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CONTROL TECHNOLOGY CENTER

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POWDER COATINGS TECHNOLOGY UPDATE

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PREFACE

The Powder Coating Technology Update report was funded as a project of the U. S. Environmental Protection Agency's (EPA's) Control Technology Center (CTC). The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) to provide technical assistance to State and local air pollution control agencies.

This report describes the current status of powder coating technology. It includes discussions of the advantages, costs, performance, and end uses of powder coatings. The report is available to State and local agencies for their use in demonstrating the feasibility of powder coatings as an alternative to coatings containing volatile organic compounds (VOC's).

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List of Abbreviations

ft = foot
ft^2 = square foot
ft^3 = cubic foot
g = gram
gal = gallon
in. = inch
kg = kilogram
lb = pound
ℓ = liter
m = meter
m^2 = square meter
m^3 = cubic meter
min = minute
μm = micron = $1x10^{-6}$ meter
TGIC = triglycidyl isocyanurate
VOC = volatile organic compound
yr = year

LIST OF TABLES

1.0 INTRODUCTION

The purpose of this report is to provide an overview of the current status of powder coating technology. Powder coating use in North America is increasing at a rate approaching 20 percent per year in terms of quantities of powder sold.[1] Recent improvements in the technology required to manufacture and apply powder coatings, in conjunction with environmental considerations, have led to this rapid growth. Many of the drawbacks previously associated with the use of dry powder coating as an industrial finish have been virtually eliminated. As a result, there are currently about 2,000 powder coating operations in the United States and the number is increasing rapidly.[2]

From an environmental standpoint, the increased use of powder coatings as an alternative to liquid, solvent-based coatings represents a significant reduction in emissions of VOC's. Because powder coatings are applied as dry, finely divided particles, there are no VOC's released during application and only minute quantities are released during the curing process. Therefore, the use of powder coatings as a means of reducing VOC emissions from industrial finishing operations is being encouraged by many air pollution control agencies. This report is intended to be helpful to those agencies by providing them information regarding the types of products being powder coated. It is anticipated that this will assist them in evaluating powder as a recommended air pollution control technology by answering questions concerning the performance, applicability, costs, and availability of powder coatings.

The information presented in this report is based on data obtained from literature searches, contacts with several State and local air pollution control agencies, and written survey questionnaires. Survey questionnaires were submitted to nine powder coating equipment suppliers, nine powder coating manufacturers, and nine powder coating users. Three of the nine equipment suppliers responded, and a summary of their responses is presented in Appendix A. A summary of the responses from the seven powder coating manufacturers who took part in the survey is presented in Appendix B. Four powder coating users responded and that summary is contained in Appendix C.

The remainder of this report is divided into five sections. The first provides a brief history of powder coatings from the 1950's through the 1980's. The next section describes the different classes of powder coatings that are currently available, including those types of powder resins that have recently been developed. The types of equipment required for a powder coating line and the types of products that are typically powder coated are discussed in Sections 4.0 and 5.0. A list of representative products currently being powder coated is also included in Section 5.0. Section 6.0 discusses the economic advantages of using powder coatings and presents a cost comparison between powder and liquid coatings. Section 7.0 presents the major points discussed in this report and conclusions.

2.0 BACKGROUND

The technology for finishing metal products with dry powder coatings rather than with conventional liquid paints has been available in this country since the mid 1950's. By the late 50's, powder was being used to coat pipe for corrosion protection and electric motor parts for insulation. These coatings were applied using a fluidized-bed process in which heated parts were dipped into a vat containing powder suspended in air. In this process, once the particles of powder contact and adhere to the heated metal parts, they begin to soften and flow into a smooth, even layer. Most of the coatings applied in fluidized beds were vinyl or epoxy powders. Typical coating thicknesses ranged from 150 to 1,000 µm (6 to 40 mils) and the applied coatings were functional rather than decorative.[3]

During the historical development of powder coating technology, there were several disadvantages or potential problems identified. Today, most of these have been resolved or minimized. The following are some of the major issues that were problems in the past:

1. Frequent color changes could entail extensive downtime for production lines and the ability to apply a wide range of colors could be restricted by equipment requirements and changeover times. Multiple booths are required for rapid color changes and special equipment is required to recover different colors separately (for recycle).

2. Storage and handling of powder requires special "climate" controls; powder will not remain "fluid" if exposed to moisture.

3. Accurate feeding of powder to the spray gun might be difficult, resulting in uneven flow.

4. Color matching and color uniformity appear to be more difficult to achieve than with liquid coatings.

5. Uniformity of coating thickness is sometimes difficult to maintain and thin films 25 to 51 µm (1 to 2 mils) are sometimes difficult to achieve.

6. Cure temperatures required for some powders are so high that damage may occur to solder joints or temperature-sensitive parts of the item being coated. High cure temperatures and long cure times require high fuel usage.

7. Powder coatings are especially susceptible to "Faraday cage" effects on sharp internal corners.

8. Airflow in the booth and the area prior to the oven must be carefully controlled to avoid dislodging the unbaked powder.

9. Because of the extra equipment requirements (multiple booths, powder handling and recovery systems), conversion of an existing liquid line could be very expensive.

Technological advances in powder coating have addressed most of these issues. These advances are discussed in this report.

The development that opened the way for powder coatings to become a major factor in the metal finishing industry was the introduction of the electrostatic spray process in the early 1960's. Electrostatic spraying of powders allowed the application of relatively thin layers of coatings and allowed powders to be used on parts not suitable for dipping in a fluidized bed. Thus, powder coatings became a viable alternative for decorative as well as functional coatings.

The emergence of powder coatings as an alternative to liquid decorative coatings led to the development of a variety of resin systems designed to meet the needs of the diverse user industries. Epoxy resins were used almost exclusively during the early years of powder coatings. Polyesters, polyester/urethanes, acrylics and (most recently) polyvinylidene fluoride, have now become equally accepted resin systems, with each having its own market share depending on the performance characteristics needed for the product. Powder coatings currently are available in virtually any color, gloss level, and texture.

Recent advances in application technology also have allowed powder coatings to be used in an increasing number of industries. Automated finishing systems that allow rapid and frequent color changes and extremely high powder utilization efficiencies have made powder an economical coating in many high-volume industries. (Powder utilization efficiency is defined as the percentage of purchased powder that is deposited on the work piece [including any powder that is recovered and resprayed].)

3.0 POWDER COATING MATERIALS

As recently as the early 1970's, the powder coating industry had a limited number of solid resin systems on which to base their powder formulations. Consequently, the ability of the powder coating industry to meet the diverse needs of the finishing industry was also limited. Because of the increased concerns over VOC emissions, worker safety, and energy costs during the 1970's, the popularity of powder coatings grew until powder coatings represented 8 percent of coating used in the finishing industry by 1987.[4] As the interest in powders grew, the industry responded with technological improvements in the resins and with many new resin systems. Powder coatings are now formulated in a virtually limitless range of colors, glosses, and textures. The two major types of powder coatings, thermoplastics and thermosettings, are discussed below.

3.1 THERMOPLASTIC POWDERS

A thermoplastic powder coating is one that melts and flows when heat is applied, but continues to have the same chemical composition once it cools and solidifies. Thermoplastic powders are based on high molecular weight polymers that exhibit excellent chemical resistance, toughness, and flexibility. These resins tend to be difficult to grind to the consistant fine particles needed for spray application, and they have a high melt viscosity. Consequently, they are used mostly in thicker film applications and are applied mainly by the fluidized bed application technique.

Typical thermoplastic powder coatings include: polyethylene powders, polypropylene powders, nylon powders, polyvinyl chloride powders, and thermoplastic polyester powders. Polyethylene powders were the first thermoplastic powder coatings to be offered. They provide excellent chemical resistance and outstanding electrical insulation properties. Polyethylene coatings are smooth, have a medium gloss, and good release properties that allow sticky materials to be cleaned from their surfaces. They are often used as coatings for laboratory equipment. Polypropylene powder produces a surface that is very inert and is often used in applications where the powder-coated part may be exposed to chemicals. Nylon powders offer excellent abrasion, wear and impact resistance, and a low coefficient of friction. They are commonly used as mechanical coatings for sliding and rotating bearing applications in appliances, farm equipment, and textile machinery. Polyvinyl chloride powders provide good durability as well as flexibility. An example of products coated with polyvinyl chloride powders is dishwasher racks. Thermoplastic polyesters offer good exterior durability and weatherability. They do not usually require a primer for good adhesion to most metals and are often used for outdoor metal furniture.

Thermoplastic powders are especially well suited for a thick coat capable of extreme performance requirements. Because of the inherent thickness of these coatings, they do not generally compete in the same market as liquid paints.

