints were compared to the results of the enclosures with full integrity and degraded integrity with an opening of 8" x 8". The tests indicated that conductive paints with surface resistivity of less than 1 ohm-square up to 10 ohms-square are similar at all frequencies tested. It should be noted that no conductive paint or any other type of conductive finish offers shielding effectiveness within the magnetic field of any appreciable nature (dB). The shielding effectiveness of the conductive (non-metallic) paint was very little from 5 MHz up to and including 10 GHz (electric and plane wave fields).

Generally, it should be noted that any conductive coating that has a surface resistivity of less than 10 ohms-square will offer a shielding increase within the electric field (200 KHz through and up to 500 MHz). Although these design guidelines are adequate for many electromagnetic shielding functions, it is important to know that the system testing should be conducted by the designer if shielding is a critical design criteria. All results have been graphically plotted in Figures 1 and 2.

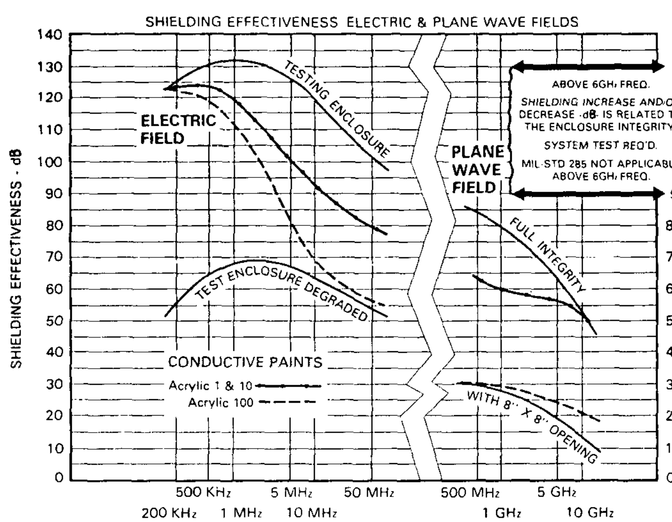


FIGURE 1

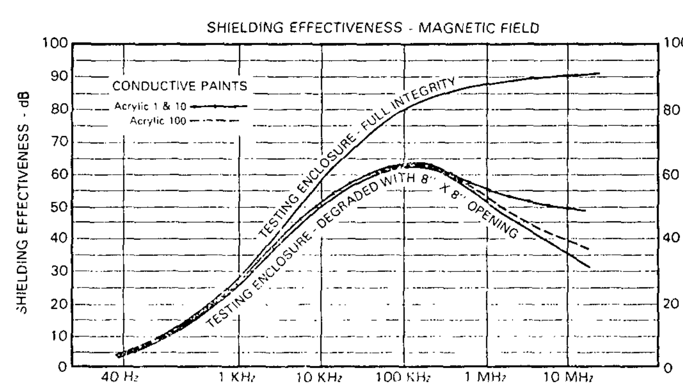


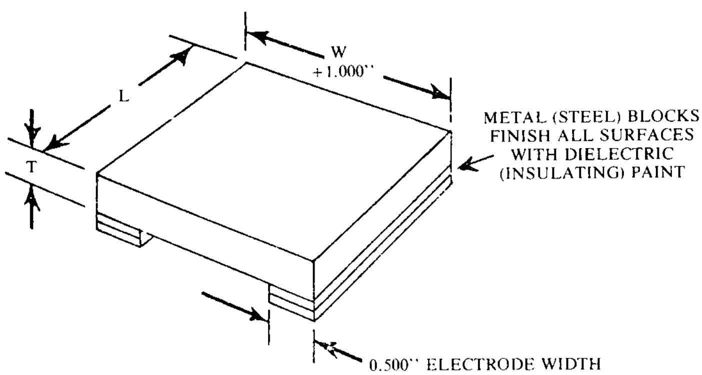
FIGURE 2

Testing for Surface Resistance

This test will determine the surface (sheet) resistivity of the conductive paint expressed in ohms/square. Ohms per square is a non-dimensional measurement and does not refer to square inches or square feet. Therefore, all surface resistivity is measured with two electrodes (L = length) that are spaced (W = width spaced) apart from each other. Thus, as long as L = W (as in a square) and thickness (T = thickness) of coating is constant, the resistance is the same for any square.

Standard test procedures are outlined and can be referred to ASTMD-257. Testing for surface resistivity is most important for it controls the conductive finish functions, coating costs, and is subject to many factors that are not known to conventional practices. Of all the tests discussed herein, this test must be maintained throughout production cycles, production practices, and production methods.

A sample surface resistivity device can be fabricated to assure meeting engineering design criteria and functional finish requirements involvingconductivity (or inversely proportional to surface resistivity.) Two sizes of surface resistivity testing devices are suggested, one for small areas of approximately 1 centimeter square (0.394") and one for larger areas of approximately 10 centimeters square (3.94"). The design is simple and relatively low in cost.



Testing Device	L & W	T	Pressure psi Weight per Square Inch
1 cm. square	0.394"	2.000"	13.8 ounces
10 cm. square	3.937"	0.564"	13.8 ounces
20 cm. square	7.874"	0.354"	13.8 ounces

Please notice that equal pressure (force per square inch of electrode) was designed for each device, assuring equal conditions of measurement. The electrode device should be designed with brass shin stock 0.010" or thinner and 0.500" wide, and attached to the steel block with double faced adhesive foam approximately 0.0625" thick. Extend the length of the electrode (shin stock) approximately 0.5" to 1.0" thereby allowing attachment of VOM (ohm meter leads).

