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Project Summary

Finishing Fabricated Metal Products with Powder Coating

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This report provides a technical and economic evaluation of a polyester powder coating system applied to the exterior and interior surfaces of metal boxes fabricated for the telephone and cable industries. This evaluation summarized many of the requirements and benefits of a clean technology that effectively eliminates the use of hazardous solvents and prevents the generation of volatile organic emissions and hazardous solid waste.

The technology routinely demonstrated a system efficiency that ranged between 95% and 98%, while providing consistent quality under flexible working conditions.

The economic analysis resulted in a net present value of $797,410 and a payback period of 0.49 yr. The economic results concur with published references indicating labor and cleanup costs for powder systems are about 38% lower than the costs compiled for wet-finishing systems.

A comparative analysis of published operating costs indicates that the powder coating system is more advantageous than systems using conventional solvent, waterborne, or high-solids coatings. The cost advantages are, in part, attributed to lower energy and maintenance requirements.

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Cincinnati, OH, to announce the key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Powder coating can be simply defined as dry paint. Instead of being dissolved or suspended in a liquid medium, such as solvent or water, powder is applied in its dry form directly to the surfaces requiring coating.

Powder coating has emerged as a clean technology alternative to waterborne, high-solids, and conventional solvent-based coating systems. The commercial availability of this technology allows small and large manufacturers to specify equipment that can effectively accommodate variable production schedules while attaining desired quality standards.

Recent advancements in the technology are resulting in system efficiencies ranging between 95% and 98%. In addition to optimizing the use of costly raw materials, a powder coating system, in comparison with conventional wet systems, can be operated in a manner that will reduce labor, maintenance, and energy costs.

From an environmental perspective, powder coating systems have effectively eliminated hazardous waste and releases of toxic chemicals to air, water, and solid media. The design features of many systems have reduced employee exposure to any hazards posed by the use of powder paints.

The purpose of this project was to document and analyze the applicability and adequacy of finishing fabricated metal boxes with a powder coating system. The project involved a technical and economic assessment of the operations employed by a small manufacturer of metal boxes fabricated for telephone and cable industries.

The evaluation was completed under the terms of the Erie County/EPA WRITE Program as a joint effort by Diversified Control, Inc., Orchard Park, NY; Erie County Environmental Compliance Services, Buffalo, NY; Recra Environmental, Inc., Amherst, NY; and the U.S. Environmental Protection Agency (USEPA) Office of Research and Development, Cincinnati, OH.

Procedure

The industrial participant for this program was Diversified Control, Inc. Diversified Control has been designing and manufacturing 16-gauge steel boxes with maximum dimensions of 24" x 24" x 8" deep. These boxes are fabricated for use by the telephone and cable industries. Diversified Control's customers require the boxes to exceed predefined quality standards including provisions for corrosion resistance. To meet customer requirements of no red rust per ASTM B117 at 1000 hr, Diversified Control is required to pretreat surfaces before applying a paint coating.

When during its initial years of operation, the company outsourced surface finishing and contractors employed wet coating systems, a number of product quality problems were encountered related to failures in salt chamber tests at 100 hr using ASTM B117. Contractors addressed these problems by pretreating the surfaces of the metal boxes with a zinc phosphate formulation and finished the metal boxes with a powder coating instead of a wet coating.

These new contracting requirements significantly increased costs for preparing and finishing the metal boxes per customer specifications. Surface preparation costs alone doubled in price.

Because of cost increases and quality concerns, Diversified Control decided to invest in equipment and operations that would provide finished goods without using contractors. The factors influencing equipment selection and operating protocol are addressed within the context of this Project Summary. The company's technical and economic assessment took into account published references addressing viable techniques and requirements.