3.2 THERMOSETTING POWDERS

Thermosetting powder coatings are based on lower molecular weight solid resins. These coatings melt when exposed to heat, flow into a uniform thin layer, and chemically cross-link within themselves or with other reactive components to form a higher molecular weight reaction product. The final coating has a different chemical structure than the basic resin. These newly formed materials are heat stable and, after curing, do not soften back to the liquid phase when heated. Resins used in thermosetting powders can be ground into very fine particles necessary for spray application and for applying thin, paint-like coatings. Because these systems can produce a surface coating that is comparable to, and competes with, liquid coatings, most of the technological advancements in recent years have been with thermosetting powders.

Thermosetting powders are derived from three generic types of resins; epoxy, polyester, and acrylic. From these three basic resin types, five coating systems are derived. Epoxy resin-based systems are the most commonly used thermosetting powders and are available in a wide range of formulations. They are used for both functional and decorative coatings. Functional properties of epoxies include corrosion resistance and outstanding electrical insulation. Decorative epoxies offer attractive finishes that are tough, corrosion resistant, flexible, and have high impact strength. These lack ultraviolet resistance and therefore, are not recommended for outdoor use in direct sunlight because of their tendency to chalk and discolor. High chemical reactivity and the use of various classes of hardeners are opening a wide range of applications for epoxies. Recent developments allow epoxies to be cured at temperatures as low as 121°C (250°F) for 20 to 30 minutes, or even shorter times at higher temperatures.[5]

Epoxy-polyester hybrid coatings consist of epoxy and polyester resins. These coatings are used mainly for decorative applications. They are more resistant to chalking and yellowing than epoxies but have a lower surface hardness and are less resistant to solvents.

Polyester-TGIC coatings contain a polyester resin cross-linked with triglycidyl isocyanurate (TGIC) as a curing agent. These powders offer very good mechanical properties, impact strength, and weather resistance. They are resistant to chalking and are often used for such outdoor applications as patio furniture, lawn mowers, and aluminum extrusions and panels for large commercial buildings.

Acrylic-urethane coatings are formulated with acrylic resins crosslinked with blocked isocyanates. They have excellent color, gloss, hardness, weatherability, and chemical resistance. They have an excellent thin film appearance but are less flexible than polyesters.

Polyester-urethane coatings are formed by cross-linking polyester hydroxyl resin with blocked isocyanate hardeners. Polyurethanes have an outstanding thin film appearance and toughness as well as good weathering properties.

Tables 1a and 1b provide a summary of the key physical properties of the thermosetting powder coatings described above.

3.3 NEWLY DEVELOPED POWDERS

In addition to the coating types discussed above, new developments are occurring in the area of enamel powders. Conventional porcelain enamel, the glassy coating traditionally found on metal surfaces such as bathtubs and washing machines, is a vitreous inorganic coating bonded to metal by fusion. The porcelain enameling process involves the re-fusing of powdered glass on the metal surface. The powdered glass is formed by melting oxide components and then quenching to form enamel frits. The frits can be converted to wet sprayable suspensions or to dry enamel powders through ball-milling. The resultant enamel coating is heat stable to over 450°C (842°F), color fast, and scratch resistant.[7] Enamel

TABLE 1a. TYPICAL PROPERITES OF THERMOSETTING POWDER COATINGS[6]
(Metric Units)

Properties	Epoxy	Epoxy/polyester hybrid	TGIC polyester	Polyester urethane	Acrylic urethane
Application thickness	25-510 µm[a]	25-250 µm	25-250 µm	25-89 µm	25-89 µm
Cure cycle (metal temperatures)[b]	232°C-3 min 121°C-30 min	232°C-3 min 163°C- 25 min	204°C-7 min 154°C-20 min	204°C-7 min 177°C-17 min	204°C-7 min 182°C-25 min
Outdoor weatherability	Poor	Poor	Excellent	Very good	Very good
Pencil hardness	HB-5H	HB-2H	HB-2H	HB-3H	H-3H
Direct impact resistance, cm-kg[c]	92-184	92-184	92-184	92-184	23-69
Adhesion	Excellent	Excellent	Excellent	Excellent	Excellent
Chemical resistance	Excellent	Very good	Good	Good	Very good

[a]Thickness of up to 3,800 µm can be applied via multiple coats in a fluidized bed.
[b]Time and temperature can be reduced, by utilizing accelerated curing mechanisms, while maintaining the same general properties.
[c]Tested at a coating thickness of 51 µm.

TABLE 1b. TYPICAL PROPERITES OF THERMOSETTING POWDER COATINGS[6] (English Units)

Properties	Epoxy	Epoxy/polyester hybrid	TGIC polyester	Polyester urethane	Acrylic urethane
Application thickness	1-20 mils[a]	1-10 mils	1-10 mils	1-3.5 mils	1-3.5 mils
Cure cycle (metal temperatures)[b]	450°F-3 min 250°F-30 min	450°F-3 min 325°F- 25 min	400°F-7 min 310°F-20 min	400°F-7 min 350°F-17 min	400°F-7 min 360°F-25 min
Outdoor weatherability	Poor	Poor	Excellent	Very good	Very good
Pencil hardness	HB-5H	HB-2H	HB-2H	HB-3H	H-3H
Direct impact resistance, in-lb[c]	80-160	80-160	80-160	80-160	20-60
Adhesion	Excellent	Excellent	Excellent	Excellent	Excellent
Chemical resistance	Excellent	Very good	Good	Good	Very good

[a]Thickness of up to 150 mils can be applied via multiple coats in a fluidized bed.
[b]Time and temperature can be reduced, by utilizing accelerated curing mechanisms, while maintaining the same general properties.
[c]Tested at a coating thickness of 2.0 mil.

powders, a potential replacement for porcelain, are presently available in a limited range of colors and are relatively expensive to manufacture. Continued development is expected to make these coatings more competitive.

Polyvinylidene fluoride coatings have recently become available in powder form.[8] These fluoropolymer powder coatings have been available in Europe for about 2 years and are now sold in the United States. Because of their high resistance to weathering, industrial pollution, and corrosion, they are used for exterior aluminum extrusions and panels for architectural purposes.

Advancements in powder coating formulations are occurring at a rapid pace. Powders are being developed to compete with almost every market that has traditionally been held by liquid coatings. Architectural coatings (based on fluoropolymers), heat resistant coatings, metallic and textured coatings, low-temperature-cure powders, transparent and clear powders, and powders that can be used to color plastic parts by introducing the powder into the mold used for compression-molded plastic are in production use at this time. Most of these developments have occurred during the last 4 to 6 years and most powder coating manufacturers believe that the potential of powder coatings is only beginning to be realized.

4.0 POWDER COATING EQUIPMENT

The process of applying powder coatings to the surface of a product is, in general terms, identical to the traditional painting line used to apply liquid coatings. For powder coating or traditional painting, parts to be coated must first go through a pretreatment operation to ensure that the surface to be coated is clean and free of grease, dust, rust, etc. In many cases, the parts are also subjected to treatments such as pickling, phosphating, or chromatizing to improve the adhesion of the surface coating. After pretreatment, the parts enter the spray booth where the coating is applied with spray guns which are available in a wide variety of designs. When the coating has been applied, parts enter the curing oven to dry (in the case of traditional painting) and cure the coating.

The following sections present information about the types of equipment that are available for each step in the process outlined above. There are numerous manufacturers of powder coating equipment competing in today's market, and each has various products that are capable of performing the same basic task. The discussions presented here will be generic, in that manufacturers' brand names will not be used, and will focus on the spray application of powder to a metal substrate. (The curing ovens used with powder coating systems are similar to those used for liquid coating lines, and therefore, are not discussed here.)

4.1 PRETREATMENT

Although the substrate pretreatment process is critical to achieving an acceptable powder coated product, it is not a requirement that is unique to powders. All industrial surface coatings require a substrate that is clean and dry. There is a wide range of pretreatment requirements for powder coating as well as for liquid coating. The pretreatment process steps required are a function of the characteristics of the coating and the substrate and the end use of the product being coated. The pretreatment process is normally carried out in a series of dip tanks containing degreasing solvents, alkali cleaners, and rinses. Parts that are not easily dipped because of their size or shape may be cleaned with pressurized and/or heated sprays. An additional step that is used in many powder coating lines is a phosphating application that adds to the corrosion protection provided by the coating system and improves the adhesion of the coating to the substrate. When the parts have passed through all of the pretreatment steps, they are normally dried in a low temperature dry-off oven. After drying, the parts are ready to be sprayed with the powder coatings.

4.2 POWDER APPLICATION

The powder coating application process makes use of four basic types of equipment: the powder delivery system, the electrostatic spray gun system, the spray booth and overspray exhaust air system, and the powder recovery system.

