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To: Project File No. 7705-L

From: Barbara W. Duletsky BWD

Subject: Use of Electrostatic Spray Techniques for the Surface Coating of Plastic Parts for Business Machines

The most common type of coating equipment used by facilities that coat plastic parts for business machines is manual air atomized spray. Electrostatic spray methods have been demonstrated that appear to achieve higher transfer efficiencies than conventional air spray. The purpose of this memorandum is to present information gained through industry contacts about electrostatic spray technology, and to draw conclusions about its applicability to the surface coating of plastic parts for business machines.

ELECTROSTATIC SPRAY

A. Theory

The basic mechanism of electrostatic spray is the difference in potential energy of the coating and the part to be coated, which causes an electrostatic force to exist between them. Typically, the coating is given a positive charge at the gun and propelled toward the part by means of a high pressure airstream. Since the grounded part is oppositely charged, the attraction of the coating particles for the part overcomes the momentum of the particles. Consequently, the coating "wraps around" the part rather than being lost as overspray. By this method, transfer efficiency is greatly improved over conventional air spray methods. Industry contacts have estimated transfer efficiency for electrostatic guns to be anywhere from 30 to 90 percent, depending on the method of atomization (i.e., air, airless, air-assisted/airless).[1-5]

When the part to be coated is a nonconductive substrate such as plastic, it is necessary to provide a conductive surface that can bleed off the electrical charge resulting from the accumulation of charged paint particles. This may be done by applying a conductive sensitizer to the surface to be coated, grounding the electromagnetic interference/radio frequency interference (EMI/RFI) shielding layer, grounding a conductive fixture or image behind the target, using a plastic that is itself conductive, or spraying an electrically conductive topcoating such as a waterborne coating.

1. Conductive sensitizer. The most common method of preparing plastic for electrostatic spraying is spray application of a conductive sensitizer. A typical sensitizer contains 1 to 8 percent by volume hydrophilic salt in solution with an organic solvent or water. It can be applied by spraying, misting, hand-wiping, or dipping. As the solvent evaporates, the salt expands by absorbing water molecules

from the air and forms a continuous, conductive film on the part. This process, as described in a vendor brochure, is shown in Figure 1.[6]

Sensitizers dissolved in organic solvents such as isopropyl alcohol are being used more frequently than waterborne sensitizers. Since isopropyl alcohol is a VOC, application of this type of conductive sensitizer is a source of VOC emissions. There are no data available on whether or not the overall VOC emissions are reduced by using a conductive sensitizer prior to electrostatic spray, but preliminary estimates and calculations show that emissions may be reduced by as much as 63 percent. Table 1 shows the approximate tradeoff between emissions from air atomized spray application of a conductive sensitizer and emission reductions achieved by using electrostatic spray for subsequent topcoats. A 1-percent solution of sensitizer in isopropyl alcohol is assumed, since this would contain the highest expected proportion of VOC. The coverage for 1 gallon of sensitizer is assumed to be 1,500 square feet, since this represents the highest level of VOC emissions for the 1,500 to 2,000 ft^2/gal range supplied by the manufacturer.[7]

2. Grounded EMI/RFI shielding. In order to attenuate EMI/RFI signals, plastic business machine housings should be effectively shielded by a layer of conductive material. This is most commonly achieved by zinc-arc spraying or by application of conductive coatings using conventional air atomized spray guns. Other EMI/RFI shielding techniques include electroless plating and the use of conductive plastics.

For zinc-arc spraying and air atomized spraying of conductive coatings, a layer of conductive material is applied to the interior surface of each housing. By grounding this layer, the exterior surface can be coated electrostatically. Although plastic acts as an insulating barrier between the conductive layer and the spray gun, the charged paint particles are still attracted toward the grounded EMI/RFI-shielded surface. Attraction may be uneven, however, depending on the uniformity of the shielding coating. This is a disadvantage, since a nonuniform electrostatic force does not provide a good basis for an even surface finish.

In the case of electroless plating, the part is dipped in a conductive solution, thus making both interior and exterior surfaces conductive. By grounding the metal surface, the topcoating can be applied electrostatically.

In the same way that charged paint particles can be applied electrostatically to a metal surface, they can also be applied to conductive plastics. Plastic can be made conductive by the use of molded-in metal flakes or carbon particles. Depending on the surface resistivity, this type of substrate can be an effective base for electrostatic spraying.