Diversified Control selected a powder coating technology and a modular pretreatment system employing a zinc phosphate formulation. The pretreatment system employs cleaning solutions that were ultimately chosen after exhaustive testing and research. The selection process determined that the cleaning solutions would not result in

- A wastewater having hazardous characteristics
- A wastewater that would potentially exceed effluent criteria governing direct discharge into the Erie County Sewer District
- A sludge or solid residue that would require routine maintenance and proper disposal
- Conditions that would etch the metal boxes

To minimize the potential sources of contamination requiring removal by the cleaning solution, company personnel routinely monitor potential changes in stock cleanliness originating from variations in processing, quenching, or transportation oils.

The selected powder coating system was designed and manufactured by Engineered Powder Applications, Inc., and the spray guns were provided by ONODA Ionics Division. The selection process took into account cost, durability, commercial availability, anticipated maintenance, and documented performance.

To accommodate variable production schedules, the company chose an electric infrared (IR) oven for curing the powder coating. To eliminate surges, which can be encountered with a filament quartz tube IR system, the company chose a resistance IR system. PROTHERM electric infrared heaters, manufactured and supplied by Process Thermal Dynamics, Inc., were installed. These units provided the company the flexibility needed to completely shut down the system during short idle and off-production periods. The company found that the electric IR system was three times less expensive than comparable gas systems, and to take advantage of rebates from the utility, the company installed additional process controls, including electronic sensors, which automatically shut off ovens during idle periods.

After the powder coating system was installed and operational, the company installed automated laser-cutting and fabrication tools as well as a robotic welding system to accommodate increases in production activities. These clean machines facilitated production and further reduced the potential for surface contamination and scrap generation.

Figure 1 provides a schematic of flow of operations.

Collectively, the equipment and operations cited in Figure 1 attain the desired quality standards. To compare this system with alternative paint coating systems, the design specifications and operating protocol for the powder coating system were documented and analyzed as follows:

- The company uses a quick color change powder booth manufactured by Engineering Powder Applications, Inc. The design specifications for this booth are summarized in Table 1.
- The system's design allows 16-gauge steel boxes to be conveyed on a batch, intermittent, or continuous basis from the pretreatment system as illustrated in Figure 2.
- In the first stage of the pretreatment system, the initial wash employs an alkaline soap, ISW-24, a temperate range between 140°F and 160°F, and a pH of 9 to 9.5. A typical retention time is 5 min.
- In the second stages, metal boxes are subjected to a rinse solution formulated with a soap/rust inhibitor to stop flash rusting. The rinse system is operated at a temperature of 80°F and a pH of 8. A typical retention time is 1 min.
- To select the most appropriate method for applying powder coating, company personnel estimated the square footage of material being painted per pound of paint consumed. This analysis took into account the size and geometry of the metal boxes, the specified film thickness, the type of coating specified for each surface, anticipated line speed, energy requirements, and growth in production activity. The chosen electrostatic spray process involves a powder feeder unit, electrostatic powder spray guns, an electrostatic voltage source, a powder recovery unit, and a spray booth. The process was deemed to be the most efficient means of applying coatings in a very short period of time, and it is conducive to batch operations.
- The company uses the GX Series 108 multimode manual spraying guns. This multimode gun allows the operator to choose any of three different spraying modes without changing equipment. (Figures 3, 4, and 5). Multimedia gun specifications are summarized in Table 2.
- Two operators use the guns to spray the powder in the form of a diffused cloud. The propelling force is provided by compressed air used to transfer the powder from the feeder to the spray gun and by the electrostatic charge imparted to the powder at the gun. A source designed to transmit high-voltage, low-amperage electrical power to an electrode attached to the spray gun supplies the electrostatic voltage.
- Figure 6 is a schematic of the end view of the booth. As the diffused, electrostatically charged powder cloud nears the grounded part, an electrical field of attraction is created, drawing the powder particles