4.2.1 Powder Delivery System

Powder is supplied to the spray gun by the powder delivery system. This system consists of a powder storage container or feed hopper, a pumping device that transports a stream of powder into hoses or feed tubes. A compressed air supply is often used as a "pump" because it aids in separating the powder into individual particles for easier transport. The powder delivery system is usually capable of supplying powder to one or several guns, often many feet from the powder supply. Delivery systems are available in many different sizes depending on the application, number of guns to be supplied, and volume of powder to be sprayed in a given time period. Recent improvements in powder delivery systems, coupled with better powder chemistries that reduce clumping of the powder, have made possible the delivery of a very consistent flow of particles to the spray gun. Agitating or fluidizing the powder in the feed hopper also helps prevent clogging or clumping of the powder prior to its entry into the transport lines.

4.2.2 Electrostatic Spray Guns

Electrostatic powder spray guns function to shape and direct the flow of powder; control the pattern size, shape and density of the powder as it is released from the gun; impart the electrostatic charge to the powder being sprayed; and control the deposition rate and location of powder on the target. All spray guns can be classified as either manual (hand-held) or automatic (mounted on a mechanical control arm). Both manual and automatic guns are manufactured by many different companies, with about 8 to 10 of these companies supplying the majority of these guns. Although the basic principles of operation of most guns are the same, there is an almost limitless variety in the style, size, and shape of spray guns. The type of gun chosen for a given coating line can, thus, be matched to the performance characteristics needed for the products being coated.

Traditionally, the electrostatic charge was imparted to the powder particles by a charging electrode located at the front of the spray gun. These "corona charging" guns generate a high-voltage, low-amperage electrostatic field between the electrode and the product being coated. The charge on the electrode is usually negative and can be controlled by the operator. Powder particles, passing through the ionized electrostatic field at the tip of the electrode become charged and are thus directed by the electrostatic field. The particles follow the field lines and air currents to the target workpiece and are deposited on the grounded surface of the workpiece. One drawback to the use of this type of gun is the difficulty of coating irregularly shaped parts that have recessed areas or cavities (that may be affected by Faraday cages) into which the electrostatic field cannot reach. Because the powder particles are directed by the presence of the field, insufficient powder may be deposited on surfaces outside the reach of the field.

A relatively recent innovation in electrostatic spray guns is the "tribo" electric gun. The powder particles in a tribo electric gun receive an electrostatic charge as a result of friction which occurs when powder particles contact a solid insulator or conductor inside the delivery hose and gun. The resulting charge is accomplished through the exchange of ions, or electrons, between the powder and the material used for construction of the supply hose and gun barrel. Because there is no actual electrostatic field, the charged particles of powder migrate toward the grounded workpiece and are free to deposit in an even layer over the entire surface of the workpiece. With the elimination of an electrostatic field, the Farraday cage effect can be prevented.

Other improvements that have been made to spray guns involve variations in the spray patterns to improve the coating transfer efficiency. Nozzles that resist clogging have been introduced. Spray guns with variable spray patterns are also available to allow the use of one gun on multiple parts of different configurations. Innovations in spray gun design have resulted in versatile and efficient guns with increased ease of operation. Manual coating is characterized by simple operation of both the equipment and controls. After a short period of training, personnel are capable of meeting the requirements for quality and uniformity of coating.

4.2.3 Powder Spray Booths

The primary function of the powder spray booth is to contain the spraying operation so that oversprayed powder cannot migrate into other work station areas. Several criteria must be met in selecting the appropriate spray booth for a given coating line. The entrance and exit openings must be properly sized to allow clearance of the largest product part. The airflows through the booth must be sufficient to channel all overspray to the collection device, but not so forceful that it disrupts the powder deposition and retention on the part. If one booth is to be used for multiple colors, the booth interior should be free of narrow crevices, seams, and irregular surfaces that would be difficult to clean. This is especially important if collected overspray is to be recycled. Airflow rates for powder spray booths are considerably lower than those for booths used for spraying solvent-based paint. The OSHA requires a minimum of 2.8 m^3/min (100 ft^3/min) of air movement through the booth in a system using solvent paint. During the cooler months, an air makeup differential of 8° to 14°C (15° to 25°F) is required to replace solvent-laden air that is exhausted through the booth. With powder coating, there is no makeup requirement for spray booth air movement.[9] Also, because there is no solvent loading of the air exhausted from a powder coating booth, the air can be recirculated within the plant.

4.2.4 Powder Recovery and Recycle System

In most manufacturers' designs, the powder recovery and recycle systems are an integral part of the spray booth. The fact that oversprayed powders can be collected and reused has led equipment manufacturers to develop systems designed especially to accommodate powder recovery. Traditional spray booths for liquid coatings have either dry or wet filter systems to remove overspray from the exhaust air stream. The collected paint is of no value and is therefore discarded. In this situation, color changes are accomplished by simply changing the spray gun from one paint delivery system to one filled with the next color to be applied. The resulting collected overspray is a combination of all the colors applied between filter replacements or booth cleanings.

For collected oversprayed powder to be of greatest value, it should be free of cross-contamination between colors. When a pellet of the wrong color adheres to the part being powder coated, it will not blend in with the color being used. There are numerous systems now available that are designed to accomplish this segregation of colors and still allow several colors to be applied in the same booth. Most of these systems make use of a moveable dry filter panel or a cartridge filter that can be dedicated to one color and can be removed easily when another color is needed. Color changes can then be accomplished by disconnecting the powder delivery system and purging the lines, cleaning the booth with compressed air or a rubber squeegee, exchanging the filter used for the previous color with the filter for the next color, and connecting the powder delivery system for the new color. Equipment manufacturers have made significant design improvements in spray booths that allow color changes to be made with a minimal downtime and allow the recovery of a high percentage of the overspray. As with spray guns, there are a large number of spray booth and powder recovery designs from which to choose, depending on the exact requirements of a given finishing system.

5.0 END USES OF POWDER COATINGS

As can be seen in Tables 2 through 4, the list of products that are being coated with powder coatings is extensive. There are certain market sectors where powder coatings have shown particularly strong growth rates. For example, powder coatings are being used extensively to produce linings on the inside of oil drilling pipe where severe pressures, high temperatures, and corrosive materials allow only a few types of coatings to be effective. The automotive industry is increasing its use of powder coatings for economic, quality, and ecological reasons. Powder is being used for the exterior body intermediate coat known as a "primer-surfacer", as well as for finishing of underhood components. Parts that require extra protection as well as a decorative finish are increasingly being powder coated. Wheels, bumpers, shock absorbers, mirror frames, oil filters, engine blocks, battery trays and coil springs are some of the many automotive products being powder coated. Clear powder coatings, as an alternative to solvent-borne clear coats, for use over automotive exterior basecoats, are being evaluated.

The appliance industry is the largest single market sector for thermosetting powders accounting for about 30 percent of powder sales.[12] As porcelain-replacement powders become further developed, the appliance market will continue to grow. Current uses include range housings, freezer cabinets, dryer drums, and washer tops and lids.

Outdoor furniture, farm implements, and lawn and garden equipment are also major markets for powder coatings. The general metal finishing industry accounts for over 40 percent of thermoset powder sales.[12] (The general metal finishing industry is defined here as including all metal finishing industries <u>except</u> for the automotive, appliance, and architectural finishing industries.)

Potential large market areas for powders are the aluminum extrusion and architectural products markets. The recent advances in polyester-TGIC and fluoropolymer powders have enabled powder coatings to compete with liquid architectural coatings in durability, weatherability, and resistance to fading. Some of these coatings have been in use in Europe since 1976 and are now being introduced into this country.