3. Grounded image. A conductive fixture or image may be placed behind the part and then grounded to facilitate electrostatic spraying. Like the previous method, the plastic part does not prevent the attraction of the coating for the grounded surface. Since the plastic part lies within the force field created by the difference in potential, the charged paint particles are deposited on the part.

4. Waterborne coatings. Waterborne coatings can be charged at the gun and sprayed electrostatically onto a plastic part. Once the coating forms a continuous film on the grounded part, the surface is rendered conductive. As long as the coating remains wet, it continues to bleed off the charge and maintains a difference

TABLE 1. EMISSIONS FROM ELECTROSTATIC SPRAY COATING (FOLLOWING APPLICATION OF A CONDUCTIVE SENSITIZER) COMPARED TO CONVENTIONAL AIR ATOMIZED SPRAY COATING

Sensitizer Application

VOC content of sensitizer	= 99% by volume, as applied
VOC density (isopropyl alcohol)	= 6.56 lb/gal
Solids content of sensitizer	= 1% by volume, as applied
Coverage at 100% transfer efficiency	= 1,500 ft^2 plastic per 1 gal sensitizer
	= 0.667 gal sensitizer/1,000 ft^2 plastic
	= 0.00667 gal solids/1,000 ft^2 plastic
Sensitizer usage at 25% transfer efficiency (air atomized spray guns)	= coverage ÷ 0.25
	= 0.0267 gal solids/1,000 ft^2 plastic
VOC emissions at 25% transfer efficiency (air atomized spray guns)	= 0.0267 gal solids/1,000 ft^2 plastic
	x 99 gal VOC/gal solids
	x 6.56 lb VOC/gal VOC
	= 17.3 lb VOC/1,000 ft^2 plastic

Coating Application

VOC content of coating	= 68% by volume, as applied
VOC density (average)	= 7.36 lb/gal
Solids content of coating	= 32% by volume, as applied
Coverage at 100% transfer efficiency	= 5 mil x 1 ft^2 solids/ft^2 plastic
	= 720 in^3 solids/1,000 ft^2 plastic
	= 3.12 gal solids/1,000 ft^2 plastic
Coating usage at 25% transfer efficiency (air atomized spray guns)	= coverage ÷ 0.25
	= 12.5 gal solids/1,000 ft^2 plastic
VOC emissions at 25% transfer efficiency (air atomized spray guns)	= 12.5 gal solids/1,000 ft^2 plastic
	x 68 gal VOC/32 gal solids
	x 7.36 lb VOC/gal VOC
	= 196 lb VOC/1,000 ft^2 plastic

(continued)

TABLE 1. (continued)

VOC emissions and emission reductions[a] for electrostatic spray:

	Transfer efficiency			
	30	50	70	90
Coating usage (gal solids/1,000 ft²): (coverage ÷ transfer efficiency)	10.4	6.24	4.46	3.47
VOC emissions for electrostatic spray (lb VOC/1,000 ft²): (Coating usage x 68 gal VOC/32 gal solids x 7.36 lb VOC/gal VOC)	163	97.6	69.8	54.3
VOC emissions from application of conductive sensitizer (lb VOC/1,000 ft²)	17.3	17.3	17.3	17.3
VOC emissions for electrostatic spray following application of conductive sensitizer (lb VOC/1,000 ft²)	180	115	87.1	71.6
VOC emissions for air atomized spray (lb VOC/1,000 ft²)	196	196	196	196
Emission reduction[a] (lb VOC/1,000 ft²)	16	81	109	124
Emission reduction[a] (percent)	8	41	56	63

[a]Emission reduction achieved by using electrostatic spray following application of a conductive sensitizer instead of conventional air atomized spray.

in potential between the plastic part and the paint particles. In addition to decreasing VOC emissions and coating consumption, this method also reduces the fire hazard caused by spraying high volumes of VOC.

B. Applications in Industry

1. Equipment and conductive coatings/substrates vendors. Electrostatic spray equipment and conductive coatings/substrates are readily available through many different vendors. Some of these vendors were contacted for information on the use of their products in the surface coating of plastic parts for business machines. Table 2 summarizes the information gathered from these contacts.