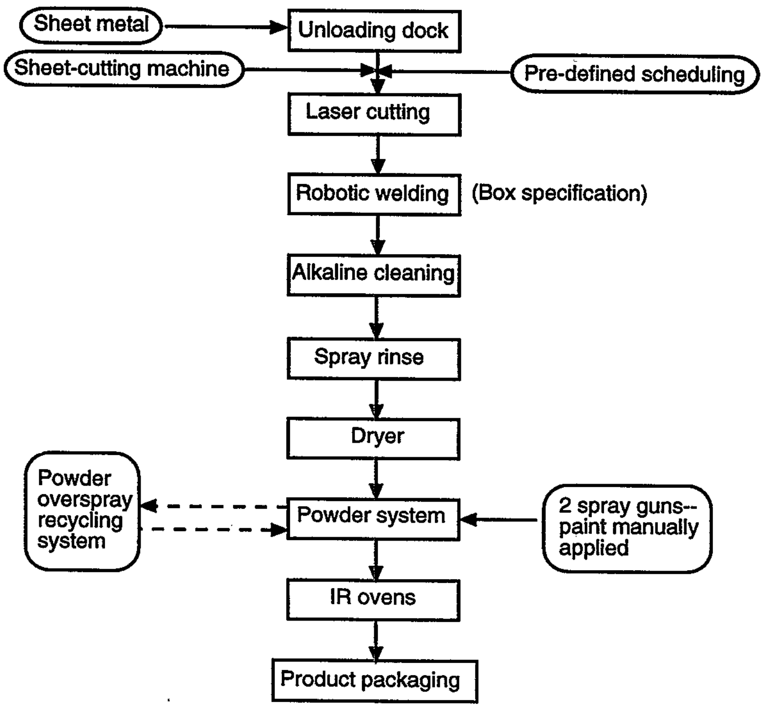

Figure 1. *Diversified Control, Inc., process flow.*

Table 1. *Engineered Powder Applications, Inc., Quick Color Change Powder Booth—Design Specifications*

Powder-Booth Components	*Specification*
Two-part openings at ends of booth	*18 in. wide x 42 in. high*
Two manual operator openings	*30 in. wide x 30 in. high*
Exhaust volume	*4,000 CFM*
Variable speed exhaust fan motor	*5 hp*
Eight primary cartridge filters	*1,848 sq ft - 98% SAE J726*
Pre-filters	*30% efficient ASHRAE 52-76*
Final filters	*95% efficient ASHRAE 52-76*
Booth overall length	*12 ft. - 0*
Compressed air	*100 psi clean, dry, no oil*
Power voltage	*480 volt/3 phase/60 Hz*
Control voltage	*120 volt/1 phase/60 Hz*

to the part and creating a layer of powder on the box surfaces.

- The company uses a dry powder paint classified as a polyester TGIC powder coating. Typical properties are summarized in Table 3.
- The powder coating system allows powder overspray to be recycled into the system. The powder is separated from the conveying air flow in the collector unit, which allows the collected powder to be recycled back to the feeder unit.

Results and Discussion

Comparative Analysis

In the process of selecting technologies and equipment for Diversified Control's operations, various options were evaluated based on published references. The technical and economic analyses employed estimated requirements and costs for installing a powder versus wet coating system.

Based on published data provided by vendors and the Powder Coating Institute, the comparative analysis indicated that

- Energy requirements and costs were lower for powder coating systems.
- Both powder system and a wet system need clean, dry, oil-free compressed air.
- Powder booths require no water for cleaning booth and filter media and, typically, no natural gas to heat the booth air.
- Air used in a powder booth is typically recycled within the plant, eliminating the need for stacks and air makeup units.
- A powder booth can be more expensive than a liquid booth, but a powder booth reclaims the oversprayed paint.
- The filters used with a powder system need to be changed only several times a year. Unlike powder systems, liquid systems generate paint-saturated booth filters, which are expensive to dispose of. A wet booth typically does not reclaim overspray; it contains banks of filters that can require daily changing.
- With a powder system, there is no solvent exhaust. Wet systems do release solvent emissions, and they require air replacement and a paint mix room.
- Spray guns used with wet systems must be routinely cleaned; this creates additional waste quantities that are not found with powder systems.
- When compared with waterborne, high solids, and conventional solvent coating applications, the capital costs for powder systems are slightly higher; however, pollution control requirements for the alternative can make the costs for powder systems advantageous.
- Material costs are significantly lower for powder systems, i.e., $2 to $3/gal versus $10 to $13/gal for solvent and waterborne systems.
- A powder system will use a paint with approximately 98% solid content versus 35% to 45% solids for solvent and waterborne systems.
- Powder systems will typically yield utilization efficiencies (actual coverage sq ft/gal) ranging between 95% and 97% versus 45% and 55% for solvent and waterborne systems. Electrostatic liquid systems efficien-