TABLE 2. END USES FOR EPOXY AND HYBRID POWDER COATINGS[10]

Hardware and consumer goods

- Bunk beds
- Kitchen blenders
- Kitchen mixers
- Crock pots
- Desk lamps
- Pens
- Vacuum cleaners
- Speaker frames
- Barbecue grills
- Microphones
- Glass containers
- Thumb tacks
- Water heaters
- Faucets
- Tape player doors
- Space heaters
- Can openers
- Gas meters
- Curtain hardware
- Floor polishers
- Cigarette lighters
- Wine racks
- Closet hardware
- Chair frames and bases
- Safe deposit boxes
- Archery bows
- Steel toys
- Wire baskets
- Bed frames
- Fishing reels
- Book ends
- Waste baskets
- Christmas tree stands
- Notebook spiral wires
- Lawn and garden edgers/tools
- Luggage frames
- Desk accessories

Electronic/electrical

- Electrical motor stators
- Electric motor rotors
- Switch boxes
- Electric boxes
- Thresholds
- Transformers
- Electric meters
- Electric connectors
- Electronic instrument housing
- Electronic instrument cabinets
- Computer room floor systems

Automotive

- Steering wheels
- Air conditioning components
- Interior trim parts
- Engine blocks
- Oil filters
- Shock absorbers
- Motor windings
- Motor housings
- Motor mounts
- Coil springs
- Valve covers
- Brake shoe frames
- Intake manifolds
- Truck light housings
- Truck seat frames
- Seat bases
- Seat belt latches
- Seat belt mounts
- Auto jacks
- Jack stands

Functional and specified

- Internal and external pipe
- Gas riser pipe
- Reinforcing bar for concrete
- Cable for prestressed concrete
- Rebar saddles
- Structural steel
- Conduit
- Military projectiles
- Military tent hardware

General industrial

- Medical furniture
- Steel carts
- Power tools
- Office furniture
- Two-wheel hand trucks
- Computer frames/cabinet
- Copier cabinets
- Storage cabinets
- Retail store racks
- Retail store shelving
- Refrigerator shelving
- Air cleaners
- Lighting fixtures
- Folding furniture
- Water pumps
- Steel drums
- Scaffolding
- Fertilizer spreaders
- Wire cloth/screen
- Industrial mixers
- Alarm system bells
- Propane tanks
- Thickness gauges
- Grain storage systems
- Filing cabinets
- Lab cabinets/furniture
- Drawer suspension units
- Warehouse rack systems
- Lug wrenches
- Tool boxes and chests
- Air compressors
- Camp stoves
- Polished hardware
- Refrigerator liners
- Hand tools
- Grapevine support poles
- Pressure reserve tanks
- Friction disc binders
- Electrostatic spray equipment
- Office partitions
- Escalator steps

TABLE 3. END USES FOR TGIC-POLYESTERS AND ALIPHATIC POLYESTER-URETHANE POWDER COATINGS[11]

Hardware consumer goods	Automotive	General industrial
Barbecue grills	Wheels	Outdoor patio furniture
Mailboxes	Automotive trim	Lawn mowers
Screen doors	Truck tool boxes	Tractors
Ice machines	Instrument bulbs	Motorcycle frames
Water cans	Windshield wipers	Bicycle frames
Snowblowers	Bumpers	Highway signs
Antennas	Roll bars	Fence wire and poles
Microwave ovens	Mirror brackets	Extruded aluminum doors
Yardlights		Extruded aluminum windows
Air conditioner cabinets		Guardrail
Flash bulbs		Golf carts
Shower curtain hardware		Building facade panels
Recreational vehicle hardware		Satellite dishes
		Marine motors and drives
Playground equipment		Vending machines
garden tillers		Roofing tile
Gas cans		Irrigation pipe
Battery cases		Refrigerator skins
Screen		Propane tanks
Wagons		Water tanks
Luggage frames		Fire extinguishers
Pool hardware		Light poles
Laundry appliances		Electric boxes
Chain saws		Transformers
		Junction boxes
		Gas pumps
		Sonar equipment
		Parking meters

TABLE 4. END USES FOR AROMATIC URETHANE AND ACRYLIC POWDER COATINGS[11]

Aromatic urethanes	Acrylics
Interior metal furniture	Wheels
Industrial racking systems	Ranges
Primers for light poles	Garden equipment
Residential aluminum window and door frames	Clothes dryers
Low cost outdoor furniture	Automotive topcoat
Store front window and door frames	
Office equipment	

The Powder Coating Institute estimates that powder coating use in North America will grow from about 57×10^6 kg (125×10^6 lb) in 1989 to about 102×10^6 kg (225×10^6 lb) in 1993. During this period, the projected annual growth rate for selected market areas is; automotive--19 percent, appliance--12 percent, architectural--40 percent, and general metal finishing--21 percent.[12]

6.0 ECONOMIC ADVANTAGES OF POWDER COATINGS VS. LIQUID COATINGS

When comparing powder coating systems with liquid coating systems, several significant advantages are readily apparent. There are also other, seemingly less significant advantages that, when viewed collectively, contribute substantial cost savings. This section discusses the economic advantages of powder vs. liquid coating systems in the following areas: energy savings, labor savings, greater operating efficiencies, and environmental benefits. A detailed cost comparison of powder vs. liquid coating systems also is provided at the end of this section.

6.1 ENERGY SAVINGS

There are two significant advantages of powder coating which contribute to lower energy costs as compared to liquid coating. The first advantage is that the air used to exhaust the powder spray booth can be recirculated directly to the plant since the powder does not contain volatile compounds at room temperature. This eliminates the cost of heating or cooling the makeup air that occurs when air is exhausted from the plant, a particular advantage where extreme weather conditions are prevalent. The second advantage is the lower cost of heating the curing oven. Ovens that cure solvent-based coatings must heat and exhaust huge volumes of air to insure that the solvent fumes do not approach the lower explosive limit. Because powder coatings have no solvent content, the airflow in the curing ovens is considerably lower.

6.2 LABOR SAVINGS

The required operator skills and training for operation of a powder coating system are less than those needed for a liquid system and considerably less than those required for an electrocoat system. In addition, powder is "ready to use" when purchased and does not require labor for mixing with solvents or catalysts as is necessary with liquid coatings. Also, there are no critical operating parameters to monitor such as viscosity and pH (which are monitored in many liquid coating systems) or percent solids, specific resistance, and binder to pigment ratio, (which all must be monitored in electrocoating systems).

6.3 GREATER OPERATING EFFICIENCY

Because no drying or flash-off time is required, and the powder application system allows parts to be racked closer together on a conveyor, more parts can pass through the production line resulting in greater operating efficiency and lower unit costs. Despite the greater line speeds, powder coating systems generally have significantly lower reject rates than do liquid coating systems. One reason for this lower reject rate is that it is virtually impossible to have drips, runs, or sags when applying powder coatings. In addition, if a powder-coated part is found to be improperly sprayed (prior to curing) the powder coating can be blown off with an air gun and the bare part recoated. Another factor which contributes to a greater operating efficiency is the fact that oversprayed powder can be reclaimed and thus, reused.

6.4 ENVIRONMENTAL BENEFITS

As regulatory agencies further limit the amount of solvent that can be emitted, many plants that use liquid coating systems are finding it necessary to purchase VOC control equipment, such as afterburners, to incinerate the emitted solvents. Another environmental problem faced by liquid coating users is the increased difficulty and cost of disposing of hazardous waste generated by liquid coating operations. With a dry powder coating system, there is no liquid paint sludge to send to a disposal site.

6.5 COST COMPARISON: POWDER VS. LIQUIDS

A detailed cost comparison between powder and liquid coating systems is provided below. The three types of liquid coating systems included in the comparison are: conventional solvent, water-borne, and high solids. Total capital and annual operating costs are provided for each of the four coating systems. Material costs represent two-thirds or more of the total annual operating costs, and therefore, detailed material costs are also provided.

6.5.1 Total Capital Costs

Capital costs for four different coating systems (i.e., conventional solvent, water-borne, higher solids, and powder) are presented in Table 5. The two sources of these costs are a reprint from Products Finishing entitled "Powder Coating Today" (1987), and an earlier

TABLE 5. TOTAL CAPITAL COSTS

Type of coating	Equipment	(Ref.)	Installed cost, $
Conventional solvent	Two waterwash booths	(13)	150,000
	One dry filter booth	(14)	--
	Four automatic guns		
	Two manual guns		
	Two reciprocators		
	Paint heating equipment		
	Solvent recovery or incineration equipment		
Water-borne	Two waterwash booths	(13)	110,000
	One dry filter booth	(14)	108,000
	Four automatic electrostatic guns		
	Two reciprocators		
	Safety interlocks and stand-offs		
Higher-solids	Two waterwash booths	(13)	110,000
	One dry filter booth	(14)	110,000
	Four automatic electrostatic guns		
	Two manual electrostatic guns		
	Paint heating equipment		
Powder	Two powder spray booths	(13)	120,000
	Four automatic electrostatic guns	(14)	150,000
	One manual electrostatic gun		
	Two reciprocators or gun movers		
	Two powder recovery systems with automatic recycle		

publication entitled "VOC Emission Reductions and Other Benefits Achieved by Major Powder Coating Operations" (1984).[13,14] Both of these sources contain information generated by the Powder Coating Institute. The "Powder Coating Today" article is actually an updated version of the 1984 publication. Cost estimates cited in these two sources were used because they are consistent with cost estimates provided by powder coating equipment suppliers in response to questionnaires submitted by the Agency. The capital costs from each literature source are similar with one notable exception--the cost of the same powder coating equipment purchased in 1983 ($150,000) has decreased to $120,000 by 1986. (Note: costs listed in the two references are based on the year prior to the publication year.) In addition, the "Powder Coating Today" article included the cost of solvent recovery or incineration equipment in the total capital cost for the conventional solvent coating system. These costs were considered reasonable based on EPA experience with paint application and control equipment. No costs were provided in the earlier reference for a conventional solvent coating system.