2. Surface coaters of miscellaneous plastic parts. Surface coating industries that are using this technique for plastic products such as safety helmets, automobile fascia, window shutters, etc., are listed in Table 3. The transfer of this technology to business machine parts may not be made directly, however. The effectiveness of this spray method depends, to a large extent, on the size and complexity of the part to be coated. For instance, parts with recessed and louvred areas are particularly difficult to cover electrostatically due to the "Faraday Cage" effect. On the other hand, electrostatic spraying of coating onto a large flat target would approach 100-percent transfer efficiency and provide complete and uniform coverage.

3. Surface coaters of plastic parts for business machines. It is uncommon for facilities that surface coat plastic business machine parts to employ electrostatic spray methods. Table 4 shows the names of the companies that were contacted specifically about their use of this method. Of the 19 companies surveyed, 5 have used electrostatic spraying on a production basis, and 4 others have experimented or intend to experiment with it. While the companies that use this method in production believe that transfer efficiency has been improved, only one was able to provide specific supporting data.[30]

Many contacts offered possible reasons for the infrequent use of this method in the industry. A major factor is the initial capital cost of the equipment. An electrostatic hand-held gun costs $2,000, which is 10 times the cost of a conventional air atomizing gun.[17] Although the vendors advertise a short payback period due to the savings in coating consumption, most coaters would not realize this savings without incurring prior losses common to incorporating new equipment. Many of the small job shops do not have the resources available to experiment with this technology. Even if the initial capital investment were not a barrier, they would not have the plant capacity to maintain their production rate while retraining the spray gun operators.

In addition to manual spray guns, automatically controlled systems are available from various equipment vendors. The capital cost of an automated system is much greater than that of manual guns, but the consistent and efficient spraying it provides has the potential to improve transfer efficiency. Automation is particularly beneficial for facilities that coat large quantities of similar parts. Once the coating line has been programmed to spray a certain rack of parts, large quantities can be coated with little or no adjustments to the controls. Advantages of this technique include improved transfer efficiency, increased production rate, and consistency in quality of the final products. Improved transfer efficiency has

TABLE 2. ELECTROSTATIC SPRAY (ES) COATING--EQUIPMENT AND CONDUCTIVE COATING/SUBSTRATE VENDORS

Company, address	Product	Method of ES coating	Comments
Advanced Chemicals and Coatings[8] Temple City, Calif.	Coatings	Grounded EMI/RFI	• Grounding the EMI/RFI shielding has been used with polyurethane topcoat applications.
Celanese Corp.[9] Charlotte, N.C.	Carbon fibers	Conductive carbon fiber mesh	• Ford Motor Co. had been involved in ES using nonwoven veil of conductive carbon fibers. • International Paper Co. manufacturers the nonwoven mesh.
Deft, Inc.[10] Irvine, Calif.	Chemicals	Conductive coatings	• Deft sells mostly to aerospace industry, but they are working with Beckman Instruments to develop coatings with ES potential. • Business machine coaters may not have the resources to experiment with costly new technologies such as ES.
Electro-Cote Chemicals, Inc.[11] Noblesville, Ind.	Chemicals (conductive sensitizer)	Conductive sensitizer	• Sensitizers are in isopropyl alcohol solution. Effectiveness increases with humidity. Up to four top coats can be applied by ES. • IBM and Armco are involved in ES coating using conductive sensitizers. • Ransburg and Air Power manufacture ES equipment.
Electro Kinetic Systems, Inc.[12] Wilmington, Del.	EMI shielding coatings	Grounded EMI/RFI	• EMI shielding can be sprayed onto exterior surfaces and used as a base for ES coating. • Solvents in EMI and top coat must be compatible for a good surface finish. • Leida Finishing may be using this method of ES coating.
Enthone, Inc.[13] Bridgeview, Ill.	Enshield® EMI/RFI shielding process	Grounded EMI/RFI	• Most people use two-component urethanes over the Enshield® electroless plating. • Coaters that may be doing ES coating over the Enshield® plating: Genron, Furniture City, E/M Lubricants.
Graco, Inc.[4] Minneapolis, Minn.	Spray equipment	No surface pretreatment	• ES centrifugual atomizer, CA-1000, can achieve transfer efficiencies of 85% on conductive or nonconductive substrates. • Also manufacture automatic and manual ES air spray guns.