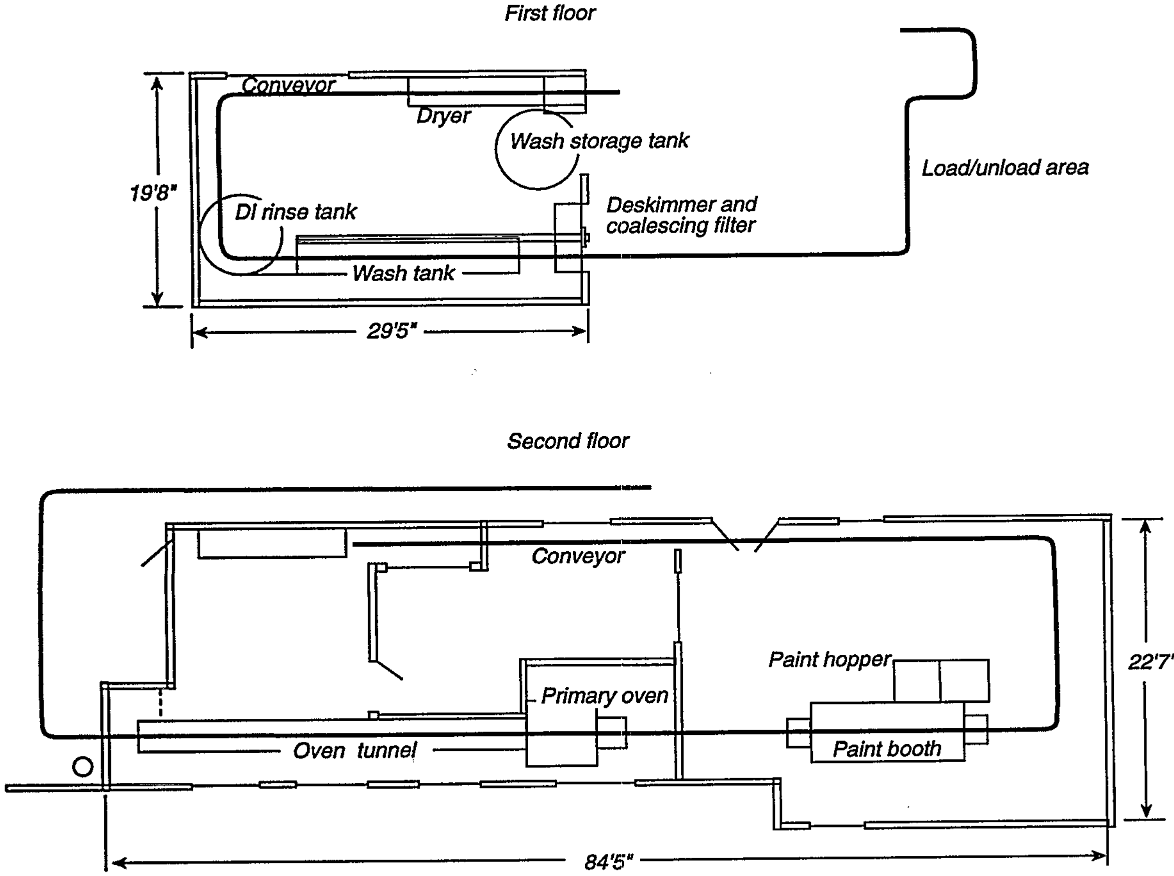

Figure 2. *Powder paint system at Diversified Control, Inc.*

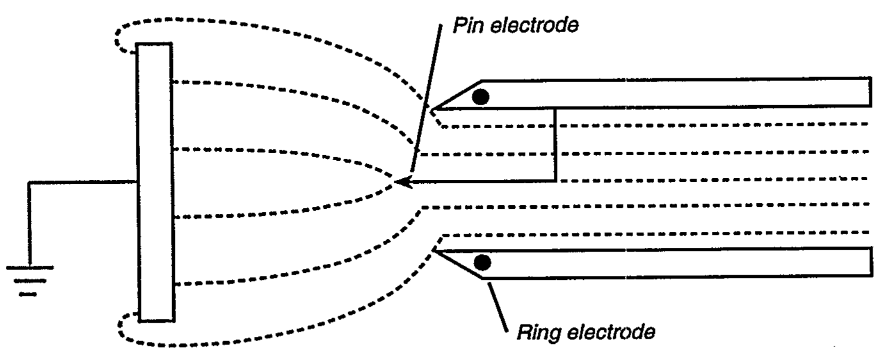

Figure 3. *E-Mode spraying pattern of the GX Series 108 spraying gun. (From: Ion Technologies Corporation)*

cies will reportedly range between 60% and 70%. When compared with fluid powder systems, electrostatic powder generally has a higher deposition efficiency.

- Labor costs for powder systems are generally lower than comparable costs for solvent and waterborne systems.