The capital costs presented in Table 5 are based on the following assumptions:

1. The parts to be coated are formed sheet steel parts that are of average complexity;
2. Both sides of each part are automatically coated and touched up manually;
3. Two colors are used;
4. 1.1×10^6 m^2 (12×10^6 ft^2) of parts are surface coated per year;
5. Conveyor speed is 4.6 m/min (15 ft/min);
6. The installation is new and has automatic equipment to more efficiently apply either a conventional solvent, water-borne, high solids, or powder coating;
7. A solvent recovery system or incinerator (cost: $40,000) is included in the system applying conventional solvent coatings to satisfy emission regulations; and
8. The same pretreatment systems and ovens can be used with each system with little or no modification.

6.5.2 Material Costs

Materials costs for the four coating systems are presented in Tables 6a and 6b; these costs are based on six different sources of information. Each source calculated the material costs in a similar manner with the higher solids system generally having a lower material cost. Cost information that was obtained from the powder coating surveys supported the cost information that was found in the literature and presented in Tables 6a, 6b, 7a, and 7b. The most complete and up-to-date source of cost information is the "Powder Coating Today" article (Reference Nos. 16 and 21 in Tables 6a, 6b, 7a, and 7b). Costs obtained from other sources were included in Tables 6a, 6b, 7a, and 7b for comparison purposes. (Note that in Table 6a and 6b, the columns for powder costs are in terms of kg (lb) rather than ℓ (gal).

The material costs presented in Reference Nos. 16 and 21 are based on 1986 data and the following assumptions:

1. The conventional solvent coating is a 38 percent (by volume) solids acrylic or alkyd baking enamel applied at an average thickness of 30 µm (1.2 mils);

2. The water-borne coating is a 35 percent (by volume) solids acrylic latex applied at an average thickness of 30 µm (1.2 mils);

3. The higher solids coating is a high-performance acrylic or polyester-type coating applied at an average thickness of 30 µm (1.2 mils); and

4. The powder coating is a high-quality polyester-urethane type applied an average thickness of 30 µm (1.2 mils).

6.5.3 Total Annual Operating Costs

The total annual operating costs for the four coating systems are presented in Tables 7a and 7b. These costs are based on five different sources of information (note that reference No. 18 in Table 7 did not provide operating costs). Operating costs were not provided by those companies that responded to the powder coating surveys, and therefore, it was not possible to make a comparison between actual plant-specific operating costs and those operating costs supplied in the literature.

All literature references and survey respondent information used to create Tables 7a and 7b identified powder coating as having the lowest

TABLE 6a. MATERIAL COSTS, DOLLARS
(Metric Units)

Item	(Ref.)	Conventional solvent	Water-borne	Higher solids	Powder[a]
Coating cost, $/ℓ	(15)	--	--	5.55	5.30
	(16)	2.70	2.90	3.90	4.65
	(14)	3.15	2.90	4.50	5.10
	(17)	2.30	--	--	4.75
	(18)	--	--	--	4.75
	(19)	3.15	2.90	4.50	5.10
Volume solids, percent	(15)	--	--	--	--
	(16)	38	35	63	98
	(14)	47	35	63	98
	(17)	43	--	--	98
	(18)	--	--	--	100
	(19)	47	35	63	100
Reducing agent cost, $/ℓ	(15)	--	N/A	N/A	N/A
	(16)	0.40	N/A	N/A	N/A
	(14)	--	N/A	N/A	N/A
	(17)	0.40	N/A	N/A	N/A
	(18)	--	N/A	N/A	N/A
	(19)	0.40	N/A	N/A	N/A
Mix ratio (coating: reducing agent)	(15)	--	N/A	N/A	N/A
	(16)	4:1	N/A	N/A	N/A
	(14)	3:1	N/A	N/A	N/A
	(17)	5:2	N/A	N/A	N/A
	(18)	--	N/A	N/A	N/A
	(19)	3:1	N/A	N/A	N/A
Mixed coating costs, $/ℓ	(15)	--	--	5.55	5.30
	(16)	2.26	2.90	3.90	4.65
	(14)	2.48	2.90	4.50	5.10
	(17)	1.77	--	--	--
	(18)	2.38	--	3.70	--
	(19)	2.48	2.90	4.50	5.10
Volume solids at spray viscosity, percent	(15)	--	--	54	98
	(16)	30.5	35	63	98
	(14)	35	35	63	98
	(17)	31	--	--	98
	(18)	35	--	55	100
	(19)	35	35	63	100
Specific gravity	(15)	--	--	--	--
	(16)	--	--	--	1.6
	(14)	--	--	--	1.6
	(17)	--	--	--	1.6
	(18)	--	--	--	1.5
	(19)	--	--	--	1.6
Theoretical coverage $m^2/ℓ/\mu m$	(15)	--	--	540	614
	(16)	305	350	630	624
	(14)	350	350	630	614
	(17)	310	--	--	614
	(18)	--	--	--	--
	(19)	--	--	--	--

[a]Substitute kg for ℓ in all calculations

(continued)

TABLE 6a. (continued)

Item	(Ref.)	Conventional solvent	Water-borne	Higher solids	Powder[a]
Dry film thickness, μm[b]	(15)	--	--	30	30
	(16)	30	30	30	30
	(14)	30	30	30	30
	(17)	30	--	--	30
	(18)	30	--	30	30
	(19)	30	30	30	30
Transfer efficiency, percent[c d]	(15)	--	--	80	95
	(16)	50	55	60	96
	(14)	60	60	70	97
	(17)	40	--	--	97
	(18)	50	--	80	98
	(19)	60	60	70	97
Actual coverage, m^2/ℓ	(15)	--	--	14.1	19.0
	(16)	5.00	6.30	12.4	19.7
	(14)	6.86	6.86	14.5	19.5
	(17)	4.07	--	--	19.5
	(18)	5.71	--	14.4	21.3
	(19)	6.86	6.86	14.4	19.5
Applied cost, $\$/m^2$	(15)	--	--	0.3918	0.2777
	(16)	0.4510	0.4607	0.3154	0.2357
	(14)	0.3606	0.4220	0.3100	0.2605
	(17)	0.4338	--	--	0.2433
	(18)	0.4155	--	0.2562	0.2228
	(19)	0.3606	0.4220	0.3111	0.2605
Annual cost to coat 1.1×10^6 m^2, $	(15)	--	--	436,800	309,600
	(16)	502,800	513,600	351,600	262,800
	(14)	402,000	470,400	345,600	290,400
	(17)	483,600	320,400	310,800	271,200
	(18)	463,200	--	285,600	248,400
	(19)	402,000	470,400	346,800	290,400

[a] Substitute kg for ℓ in all calculations.
[b] Coating thicknesses were normalized to put costs on a common basis.
[c] Transfer efficiency is the ratio of coating that adheres to the part and the coating that is sprayed through the gun. In the case of powder coating, where powder is recovered and recycled, the term "utilization efficiency" is used.
[d] The transfer efficiencies used by the sources for this table are somewhat high. This may cause the costs of the nonpowder alternatives presented here to appear lower than they actually would be.