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TABLE 2. (continued)

Company, address	Product	Method of ES coating	Comments
Kremlin, Inc.[14] Addison, Ill.	Spray equipment	Grounded metal hangers	• Uneven coverage since paint is attracted unevenly. • On metal, air-assisted/airless ES gets 38% better transfer efficiency than air-atomized ES.
LeaRonal, Inc.[15] Freeport, N.Y.	Vest®, vapor etch shielding technology	Grounded EMI/RFI	• Shielding process involves vapor etching followed by electroplating. • The surface may be conductive enough after vapor etching for ES coating. • The plating is a good base for ES coating. Xerox has experimented with this technique.
Nordson Corp.[16] Matthews, N.C.	Spray equipment	Conductive sensitizer	• Rendered nonconductive if heat is applied. Otherwise a good method.
		Grounded image	• Not as effective as using a conductive sensitizer.
		Grounded metal rack	• Coating is attracted only to points of contact with metal.
		Grounded EMI/RFI	• Causes uneven attraction due to nonuniform shielding.
		Conductive plastics	• Call Eastman or Celanese for more information.
Nordson Corp.[17] Amherst, Ohio	Spray equipment	General	• Cost inhibits most small coaters from using ES. • Hewlett-Packard in the San Francisco area is spraying waterborne coatings by ES.
Ransburg Corp.[18] Indianapolis, Ind.	Spray equipment	Conductive sensitizer	• Ransburg manufactures manual and automatic ES. • Air ES guns achieve 50-75 percent transfer efficiency.
Transmet Corp.[19] Columbus, Ohio	Aluminum filler for conductive plastics	Conductive plastics	• Highly unlikely that parts could be coated by ES, since most of the aluminum is concentrated near the center and the surface is resin-rich.
Udylite Plating Systems[20] Warren, Mich.	Attenuplate® EMI/RFI shielding process	Grounded EMI/RFI	• Attenuplate® process can be used as a base for ES coating, although it provides surfaces with much higher conductivity than needed by ES. • E/M Lubricants may be involved with ES coating by this method.
Arvid C. Walberg & Co.[21] Downer's Grove, Ill.	Spray equipment	Waterborne coatings	• Walberg manufactures both automatic and hand-held ES equipment. • Waterborne coatings are conductive, so no sensitizer is needed. • Metamora Co. is using a Walberg system.

TABLE 3. ELECTROSTATIC SPRAY (ES) COATING--MISCELLANOUS PLASTIC COATERS

Company, address	Type of experience	Method of ES coating	Product coated	Comments
Arthur Fulmer Co.[22] Miami, Fla.	Production	Conductive plastics	Safety helmets	· Conductive gel is molded-in with fiberglass and then coatings are applied by Ransburg ES reciprocating disc.
Davidson Rubber Co.[3] Dover, N.H.	Production	Grounded image, conductive sensitizer	Plastic parts for automobiles	· Research with electrostatic bells to determine standard test for transfer efficiency. · Experimented with several types of ES primers.
Ford Motor Co.[9]	Production	Carbon fiber mesh	Automobile hood scoops	· Doing research involving colamination of nonwoven veil of carbon fiber mesh, followed by ES coating.
Guide Division of GM[2]	Production	Grounded aluminum fixture behind part	Automobile fascias	· Six Graco ES guns in each booth triggered automatically. · System is computer controlled and TE = 60 to 70%.
Jay Plastics[23] Mansfield, Ohio	Production	Metallic layer	Miscellaneous	· After base coat, products receive sputtering application of a decorative metallic layer. Outer coating is sprayed automatically with Ransburg ES guns.
Metamora Products Corp.[24] Metamora, Mich.	Production	Waterborne coatings	Window shutters	· Using Walberg system for ES coating. · About to install DeVilbiss system.