- Cleanup and maintenance costs for powder systems are typically 50% lower than those costs associated with solvent and waterborne systems.
- Waste quantities attributed to a powder system are significantly lower than the quantities generated with solvent and waterborne systems.

Economic Analysis

Company personnel completed the following assessment of the benefits attributed to the purchase of new electrostatic powder guns and a control panel.

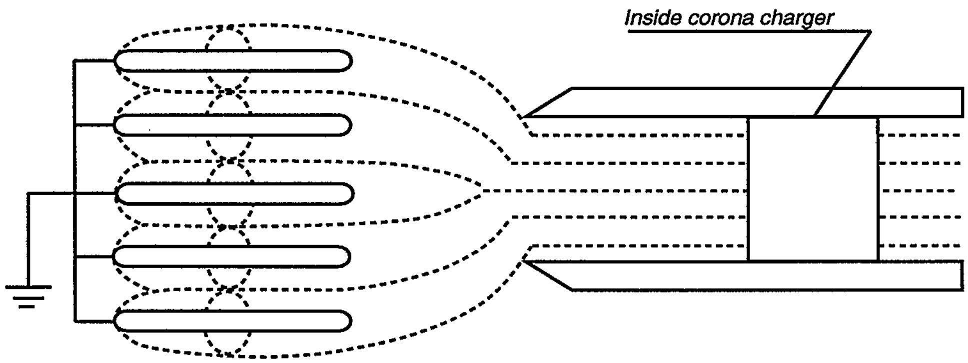

Figure 4. P-Mode spraying pattern of the GX Series 108 spraying gun. (From: Ion Technologies Corporation)