It is important that the adhesive tape be of a foam type, allowing variance in surface flatness and other irregularities. Care should be taken to check instrumentation for correct and accurate readings (zero test is adequate), and electrodes should be cleaned prior to use by wiping with Scotch-Brite lightly on the contacting surfaces.

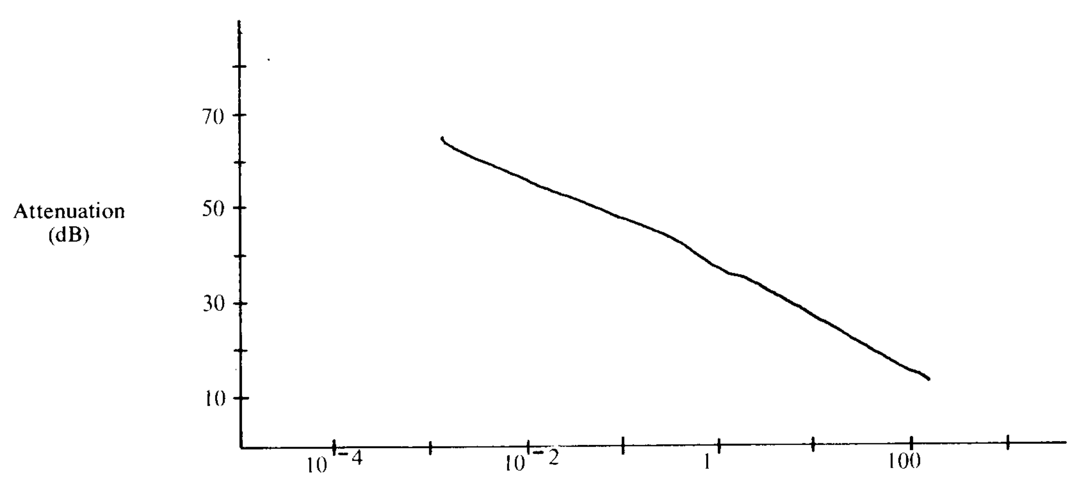
SELECTION OF MATERIALS

The degree to which electronic devices require shielding varys greatly. In some noncritical applications, 20 dB attenuation may suffice. Other systems may require 50 dB or more to operate effectively. Most often, effective RF shielding requires attenuation of 30 dB or more, making surfaces with relatively high conductivities (low resistivities) necessary. Usually, a metal filled coating is necessary to provide this degree of shielding.

Sheet Resistance of Common Shielding Materials.

MATERIAL	OHMS/SQUARE/MIL
Copper Foil	0.0007
Aluminum Foil	0.001
Iron	0.004
Silver filled coatings	0.1
Copper filled coatings	0.2
Graphite filled coatings	150

Attenuation vs. Sheet Resistance*



*Reciprocal of conductivity at a given thickness, usually 1 mil.
Tests conducted at frequency of 100 MHz.

In selecting conductive coatings, one must be quite cognizant of the costs involved, particularly in consumer applications. The tables below give comparative costs of alternative shielding methods for plastics.

Comparative Costs of Shielding Methods

METHOD	\$/ft^2
Flame Spray	\$2.50 - \$3.00
Silver Coatings	\$2.00 - \$5.00
Vacuum Metalizing	\$1.00 - \$1.50
Plating	\$1.00 - \$2.00
Copper Coatings	\$0.20 - \$0.50
Graphite Coatings (Non-Metallic)	\$0.10 - \$0.50

CONDUCTIVE ADHESIVES

In addition to the conductive coatings described in the preceding section, conductive adhesives are becoming increasingly important in providing a complete seal, not only for shielded plastic packages, but also for metal enclosures where mating surfaces may be subject to loss of electrical continuity due to oxidation or dimensional distortion.

Conductive adhesives are usually plastic materials filled either with metallic or with non-metallic conductive particles, similar to the systems described in the section on conductive coatings above. The plastic may be either thermosetting or thermoplastic. A thermoset plastic "cross-lines" on curing, resulting in an infusible adhesive; while a thermoplastic material may be "slowed" or "melted", without decomposition, by application of heat. Each type has its advantages and disadvantages. Thermoset materials, including epoxies and many chemically similar systems, provide the advantage of superior chemical and environmental resistance, but may be somewhat difficult to apply, and usually require elevated temperatures, or extended periods of time to cure. Thermoplastics, including acrylics, are easier to apply and cure, but usually exhibit inferior chemical and environmental resistance. Many physical properties, such as flexibility, hardness, adhesion, etc. are primarily functions of the type of plastic used, and can often be optimized in specific adhesive formulations, both thermosetting and thermoplastic.

Shielding effectiveness of conductive adhesives in the RF range is primarily a function of electrical resistivity, similar to conductive coatings. Electrical resistivity for adhesives is usually measured in ohm-cm (per ASTM D2739-72), rather than the ohms per square method used for coatings. Effective shielding in the RF range can usually be obtained by using materials with volume resistivities of 0.05 ohm-cm or less, although grounding and static neutralization may sometimes be accomplished with resistivities as high as 10^{10} ohm-cm. Some typical volume resistivity ranges of common conductive adhesives are listed below, based on the highest practical loading of conductive material:

Silver filled - thermoset	$3\text{-}9 \times 10^{-4}$
Copper filled - thermoset	$5\text{-}9 \times 10^{-4}$
Silver filled - thermoplastic	$2\text{-}5 \times 10^{-3}$
Graphite filled - thermoset	0.25 - 0.5
Carbon filled - thermoset	1.0 - 1.5

The above article is a revision and expansion of a similar article which appeared in the 1976 edition of **ITEM**.