TABLE 4. ELECTROSTATIC SPRAY (ES) COATING--SURFACE COATERS OF PLASTIC PARTS FOR BUSINESS MACHINES

Company, address	Type of experience	Method of ES coating	Comments
Armco[25] Hartford City, Ind.	None	N/A	• They do not coat their own business machine parts, and the contractors who coat the parts do not use ES.
Beckman Instruments[26] Fullerton, Calif.	None	N/A	• Parts are coated by Cashiers Plastics, Structural Plastic Systems, Northwest Molded Products, and Kaiser-Haskin Co.
Cashier's Structural Foam Div.[27] Chandler, Ariz.	None	N/A	• ES lends itself to a high degree of automation, long runs, and requires an increased capital investment. • As the company grows and volume increases, they will reconsider ES.
Component Finishing[28] Santa Clara, Calif.	Limited production	No surface preparation	• One-percent of the plastic coated is done by ES. This probably will not increase because plastic is difficult to ground.
E-Systems[29] Dallas, Tex.	Experimental	?	• A negligible amount of ES coating is done on plastic, mainly for research purposes.
Eastman-Kodak Co.[30] Rochester, N.Y.	Production	?	• Transfer efficiency data indicate 50 to 60% for automatic ES, and 30 to 40% for manual ES.
E/M Lubricants, Inc.[31] W. Lafayette, Ind.	None	N/A	• E/M has not been involved with ES coating.
FCM Plastics Div.[32] Grand Rapids, Mich.	Past production	Grounded electroless plating	• Their electroless coating is a good base for ES, but presently no jobs specify ES coating. • Transfer efficiency is greater for ES than for conventional.
Finishing Technology, Inc.[33] Tempe, Ariz.	Planned experimental	Conductive sensitizer	• ES coating of metal parts is done here. • The company has some conductive sensitizer with which they plan to test ES coating of plastics in the near future.
Foam Molding Company of Arkansas, Inc.[34] Rogers, Ark.	None	N/A	• Using conventional (manual air spray) equipment.
IBM Corp.[35] Lexington, Ky.	Past production	?	• VOC ES was discontinued in June 1981, and waterborne ES was discontinued in July 1983.

(continued)

TABLE 4. (continued)

Company, address	Type of experience	Method of ES coating	Comments
Leida Finishing[36] Wallingford, Penn.	None	N/A	• Leida coats metal parts by ES, but not plastic. • Number of batches to be coated would have to be large enough to justify the purchase of ES equipment and the setup time for each run.
Premix, Inc.[37] N. Kingsville, Ohio	None	N/A	• According to the plant engineer, Premix has never done ES coating.
Storage Technology[38] Louisville, Colo.	Past experimental	Conductive sensitizer	• For facilities that coat high volumes of similar parts, there would be a good payback. • The technique is not good for Storage Technology, since they specify low quantities of varied parts.
Structural Plastics Systems[39] Torrance, Calif.	None	N/A	• SPS has not used ES or airless equipment due to the capital expenditure involved. • Manual air-spray is suitable for most of their jobs.
Timespec[40] San Carlos, Calif.	None	N/A	• Timespec uses manual air guns. • ES coating of plastic is not possible because of the need for a conductive surface.
Xerox Corp.[41] Webster, N.Y.	None	N/A	• Xerox coats metal parts by ES. Plastic is nonconductive and a conductive sensitizer would need to be applied. • The biggest problem would be overcoming the Faraday effect when coating complex shapes.
Confidential Contact No. 1	Experimental	Conductive sensitizer	• Need flexible coating systems because of the wide assortment of parts coated. • Installing an ES system would require a spray booth for sensitizer application.
Confidential Contact No. 2	Production	Conductive sensitizer	• There is a trade-off in ES coating: while transfer efficiency increases by 30%, total VOC emissions may not decrease since the sensitizer is almost all solvent.

the consequent effects of decreasing VOC emissions, decreasing coating consumption, and decreasing booth maintenance costs.

Automation is not economically beneficial for facilities that perform a wide variety of low-volume coating jobs. For these facilities, the amount of time needed to set up and fine tune the automatic controls would not be justified by the relatively short run of parts through the coating line. The savings in paint consumption would be small compared to the cost of production time lost while programming the controls.

Whether automatic or manual electrostatic spray equipment is used, touch-up spraying with air atomized spray guns is usually necessary, especially for complex parts with many recesses. The manual touch-up step would limit both the increase in production rate and the VOC emission reduction that are gained by switching to electrostatic spray systems.

C. Conclusions

While electrostatic spray technology appears to achieve higher transfer efficiency than air atomized spray for the surface coating of plastic parts for business machines, little data are available from actual testing to quantify the improvement. If there is an economic payback in using the methods presented herein, it has not been dramatic enough to convince most coaters serving the business machine industry to begin using them. Some coaters have been experimenting with electrostatic systems for use in their facilities, but most do not have the resources to install new equipment while maintaining their current levels of production.

According to the information received from industry contacts, electrostatic spray coating technology is readily available and is applicable to the surface coating of plastic parts for business machines. The infrequent use of the technology for this purpose reflects the difficulty of coating a nonconductive surface electrostatically and the high capital cost of implementing this technology in an existing plant.

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