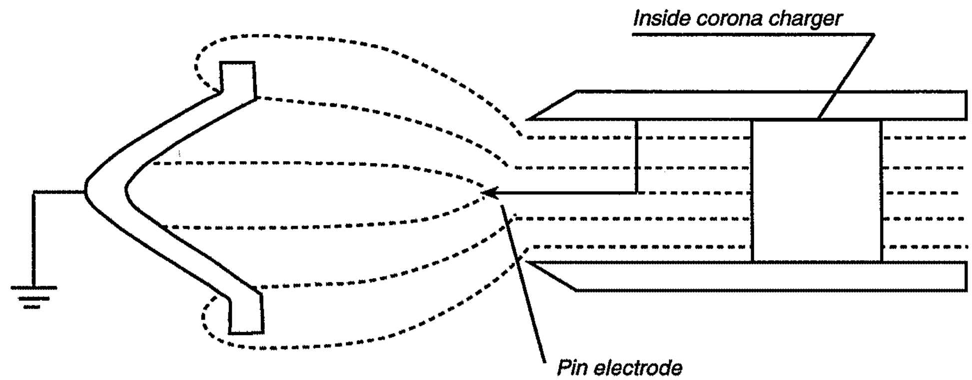

Figure 5. H-Mode spraying pattern of the GX Series 108 spraying gun. (From: Ion Technologies Corporation)

Table 2. Specifications of Multimedia Gun

Gun Component	Mode H	Mode E	Mode P
High Voltage Source	Internal cascade built into the gun barrel		
Gun Cable Input Voltage	24V maximum (AC peak value)		
Output Voltage:			
- Outside Charge	56KV	80KV	none
- Inside Charge	80KV	none	80KV
Short Circuit Output Current	160 micro amps (cutoff current set at 50 micro amp) standard		
Weight	Manual gun GX108 - 755 gr (3002)		
Gun Cable	7 m (23 ft) standard		

Old Equipment (1989)

- 1,146,240 estimated sq ft being painted/yr
- 33 sq ft painted/lb paint in 1989
- $74,679.20 total cost of paint required with old equipment at production levels

Proposed Method (1990)

- 1,146,240 estimated sq ft being painted/yr
- 66.5 sq ft painted/lb paint
- $37,058.91 total cost of paint required for 1 yr with new equipment

Estimated Annual Savings = $37,620.29

Table 4 summarizes the fixed costs associated with the operations employed by Diversified Control, Inc.

Variable costs, estimated on a daily basis from data available for a 5-mo period, include the costs for powder paints, electricity, and labor. The compared costs were calculated at $0.151/sq ft for powder coatings and historical costs of $0.305/sq ft for wet paint applications. The fee for contracting the wet painting was $6.50/box and is assumed to include all ancillary costs such as disposal fees, permits, and insurance premiums.

To accomplish the net present value (NPV) for the project, a tax rate of 40% was assumed along with discount factor of 10%. The NPV for the equipment purchase and installation, when added to the NPV for operation and maintenance, provided a project cost of $123,140. This cost is more than offset by the estimated tax savings on depreciation and savings on variable costs of $920,550 for a NPV of $797,410. The payback period was calculated at 0.49 yr.

Environmental Benefits

The powder coating system has eliminated waste categorized as sludge, discarded spray booth filters, hazardous solvents, volatile organic emissions, and hazardous housekeeping solids.

The pretreatment system does generate a spent solution that does not display hazardous characteristics. Limited analyses indicated the presence of zinc at elevated concentrations; however, the loadings do not restrict discharge. Rinse waters are pretreated to remove any phase-separable oils. The resulting water is recirculated for reuse.

Energy requirements are reduced along with fumes emitted during operations. The system eliminates the need for permits.

Health and Safety

Documented benefits include:

- Eliminated fire hazards
- Reduced in-plant emissions resulting in less workplace exposure
- Minimized vent emissions from curing ovens

The physical and chemical properties of TGIC polyesters must be carefully controlled.

Operating Performance

The work openings provided with the Engineered Powder Applicators, Inc., paint booth have been sized properly allowing for clearance of the boxes being sprayed, ample access to boxes for manufacturing operation, proper face velocity of air at the opening, variable line speeds, parts

