THE EFFECT OF ENVIRONMENTAL REGULATIONS ON EMI SHIELDING COATING PERFORMANCE

For several years, designers of digital equipment housed in plastic enclosures have been concerned with the environmental effects of EMI/RFI shielding. Their first concern has been to provide adequate shielding of the electronics to meet the FCC-mandated emissions levels.

Secondly, they have been concerned with the stability of the various coatings used to ensure that exposure to normal environmental stresses does not compromise the effectiveness of their shielding, causing higher emissions levels in the field.

Now, a third environmental concern must be addressed; the effect of the shielding operation itself on the environment. The U.S. Environmental Protection Agency, as authorized by Section 111 of the Clean Air Act, is developing a New Source Performance Standard which would regulate the amount of volatile organic compounds (VOC) released into the atmosphere during the coating of plastic parts for business machine housings.

This could cause a shift away from the nickel-filled acrylic lacquers that are now most widely used for shielding, towards more environmentally sound alternatives such as high solids and waterborne shielding coatings. This article will discuss the alternative coatings available and compare the electrical and physical properties that determine their usefulness.

WHAT IS VOC?

The typical shielding coating consists of three main parts: the *conductive pigment* (usually nickel, copper or silver), the *binder resin* (polymers whose function is to bind the pigment together into a coherent film), and the *solvent* (volatile organic compounds and/or water whose function is to dissolve the binder and produce a low viscosity, sprayable coating).

When a coating is applied, all of the solvent is released into the atmosphere. It is this portion that concerns the EPA and other groups interested in protecting the environment. Most of the solvents commonly used in shielding coatings are, to some extent, photochemically reactive. That is, they react in the atmosphere to produce ozone, a major respiratory irritant and component of urban smog. Since spray painting operations cannot easily adapt to emissions control strategies such as solvent recovery or incineration, the EPA has chosen to regulate the amount of VOC contained in a gallon of coating. They have already done this in the metal and textiles coating industries, and are now ready to address coatings for plastic parts. In other industries, there has been a shift to high-solids content and water reducible coatings. Thus, there is no reason to think that coatings for plastic parts will differ greatly from this pattern.

SHIELDING COATING OPTIONS

Acrylic Lacquers. Currently, most people choose solvent-borne nickel-acrylic lacquers for their shielding needs. These coatings are economical and easy to mix and use. They adapt well to high-volume production situations, where their rapid drying characteristics and unlimited pot life (useful time after mixing) contribute to a smooth, rapid process flow.

However, a look at Table 1 shows that their VOC content is the highest of all the available types. So, despite all of its advantages from the processor's point of view, operations using this coating type will be the most affected by regulations governing VOC emissions.

Type	VOC lbs/gal	% Solids by Volume	25°C Cure Time hrs	Pot life hrs
Acrylic	6.2	15	1-4	—
Urethane	5	25	12-24	8
High Solids Urethane	4.5	35	4-12	2-6
Water-borne	1.7	25	12-24	≥8

Table 1. Physical Characteristics of Shielding Coatings (as applied).

Two-Component Urethanes. Urethane conductive coatings have been used for years in applications requiring their unique combination of shielding effectiveness, abrasion resistance, adhesion to difficult substrates, and tolerance of chemical and environmental stress. Because they are reactive systems, they possess a limited useful life after mixing. This requires more careful scheduling of coating use by the applicator to avoid waste. Also, the cure time for these coatings is much longer than for acrylic coatings and some users may choose to use curing ovens to maintain a rapid throughput rate.

High-Solids Urethanes. Table 1 shows that, at 4.5 lbs VOC per gallon and 35 percent solids by volume, high-solids urethane coatings offer the lowest VOC emission levels of any solvent-borne shielding coatings available. The high solids contribute to the efficiency of coating operations and their greater reactivity provides much more rapid cure times than standard urethanes. However, this reactivity also leads to much shorter pot lives; this may cause production problems in low-volume or low-production rate situations. In some instances these limitations may require the use of special equipment, such as a two-component spray gun, which keeps the components separate until they are sprayed.

Waterborne Coatings. In waterborne coatings, water replaces the majority of the solvent in the formulation. This gives these paints by far the lowest VOC content of the various shielding coatings available. It also reduces fire hazards in the workplace and worker exposure to possible toxic solvent fumes. In general, these coatings do not possess pot life restrictions but, because of the slow evaporation rate of water, have relatively long cure times. Users may resort to cure ovens to shorten drying times and may experience poor drying characteristics on very humid days. Waterborne coatings tend to be more sensitive to surface preparation than solvent-borne coatings. Excessive mold release or oily surfaces can cause severe application troubles that are seldom experienced with solvent-borne shielding paints.

ELECTRICAL PERFORMANCE OF ALTERNATE COATINGS

Although all citizens must be aware of the environmental effects of their actions and compliance with government regulations, design engineers' primary responsibilities must be to ensure the quality and performance of their product. When selecting a shielding coating, its electrical performance must be considered, both as applied and after environmental stress, to ensure that the coating provides adequate shielding and will continue to do so after years of service. The engineer must also consider its compatibility with and adhesion to, the substrate plastic, to insure that a flaking conductive coating does not damage sensitive electronics or present a possible fire hazard by shorting out exposed circuitry.

The addition of air quality regulations to the list of factors an engineer must consider when choosing a shielding coating will surely complicate the selection process. Performance testing must play an essential role in the evaluations, because significant differences exist between the various types of coatings, and between different products of the same type. With that in mind, it is still useful to discuss the general properties of the different classes of coatings as they relate to the important considerations of shielding effectiveness, stability, and system compatibility.

