EMI/RFI SHIELDING FOR STRUCTURAL FOAM BUSINESS MACHINE COMPONENTS

Introduction

The use of structural foam plastic housings by the business machine industry has created a need to shield electromagnetic interference (EMI) and radio frequency interference (RFI). EMI/RFI is electronic noise and may be internally or externally generated and must be controlled.

This article will deal with the new FCC regulations as related to business machines and electronic games. Test methods, including environmental testing, attenuation measurements and ohms per square will be discussed. Shielding methods under consideration including vacuum metalizing; sputtering; zinc arc spray; conductive nickel urethane; and conductive nickel acrylic.

Measuring Shielding Effectiveness

A common method of measuring the effectiveness of a shielding system is to establish the level of attenuation, in decibels, needed to provide protection to the system. Attenuation is a function of the electrical conductivity and absorption of the shielding material at various frequencies. The following explains the relative levels of RFI effective attenuation:

0-10 decibels	Very little shielding
10-30 decibels	Minimum range of meaningful shielding
30-60 decibels	Average shielding; should solve moderate problems
60-90 decibels	Above average shielding
90-120 decibels	Best shielding

30-60 dB attenuation should solve normal shielding problems. Being logarithmic, 30 dB attenuation shields 99.9% while 60 dB attenuation shields 99.9999% of radiated EMI/RFI.

The degree of attenuation, or shielding effectiveness, is not a constant for each of the various shielding materials, but it is affected by the frequency of the incoming signal. Film thickness contributes to the absorption properties of the coating and must be stringently controlled. Once attenuation data is established at a given film thickness, ohms per square is an easy quality control check and can be used as a guideline for shielding effectiveness. General ohms per square guidelines are:

1 ohm/square	Shielding
10 ohms/square	Grounding
50 ohms/square	Electrostatic Discharge

Ohms per square are determined by placing square probes the same distance apart as the probes are square. While attenuation data and ohms per square are indicative of shielding effectiveness, the actual finished cabinet must be tested.

Physical Testing

Besides attenuation testing, it is equally important that the shielding method remain stable in its operating environment. The Society of Plastics Industry (SPI), Structural Foam Division, Physical Test Committee, has developed a preliminary specification which incorporates environmental tests to measure adhesion and conductive properties.

Underwriters Laboratory UL746C defines a level of performance for ductile and brittle coatings. The main concern is loss of adhesion or flaking off into the electronic components. Conductivity testing is performed but only for informational reasons. Shielding effectiveness is beyond the scope of this specification.

Methods for Producing Shielding on Plastics

Metal coatings are applied by various techniques to provide EMI/RFI shielding. These techniques include:

- Vacuum Metalizing
- Sputtering
- Zinc Arc Spray
- Conductive Nickel Organic Coatings

Figure 1 compares the shielding effectiveness of these techniques. Figure 2 compares their conductivity over distance.

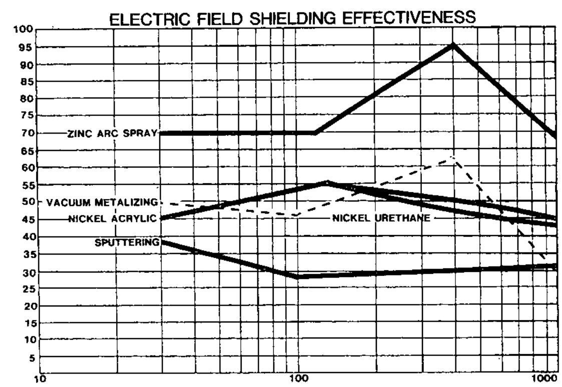

Figure 1.

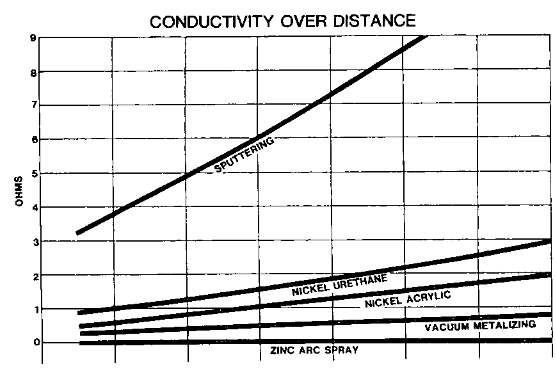

Figure 2.