TABLE 6a. (continued)

Item	(Ref.)	Conventional solvent	Water-borne	Higher solids	Powder[a]
Dry film thickness, μm[b]	(15)	--	--	30	30
	(16)	30	30	30	30
	(14)	30	30	30	30
	(17)	30	--	--	30
	(18)	30	--	30	30
	(19)	30	30	30	30
Transfer efficiency, percent[c d]	(15)	--	--	80	95
	(16)	50	55	60	96
	(14)	60	60	70	97
	(17)	40	--	--	97
	(18)	50	--	80	98
	(19)	60	60	70	97
Actual coverage, m^2/ℓ	(15)	--	--	14.1	19.0
	(16)	5.00	6.30	12.4	19.7
	(14)	6.86	6.86	14.5	19.5
	(17)	4.07	--	--	19.5
	(18)	5.71	--	14.4	21.3
	(19)	6.86	6.86	14.4	19.5
Applied cost, $\$/m^2$	(15)	--	--	0.3918	0.2777
	(16)	0.4510	0.4607	0.3154	0.2357
	(14)	0.3606	0.4220	0.3100	0.2605
	(17)	0.4338	--	--	0.2433
	(18)	0.4155	--	0.2562	0.2228
	(19)	0.3606	0.4220	0.3111	0.2605
Annual cost to coat 1.1×10^6 m^2, \$	(15)	--	--	436,800	309,600
	(16)	502,800	513,600	351,600	262,800
	(14)	402,000	470,400	345,600	290,400
	(17)	483,600	320,400	310,800	271,200
	(18)	463,200	--	285,600	248,400
	(19)	402,000	470,400	346,800	290,400

[a]Substitute kg for ℓ in all calculations.
[b]Coating thicknesses were normalized to put costs on a common basis.
[c]Transfer efficiency is the ratio of coating that adheres to the part and the coating that is sprayed through the gun. In the case of powder coating, where powder is recovered and recycled, the term "utilization efficiency" is used.
[d]The transfer efficiencies used by the sources for this table are somewhat high. This may cause the costs of the nonpowder alternatives presented here to appear lower than they actually would be. Traditionally, high transfer efficiency has been of importance to a coating facility for several reasons. The value added to most products by the coating is small and the cost of the coating is usually almost negligible in comparison to labor and equipment costs. One major automobile manufacturer represented its transfer efficiency at almost twice the 30 percent that was subsequently determined by tests. Modern reciprocating systems and highly roboticized systems can operate poorly, as tests of state of the art equipment demonstrated in the mid-1980's. A new auto assembly line with reciprocators was found to be operating at 15 percent transfer efficiency and a second plant with a state of the art coating line was found to achieve less than 20 percent. In fact, the EPA authority on transfer efficiency has been quoted "never underestimate people's inability to recognize how low their transfer efficiency really is."

TABLE 6b. MATERIAL COSTS, DOLLARS (English Units)

Item	(Ref.)	Conventional solvent	Water-borne	Higher solids	Powder[a]
Coating cost, $/gal	(15)	--	--	21.00	2.40
	(16)	10.30	11.00	14.80	2.10
	(14)	12.00	11.00	17.00	2.30
	(17)	8.75	--	--	2.15
	(18)	--	--	--	2.15
	(19)	12.00	11.00	17.00	2.30
Volume solids, percent	(15)	--	--	--	--
	(16)	38	35	63	98
	(14)	47	35	63	98
	(17)	43	--	--	98
	(18)	--	--	--	100
	(19)	47	35	63	100
Reducing agent cost, $/gal	(15)	--	N/A	N/A	N/A
	(16)	1.50	N/A	N/A	N/A
	(14)	--	N/A	N/A	N/A
	(17)	1.55	N/A	N/A	N/A
	(18)	--	N/A	N/A	N/A
	(19)	1.50	N/A	N/A	N/A
Mix ratio (coating: reducing agent)	(15)	--	N/A	N/A	N/A
	(16)	4:1	N/A	N/A	N/A
	(14)	3:1	N/A	N/A	N/A
	(17)	5:2	N/A	N/A	N/A
	(18)	--	N/A	N/A	N/A
	(19)	3:1	N/A	N/A	N/A
Mixed coating costs, $/gal	(15)	--	--	21.00	2.40
	(16)	8.54	11.00	14.80	2.10
	(14)	9.38	11.00	17.00	2.30
	(17)	6.69	--	--	--
	(18)	9.00	--	14.00	--
	(19)	9.38	11.00	17.00	2.30
Volume solids at spray viscosity, percent	(15)	--	--	54	98
	(16)	30.5	35	63	98
	(14)	35	35	63	98
	(17)	31	--	--	98
	(18)	35	--	55	100
	(19)	35	35	63	100
Specific gravity	(15)	--	--	--	--
	(16)	--	--	--	1.6
	(14)	--	--	--	1.6
	(17)	--	--	--	1.6
	(18)	--	--	--	1.5
	(19)	--	--	--	1.6
Theoretical coverage ft^2/gal/mil	(15)	--	--	866	118
	(16)	489	561	1,010	120
	(14)	561	561	1,011	118
	(17)	497	--	--	118
	(18)	--	--	--	--
	(19)	--	--	--	--

[a]Substitute pounds for gallons in all calculations

(continued)

TABLE 6b. (continued)

Item	(Ref.)	Conventional solvent	Water-borne	Higher solids	Powder[a]
Dry film thickness, mils[b]	(15)	--	--	1.2	1.2
	(16)	1.2	1.2	1.2	1.2
	(14)	1.2	1.2	1.2	1.2
	(17)	1.2	--	--	1.2
	(18)	1.2	--	1.2	1.2
	(19)	1.2	1.2	1.2	1.2
Transfer efficiency, percent[c d]	(15)	--	--	80	95
	(16)	50	55	60	96
	(14)	60	60	70	97
	(17)	40	--	--	97
	(18)	50	--	80	98
	(19)	60	60	70	97
Actual coverage, ft^2/gal	(15)	--	--	577	93
	(16)	204	257	505	96
	(14)	280	280	590	95
	(17)	166	--	--	95
	(18)	233	--	588	104
	(19)	280	280	588	95
Applied cost, $/$ft^2$	(15)	--	--	0.0364	0.0258
	(16)	0.0419	0.0428	0.0293	0.0219
	(14)	0.0335	0.0392	0.0288	0.0242
	(17)	0.0403	--	--	0.0226
	(18)	0.0386	--	0.0238	0.0207
	(19)	0.0335	0.0392	0.0289	0.0242
Annual cost to coat 12×10^6 ft^2, $	(15)	--	--	436,800	309,600
	(16)	502,800	513,600	351,600	262,800
	(14)	402,000	470,400	345,600	290,400
	(17)	483,600	320,400	310,800	271,200
	(18)	463,200	--	285,600	248,400
	(19)	402,000	470,400	346,800	290,400

[a] Substitute pounds for gallons in all calculations.

[b] Coating thicknesses were normalized to put costs on a common basis.

[c] Transfer efficiency is the ratio of coating that adheres to the part and the coating that is sprayed through the gun. In the case of powder coating, where powder is recovered and recycled, the term "utilization efficiency" is used.

[d] The transfer efficiencies used by the sources for this table are somewhat high. This may cause the costs of the nonpowder alternatives presented here to appear lower than they actually would be. Traditionally, high transfer efficiency has been of importance to a coating facility for several reasons. The value added to most products by the coating is small and the cost of the coating is usually almost negligible in comparison to labor and equipment costs. One major automobile manufacturer represented its transfer efficiency at almost twice the 30 percent that was subsequently determined by tests. Modern reciprocating systems and highly roboticized systems can operate poorly, as tests of state of the art equipment demonstrated in the mid-1980's. A new auto assembly line with reciprocators was found to be operating at 15 percent transfer efficiency and a second plant with a state of the art coating line was found to achieve less than 20 percent. In fact, the EPA authority on transfer efficiency has been quoted "never underestimate people's inability to recognize how low their transfer efficiency really is."

TABLE 7a. TOTAL ANNUAL OPERATING COSTS, DOLLARS[a] (Metric Units)

Item	(Ref.)	Conventional solvent	Water-borne	High solids	Powder
Material, $/yr	(20)	--	--	436,800	309,600
	(21)	502,800	513,600	351,600	262,800
	(14)	402,000	470,400	345,600	290,400
	(17)	483,600	320,400	310,800	271,200
	(18)	--	--	--	--
	(19)	402,000	470,400	346,800	290,400
Labor and cleanup, $/yr	(20)	--	--	111,440	85,200
	(21)	141,900	141,900	141,900	82,900
	(14)	132,100	132,100	128,400	75,600
	(17)	118,000	126,200	126,200	72,000
	(18)	--	--	--	--
	(19)	121,300	121,300	121,300	74,540
Maintenance, $/yr	(20)	--	--	11,840	5,060
	(21)	24,000	24,000	24,000	16,000
	(14)	18,000	18,000	18,000	10,000
	(17)	14,500	18,800	18,800	9,000
	(18)	--	--	--	--
	(19)	--	--	--	--
Energy, $/yr	(20)	--	--	39,460	35,800
	(21)	30,500	32,514	28,300	16,400
	(14)	29,100	31,100	27,100	15,700
	(17)	23,200	22,600	19,700	11,400
	(18)	--	--	--	--
	(19)	14,640	11,140	11,200	7,420
Sludge disposal, $/h	(20)	--	--	8,460	N/A
	(21)	48,758	40,750	31,500	700
	(14)	10,800	10,800	7,100	1,100
	(17)	13,480	--	--	1,000
	(18)	--	--	--	--
	(19)	11,280	11,280	11,280	1,080
Filter replacement, $/h	(20)	--	--	1,920	N/A
	(21)	--	--	--	--
	(14)	--	--	--	--
	(17)	2,500	--	--	500
	(18)	--	--	--	--
	(19)	3,000	3,000	3,000	840
Amortization, 10-yr straight line, $	(20)	--	--	--	--
	(21)	15,000	11,000	11,000	12,000
	(14)	--	10,800	11,000	15,000
	(17)	--	9,800	10,000	15,000
	(18)	--	--	--	--
	(19)	--	--	--	--
Total annual cost, $[b]	(20)	--	--	609,920	435,660
	(21)	762,960	763,760	588,300	391,400
	(14)	592,000	673,200	537,200	407,800
	(17)	655,280	497,800	485,500	380,100
	(18)	--	--	--	--
	(19)	552,220	617,120	493,580	374,280
Applied cost, $/m^2	(20)	--	--	0.5468	0.3907
	(21)	0.6846	0.6846	0.5274	0.3509
	(14)	0.5307	0.6039	0.4822	0.3660
	(17)	0.5877	0.4467	0.4349	0.3412
	(18)	--	--	--	--
	(19)	0.4952	0.5533	0.4424	0.3358

[a]Assumed 2,000 operating hours per year.
[b]Numbers have been rounded.