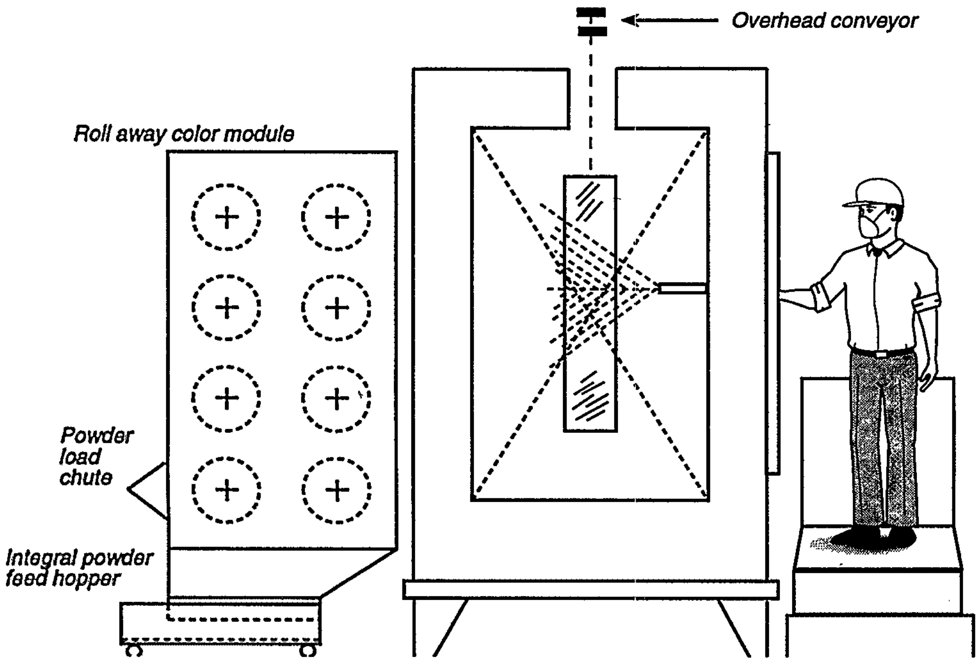

Figure 6. Schematic end view of the spray booth illustrating electrical field of attraction (From: Engineered Powder Applicators, Inc.)

Table 3. Typical Properties of Polyester TGIC Powders When Used Over a Good Metal Pretreatment

Property	Range
Hardness (pencil)	HB-H
Impact (lb)	60-160
Gloss (60° m)	20-90
Colors	All colors (clear and textures)
Salt Spray	1000+ hr
Condensing Humidity	1000+ hr
Cure Range (typ. 3 mil - .07 mm)	10 min @ 400°F (204°C)
Time (at metal temp)	30 min @ 300°F (149°C)

Table 4. Fixed Costs for Installing the Powder Coating Technology

Unit	Purchase Costs
Powdered Coating Application Booth	$ 26,000
Protherm Curing Oven	21,000
Conveyor	12,000
Wash tanks	8,000
Powder Application Guns	9,000
Miscellaneous	3,000
Spare Parts	2,000
Piping, Electrical, Instruments, Insulation	11,000
Structural	10,000
Construction/Installation	10,000
Engineering	5,000
	$ 117,000

load density, and spacing of hangers and racks.

The design features and operating protocol of the Diversified Control system effectively achieves the desired performance standards. Formation of good coating free of voids, pinholes, and distortions depends on controlling the particle size distribution, melting point, melt viscosity, and electrostatic properties.

Conclusions

The decision by Diversified Control, Inc., to specify and install a powder coating system has resulted in numerous benefits, including appreciable savings attributed to reduced labor and energy costs, increased production rates, significant cuts in reject rates, efficient floor space requirements, and reduced waste disposal costs.

Quality conformance heavily relies on proper surface preparation and in-plant process control. When compared with alternative coating systems, the savings cited by Diversified Control are very advantageous and justify process expansions that use powder applications.

The full report was submitted in fulfillment of CR-816762 by Erie County Department of Environment and Planning under the sponsorship of the U.S. Environmental Protection Agency.

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***Paul M. Randall** is the EPA Project Officer (see below).*
The complete report, entitled "Finishing Fabricated Metal Products with Powder Coating," (Order No. PB97-125397; Cost: $21.50, subject to change) will be available only from
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