Vacuum Metalizing. Vacuum metalizing is the deposition of a metallic film by evaporation in a high vacuum atmosphere. Aluminum is the most common evaporant. The resultant metal film is very uniform in thickness at about 4000-5000 angstroms. Film thickness for decorative vacuum metalizing is 1000 angstroms. Prior to metalizing, a basecoat is sprayed and baked to provide adhesion of the aluminum to the substrate. On nonfoamed substrates, parts are glow-discharged rather than basecoated. Shielding or masking is required to protect the topside or decorative side from being coated with metal. These may be metal or inexpensive, vacuum-formed plastic masks.

A 72-inch vacuum metalizer costs about $175,000-$200,000. This is not a factor to those who have metalizing capacity already. It may be cycled from 3-6 times per hour. Depending on part size, 60-100 parts are coated per shot.

Selling prices are $150-$200 per cycle. Therefore, the range is $1.50 - $3.33 per part. Using an average of two (2) ft^2 per part, selling prices are $.75 - $1.66 ft^2. The outside dimension including open spaces of the part are to be used for the calculation rather than surface area since the number of parts per cycle is the controlling factor.

Film thickness of the metal can be easily controlled even on the side walls of parts by rotating during the metal deposition process. Excellent attenuation properties are achieved, and adhesion is very good. Conductivity is also excellent over long distances. These are the advantages.

Among the disadvantages, masking is required. No masking is needed if the part is subsequently topcoated on the outside, but there is a high capital cost. Even though the aluminum oxide on the top layer protects the aluminum somewhat, it is susceptible to corrosion in humidity testing. A topcoat could be used to protect the aluminum, but not much is known about the effect of topcoats on attenuation.

Sputtering. Sputtering, like vacuum metalizing, is performed in a high vacuum atmosphere. Instead of evaporating the metal, the metal target is bombarded by electrically excited argon ions that dislodge or "sputter" metal atoms. The metal atoms are deposited on parts that are passed by the target. The process is line of sight.

Parts in the "as molded and decorated" state are placed in paint masks to control surface deposition of metal alloys. Chrome alloy is applied directly to the clean plastic surface as a basecoat for good adhesion. No organic basecoat is necessary but could be used to enhance adhesion. Copper alloy is the second metal deposit for conductive properties. The final metal coat is chrome, again for its excellent barrier properties to the atmosphere. Metal thickness in angstroms is controllable by the sputtercoating process. Thickness is thought to be approximately 5000 angstroms. Fixtures are then removed and parts are packed.

Sputtering equipment capital costs range from $300,000 to $3,000,000, depending upon production requirements. For those companies with sputtering capacity currently, EMI/RFI offers an attractive opportunity.

Cost per square foot is relative to the size of the part and number of parts amassed on a platen because dead space is a factor of the parts height. The selling price ranges from $1.00 to $2.00 ft^2.

Sputtering allows decorated parts to be masked and shielded in an "as molded" condition so long as they are clean. Electrical properties are very consistent and uniform at 1.5 ohms per square inch. The operation is very clean, with excellent productivity and a low scrap rate (less than 5%).

Among the disadvantages is the high capital cost. Uniform film thickness is difficult to achieve, particularly on the side walls. Masking is required, and the coating looses conductivity on environmental testing. Sputtering passes 3 - 5 days of humidity but not 2 weeks. Interim tests were not performed. Basecoats and topcoats or other alloys need to be explored to correct this deficiency.

Zinc Arc Spray/Flame Spray. Zinc arc spray involves electrically-isolated wires which are continuously fed into a gun so that only the ends of the wires come into contact. As the ends reach a critical distance, an intense arc melts the ends and an air jet forces the molten, atomized material toward the target area. As the molten zinc hits the thermoplastic surface, it solidifies rapidly, forming a dense metallic film sometimes in excess of 4-6 mil.