TABLE 7b. TOTAL ANNUAL OPERATING COSTS, DOLLARS[a] (English Units)

Item	(Ref.)	Conventional solvent	Water-borne	High solids	Powder
Material, $/yr	(20)	--	--	436,800	309,600
	(21)	502,800	513,600	351,600	262,800
	(14)	402,000	470,400	345,600	290,400
	(17)	483,600	320,400	310,800	271,200
	(18)	--	--	--	--
	(19)	402,000	470,400	346,800	290,400
Labor and cleanup, $/yr	(20)	--	--	111,440	85,200
	(21)	141,900	141,900	141,900	82,900
	(14)	132,100	132,100	128,400	75,600
	(17)	118,000	126,200	126,200	72,000
	(18)	--	--	--	--
	(19)	121,300	121,300	121,300	74,540
Maintenance, $/yr	(20)	--	--	11,840	5,060
	(21)	24,000	24,000	24,000	16,000
	(14)	18,000	18,000	18,000	10,000
	(17)	14,500	18,800	18,800	9,000
	(18)	--	--	--	--
	(19)	--	--	--	--
Energy, $/yr	(20)	--	--	39,460	35,800
	(21)	30,500	32,514	28,300	16,400
	(14)	29,100	31,100	27,100	15,700
	(17)	23,200	22,600	19,700	11,400
	(18)	--	--	--	--
	(19)	14,640	11,140	11,200	7,420
Sludge disposal, $/h	(20)	--	--	8,460	N/A
	(21)	48,758	40,750	31,500	700
	(14)	10,800	10,800	7,100	1,100
	(17)	13,480	--	--	1,000
	(18)	--	--	--	--
	(19)	11,280	11,280	11,280	1,080
Filter replacement, $/h	(20)	--	--	1,920	N/A
	(21)	--	--	--	--
	(14)	--	--	--	--
	(17)	2,500	--	--	500
	(18)	--	--	--	--
	(19)	3,000	3,000	3,000	840
Amortization, 10-yr straight line, $	(20)	--	--	--	--
	(21)	15,000	11,000	11,000	12,000
	(14)	--	10,800	11,000	15,000
	(17)	--	9,800	10,000	15,000
	(18)	--	--	--	--
	(19)	--	--	--	--
Total annual cost, $[b]	(20)	--	--	609,920	435,660
	(21)	762,960	763,760	588,300	391,400
	(14)	592,000	673,200	537,200	407,800
	(17)	655,280	497,800	485,500	380,100
	(18)	--	--	--	--
	(19)	552,220	617,120	493,580	374,280
Applied cost, $/ft^2	(20)	--	--	0.0508	0.0363
	(21)	0.0636	0.0636	0.0490	0.0326
	(14)	0.0493	0.0561	0.0448	0.0340
	(17)	0.0546	0.0415	0.0404	0.0317
	(18)	--	--	--	--
	(19)	0.0460	0.0514	0.0411	0.0312

[a] Assumed 2,000 operating hours per year.
[b] Numbers have been rounded.

annual operating costs. The highest operating costs were associated with the conventional solvent or water-borne coating systems. Labor, cleanup, maintenance, energy, and waste disposal costs were lowest for the powder coating system, which contributed to overall lower annual operating costs. The "Powder Coating Today" article (Reference No. 21) again provided the most complete and up-to-date information on annual operating costs. The operating costs presented in that brochure are based on 1986 data and the following assumptions:

1. Labor costs $12.00 per hour and supervision costs $15.20 per hour
2. Cost of electricity = $0.076 per kWh
3. Cost of natural gas = $162 per thousand m^3 ($4.60 per thousand ft^3), and
4. Removal of nonhazardous paint sludge was estimated to cost $255 per 208 ℓ (55-gal) drum.

As shown in Tables 7a and 7b, material costs represent about 2/3 or more of the total operating costs of a coating line. The material costs for any of the four coating systems could be less than those shown if either the volume solids and/or transfer efficiency is increased and/or the film thickness lowered. For example, if the transfer efficiency for the higher solids case (Reference 16, Tables 6a and 6b) is increased from 60 to 70 percent, the annual cost to coat (material cost) will drop from $351,600 to $301,400. The annual cost to coat = [(coating thickness) (mixed coating cost)(surface area coated per year)]+[(theoretical coverage)(utilization efficiency)]. Likewise, if the powder coating thickness in Reference 16 (Tables 6a and 6b) were decreased from 30 to 25 µm (1.2 to 1.0 mils), the material cost would drop from $262,800 to $219,000.

It should be noted that, currently, the minimum consistent powder coating film thickness is in the range of 25 µm (1 mil). If the product to be coated requires less film thickness, the cost of applying more powder than necessary should be considered when comparing powder coating costs to costs of alternative coatings.

7.0 CONCLUSIONS

The use of powder coatings as functional and decorative industrial finishes is increasing at a dramatic rate. At an annual rate of nearly 20 percent, powder coating is the fastest-growing finishing technology on the market.[1] (However, the initial sales volumes of powder coatings were much lower than those of liquid coatings in the same time period. Therefore, a direct comparison of growth rates is misleading.) Significant improvements in the powder coatings, the application systems, and the powder recovery systems have made powder one of the most cost-effective finishing systems available. In addition, because powder coatings contain no solvents and usually are applied in dry filter booths, air and water pollution problems are eliminated in well-operated facilities. Energy costs attributable to heating and ventilation are significantly reduced.

The use of powder coatings as an alternative to liquid, solvent-based coatings results in a significant decrease in VOC emissions. Powder coatings can be characterized as the lowest VOC-content coating among the compliance options available to industrial finishers. Tables 8a and 8b present a VOC reduction comparison of the four coating systems. The values in this table were based on the average of the values presented in Tables 6a and 6b. As shown in Tables 8a and 8b, VOC emissions for powder coating systems are substantially lower than those for the liquid coating alternatives. Emissions are 98.4 percent lower than those shown for conventional solvent coating systems, 98.1 percent lower than those shown for higher solids coating systems, and 97.7 percent lower than for waterborne systems.

Most of the drawbacks to the use of powders that existed a few years ago (see Section 2.0) have been eliminated. New resin systems allow powders to meet the coating specifications for almost any product. Thin films (from less than 25 μm [1 mil] to about 76 μm [3 mils]) in a very wide range of colors, glosses, and textures can be applied at powder utilization rates of 95 percent or higher.[22] Many of these coatings can be cured at temperatures of 121°C to 177°C (250°F to 350°F) in 15 to 30 minutes.[6] Powder manufacturers are continuing to work toward perfecting resin and curing agent designs that will allow lower cost

TABLE 8a. VOC REDUCTION COMPARISON[a]
(Metric Units)

	Conventional solvent	Water-borne	Higher solids	Powder
Volume solids at spray viscosity, percent[b]	33	35	60	99
Volume VOC content, percent[c d]	67	16	40	1
Actual coverage, m^2/ℓ (m^2/kg for powder)[b e]	5.71	6.66	14.0	19.7
VOC emissions, metric tons/yr[f]	34.5	23.6	28.1	0.54

[a]Assumed 1.1×10^6 m^2 of parts coated per year.
[b]Average of values presented in Table 6a.
[c]Assumed density of solvent equals 882 g/ℓ.
[d]Water-borne coating VOC content assumed to be 25 percent of the nonsolids portion.
[e]Based on transfer efficiencies presented in Table 6a.
[f]Control device assumed for conventional solvent coatings with overall efficiency of about 70 percent (based on capture efficiency of about 75 percent and destruction efficiency of about 95 percent). All other systems assumed to have no control device.