Sheet Resistivity and Shielding Effectiveness. Most conductive coatings are specified on the basis of their sheet resistivity, measured in ohms per square. This measurement is found to correlate fairly well with actual E-field shielding performance. The majority of suppliers and users of conductive coatings recommend one ohm per square as a guideline for establishing specifications, but many applications require more or less shielding to meet the system requirements. Specifying lower resistivity than is required is a costly proposition, but selecting a higher value that provides marginal performance on prototypes may cause problems with FCC compliance due to normal production variations. As Table 2 shows, all of the available types of conductive coatings are able to meet a one ohm per square specification, although some may require a thicker film than others. At this sheet resistivity value, most coatings may be expected to provide 45 to 60 dB attenuation at 100 MHz. An exception is coatings based on nickel-flake pigment, which, because of the flakes' overlapping layers and higher coating density, show somewhat higher attenuation than would be expected based on their surface resistivity alone. Another factor that can affect a coating's ability to repeatedly meet conductivity and shielding effectiveness is its processing characteristics. Improper solvent balance or poor dispersion of the conductive pigment can cause the coating to perform poorly in difficult to spray areas, such as part sidewalls and around ribs and bosses, resulting in high resistance paths within a part and a corresponding loss in shielding effectiveness.

Type	Sheet Resistivity at 2 mils	Environmental Stability	Compatibility with Plastics
Acrylic	.5-1	Poor to Excellent	Good
Urethane	.5-1	Excellent	Excellent
High Solids Urethane	.3-.7	Excellent	Very Good
Water-borne	.5-1.5	Poor to Very Good	Very Good, Best for Polycarbonate

Table 2. Electrical Characteristics of Shielding Coatings.

The design engineer should consult his conductive coating supplier for recommendations as early in the design process as possible, since a paint's processing characteristics are best known to those who have years of experience providing technical support to users.

Environmental Stability. In the absence of accepted standardized tests for the evaluation of conductive coatings, suppliers and users of these products have been left very much on their own to develop comparative tests. This has led to wide variations in the reported stability of coatings. In general, the stability of conductive coatings has improved steadily over the past several years. Urethane coatings, because they react to form a cross-linked, insoluble film, exhibit excellent stability in most of the accelerated tests commonly used. Acrylic lacquers, because they are applied at a low viscosity, tend to have higher concentrations of additives intended to retard pigment settling, promote ease of handling, and improve application properties. These additive packages vary widely from one manufacturer to another and have a pronounced effect on the stability of the coating. Because of these effects, data from stability tests vary widely, depending upon the test conditions, applied film thickness, spray technique, and other variables.

Probably no class of coating is as sensitive to accelerated humidity test procedures as waterborne coatings. By definition, these coatings must be compatible with water during their manufacture and application, and then dry to form a film with good moisture resistance properties. The hydrophilic (or water-loving) nature of the resins and additives used may make the coating subject to extreme degradation in accelerated tests which expose the coating to 100 per cent relative humidity (condensing) environments. As Table 3 shows, the same coating may easily tolerate less severe conditions and perform well in tests that do not result in condensation, as in actual use. As coating B in this table illustrates, great progress is being made in reducing the moisture sensitivity of waterborne coatings. Waterborne decorative coatings for plastics have been developed whose properties are comparable to solvent-borne systems, and waterborne shielding coatings are in development whose properties are expected to rival those of solvent-borne shielding coatings even in accelerated, high humidity tests.

	50% RH, 65° ohms/sq.	100% RH, 65° ohms/sq.	Cycling, 25° to 65° 100% RH 20 times ohms/sq.	5 yrs Office Exposure ohms/sq.
Waterborne A				
Initial	1.04	.78	.95	.90
Final	.77	25.5	over 1000	.74
Waterborne B				
Initial			.62	
Final			1.24	

Table 3. Accelerated Testing of Waterborne Coatings.

Coating-Substrate Compatibility. To perform its job properly, a conductive coating must do more than provide adequate shielding throughout its life. It must also maintain excellent adhesion to the substrate plastic without degrading the plastic's physical properties. The type of plastic being used must be considered when choosing a conductive coating. For example, polycarbonate and styrene are readily attacked by the solvents in most acrylic coatings, resulting in stress-induced cracking of the plastic and conductive coatings. The coating may not adhere at all to polyester surfaces (such as SMC) or RIM polyurethane. With substrates such as these, urethane coatings may be a better choice, since they exhibit better overall adhesion to most plastics, and their lower solvent content minimizes degradation of the plastics' physical properties. Waterborne coatings are ideal for solvent-sensitive plastics such as polycarbonate and exhibit excellent adhesion to most engineering resins.

Because of the compatibility problems that can arise from selecting the wrong coating for a given substrate plastic, the designer is urged to contact his conductive coating supplier for recommendations.

SUMMARY

The EPA intends to regulate emissions from facilities involved in coating plastic parts for business machine housings. If they follow the patterns established for similar industries, this will cause a shift away from the nickel-acrylic conductive coatings currently popular towards alternative types such as high-solids and waterborne coatings.

These coatings are already available and are constantly being improved. Their application properties may necessitate some process changes for the user, but the engineer should find their electrical properties to be very similar to those conductive coatings already in widespread use today.

Author's Note: A New Source Performance Standard, when implemented, will affect all new coating facilities and certain expansions and modifications to existing facilities. Those who would like more information regarding the proposed regulations, or who would like to have their comments considered during the development of the NSPS, may contact:

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