The arc spray system is differentiated from flame spray in that it relies on an electric arc to melt the zinc (or other metals) as opposed to an acetylene flame. This results in a higher thermal efficiency with the molten metal contacting the outer plastic skin at much lower temperature, thereby reducing the likelihood of distortion or warpage.

One of the areas of concern with the arc spray system has been the interface between the thermoplastic substrate and the metallic film. Achieving adhesion is one problem in this area and the solutions have taken the form of grit blasting or preparing the substrate with an organic coating.

Selling prices per square foot range from $1.75 - $2.00 ft^2. The range varies by part configuration and the amount of surface preparation that is required.

A basic zinc arc spray unit costs $6,000 - $7,000. Water wash booths and air supplies for the operator raise the cost to $15,000 for one booth. Multiples of this amount are required to keep up with production capacity of other processes.

The arc spray systems are still very attractive alternatives to many companies because they provide the basics:

- A metal shell inside a decorative thermoplastic housing.
- Testing seems to consistently indicate the ability of zinc arc spray to perform as an EMI shield.
- The process is widely available.

The application still poses the same limitations for the suppliers in that toxic zinc is deflected during the process, causing health and safety problems. Inconsistent adhesion is found if surface preparation is incomplete. The difference in the coefficient of expansion between the plastic and the metal contribute to this problem. Flaking can cause the electronic unit to "short out". A film thickness of 4-6 mils is required to insure that air pockets do not create holes in the shield. Parts can be distorted due to heat, and the physical properties of the plastic itself (particularly impact) can be weakened due to the hard zinc layer.

Nickel Coatings. Conductive nickel acrylic and urethane coatings are commonly used for EMI applications. These are applied by spray at 2.0 - 2.5 mils dry film thickness. Film thickness is critical to achieve proper attenuation properties. Too little film thickness does not provide proper shielding. Too much film thickness adds to cost and can cause "mud-cracking" which hurts adhesion and shielding effectiveness.

Film thickness is a function of paint volume solids, solvent evaporation, and spray technique. Dry film thickness is measured with a Tooke gauge on the part or can be measured magnetically on accompanying steel panels. The Tooke gauge destroys the part because the film is cut. It can be repaired in touch-up. Steel panels can be deceptive since the operator will take particular care to coat the test plaque.

A correlation exists between wet and dry film thickness for a particular coating. As a rule of thumb, 2-3 mils wet film thickness will yield 1 mil dry film thickness, depending on speed of reducing solvent. Wet film thickness is measured with a wet film thickness gauge which is available for about $5-$6.

Electronic methods are available for measuring film thickness with an Durmiton Electronic Eddy Current machine. One supplier is: UPA Technology Inc., Syosset, New York. The cost is about $3,500 ± 300. Consideration of various film thicknesses will be discussed in the testing section.

Acrylic nickel lacquers dry rapidly and have adhesion to most thermoplastics. Urethanes are used where additional hardness and chemical resistance are required, or to provide adhesion to SMC. Urethanes are also used where decorative topcoats are used in conjunction with the nickel coating. Urethanes resist solvent penetration from the topcoats which tend to insulate the nickel particles and cause a reduction in conductivity and attenuation.

No additional capital is required, assuming normal spraying equipment is already in use for the decorative side. Part cost is $1.45 - $1.85 ft^2, depending on part size and configuration. Coating cost is about .29 - .45 ft^2 based on 100% spray efficiency and 2 mils film thickness.

No special equipment is required and the process is readily available. Paint manufacturers are familiar with application techniques and problems, and the process exhibits excellent long-term shielding performance and adhesion properties. The coatings and particularly urethanes may be overcoated with color coats to achieve desired styling effects without adversely affecting shielding effectiveness or physical performance. Intercoat adhesion is excellent. However, control of film thickness for both economic and performance considerations is critical.

This article was written for ITEM by Charles D. Storms, President, Red Spot Paint & Varnish Co., Inc., Evansville, IN.