TABLE 8b. VOC REDUCTION COMPARISON[a]
(English Units)

	Conventional solvent	Water-borne	Higher solids	Powder
Volume solids at spray viscosity, percent[b]	33	35	60	99
Volume VOC content, percent[c d]	67	16	40	1
Actual coverage, ft^2/gal (ft^2/lb for powder)[b e]	233	272	570	96
VOC emissions, tons/yr[f]	38	26	31	0.6

[a]Assumed 12×10^6 ft^2 of parts coated per year.
[b]Average of values presented in Table 6b.
[c]Assumed density of solvent equals 7.36 lb/gal.
[d]Water-borne coating VOC content assumed to be 25 percent of the nonsolids portion.
[e]Based on transfer efficiencies presented in Table 6b.
[f]Control device assumed for conventional solvent coatings with overall efficiency of about 70 percent (based on capture efficiency of about 75 percent and destruction efficiency of about 95 percent). All other systems assumed to have no control device.

coatings and low-temperature cure coatings. Significant advancements are also being made in the weatherability of powders for use in automotive and architectural applications. Clear powder coatings are used for a wide range of applications in a number of markets, including the automotive industry. Clear polyester and acrylic powders are being used to finish wheels, and resin systems are available in powder coating technology that provide the exterior durability properties required of an automotive exterior body topcoat.

Recent and ongoing developments in the equipment used for powder application have significantly reduced the time and effort required for color changes. Properly designed powder systems can change colors in minutes. Currently, high-production powder systems apply more than 20 different colors, with several color changes per day.[23] Coil coating technology for powder is being developed. (Coil coating is the coating of flat metal sheet or strip that comes in rolls or coils. The metal is coated on one or both sides on a continuous production line basis.) Vertical coating booths are enabling powder to compete more effectively in the aluminum extrusion finishing market. Advances in microprocessors, robotics, and infrared curing technology are allowing increased production in powder coating facilities. All of these advances, plus the inherent advantages of working with powder ensure that powder coatings will have a permanent and ever-increasing share of the finishing market.

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APPENDIX A.

SURVEY SUMMARY: POWDER COATING EQUIPMENT SUPPLIERS

APPENDIX A. SURVEY SUMMARY: POWDER COATING EQUIPMENT SUPPLIERS

Three of the nine powder coating equipment suppliers surveyed responded to the survey. A brief summary of their responses is provided below. A list of the equipment suppliers who responded and a compilation of their individual responses are also attached.

Types of equipment sold

One of the responding companies only sells a portable powder coating unit equipped with either a manual or an automatic electrostatic spray gun. The other two respondents sell a wide range of powder coating application and recovery equipment for both electrostatic spraying and fluidized bed dipping. None of the three respondents sells curing ovens.

Color changeovers

The portable powder coating unit sold by one of the respondents can be color changed effectively by one operator in approximately 5 minutes. The other respondents noted that the color change time depends upon the size of the booth, the number of guns, and the type of powder collection equipment used. The color change times ranged from as little as 5 minutes for laboratory-size equipment to as long as 4 hours for a large, 10 gun unit using a filter cyclone for powder recovery.

Transfer efficiencies

The transfer efficiency provided by the portable powder application unit is estimated at 20 to 45 percent, depending on the technique and material applied. Manual spray systems may achieve transfer efficiencies of 60 to 75 percent depending upon the equipment and powder used. The respondents also cited the following factors that affect transfer efficiencies: (1) powder composition (i.e., resistivity, particle size, particle shape, moisture content, resin chemistry, flow properties), (2) efficiency of charging the powder with either internal or external electrodes, (3) shape and velocity of the atomized powder cloud exiting the discharge nozzle, (4) distance to the grounded workpiece, (5) shape, complexity, and "openness" of the parts to be coated, and (6) film thickness. In general "open" parts like large frames will have transfer efficiencies of 50 to 60 percent at a coating thickness of about 2 mils. Dense parts such as flat panels may have transfer efficiencies of 65 to 85 percent at the same coating thickness. Fluidized bed dipping achieves 100 percent transfer efficiency, but at higher film thicknesses and on a limited range of parts.

Coating thickness

Minimum coating thicknesses of about 0.6 to 0.8 mils and "typical" thicknesses of 1.2 to 2.5 mils were reported. Maximum thicknesses of 20 to 30 mils were also reported. One respondent noted that automatic application systems provide the most consistent thin films; he also noted that preheating parts greatly increases the maximum achievable film thickness.

New powder coating technology

One respondent felt that recent equipment developments have not had a significant impact on developing or expanding new markets, and that all of the new developments have been in the powder material technology. Another respondent noted that new fluorocarbon-based powders are expected to permit the expansion of powder coating into the high-performance architect aluminum extrusion market, currently limited to two-coat liquid coatings. The development of equipment that allows faster color changes was also mentioned.

Equipment costs

The respondents provided costs for a wide range of equipment types and sizes. A portable powder system costs approximately $3,700, and laboratory models cost $14,500 and up. "Budget" prices for complete booth equipment, powder guns, and fire detection packages ranged from $55,000 to $141,000 depending on the size of the equipment. The powder applicators, delivery, and recovery equipment for an eight gun, 30 in.x66 in. (wxh) automatic coating system may range from $90,000 to $125,000.

Experience with powder coatings and industries served

The three respondents have been manufacturing and selling powder application equipment from 5 to 29 years, and have an average experience of 16 years. They service a wide variety of industries, including metal furniture, lawn and garden tractors, automotive parts, light poles, lighting fixtures, and gas tanks, among many others.

Powder versus liquid coating costs

One respondent is not involved in liquid coatings, and therefore, could not provide a cost comparison between the two coating methods. Another respondent does sell equipment to liquid coating users but did not have any comparative information available. The third respondent sells a limited amount of equipment to liquid coating users and felt that, in general, powder coating systems are comparable in capital investment to new liquid coating systems.

2 Attachments

Attachment 1

LIST OF RESPONDENTS: POWDER COATING EQUIPMENT VENDORS

Mr. Frank A. Robinson, Jr.
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Mr. Donald S. Tyler
President
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Mr. William Diaz
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SURVEY RESPONSES: POWDER COATING EQUIPMENT SUPPLIERS

1. Company name and address; contact name, title, and telephone number. (See attachment).

2. List the types of equipment that you sell for each step in the powder coating process (powder storage and handling, substrate pretreatment, powder delivery, application, recovery, and powder curing).

   DeVilbiss: DeVilbiss sells a portable powder coating application unit that may be equipped with either an automatic or a manual electrostatic spray gun.

   Finishing Systems: The equipment that Finishing Systems Services, Inc. (FSSI) fabricates is marketed under the RECLAIM™ trademark. The following equipment is manufactured by FSSI for the powder coating industry:

   Powder handling and conditioning equipment

   - virgin powder drum unloader
   - powder sieving and conditioning equipment
   - powder transfer retrofit for existing cyclone equipment

   RECLAIM™ powder application equipment

   - complete manual spray gun outfits with supply hopper
   - laboratory and QC station manual spray gun outfits
   - manual spray gun outfits for mounting on the powder booth
   - complete automatic/manual powder spray systems for retrofitting existing liquid spray lines or adding provisions for powder
   - complete automatic/manual powder spray systems for new lines
   - ultra-violet fire detection system for automatic powder lines
   - custom design powder application equipment for special products
   - electric and pneumatic automatic gun movers and reciprocators

   RECLAIM™ brand powder recovery and recycling systems

   Cartridge filter design powder recovery booth models:

   - laboratory and QC station cartridge powder collection booth for spraying small samples or testing various powders
   - chain on edge conveyor type cartridge booths for coating small parts on rotating fixtures which travel through a slot at the bottom of the booth floor. Models with single color and roll-away color change collectors
   - manual station single color format booths with airflow capacities of 3,000 to 6,000 ft^3/min
   - color change design manual and automatic powder booths with multiple spray stations. Standard and custom models with airflow capacities of 3,000 to 20,000 ft^3/min

- special design cartridge style booths with cyclones for multiple color capability within the same recovery system
- custom design booths for special oversize products
- custom powder management systems for fluid-bed dipping systems
- custom design dust collection booths for nondecorative coatings, fire extinguisher chemicals, and rubber industry

Volstatic: Volstatic manufactures electrostatic powder coating application and recovery apparatus, including:

a. Manual spray application apparatus for production use
b. Manual spray application apparatus for laboratory or field test use
c. Automatic spray apparatus, single gun through multi-gun configurations, typically 2 to 12 guns per booth
d. Electrostatic generators, single and multi-gun configurations
e. Spray booths for manual application
f. Spray booths for automatic application (or combination manual/automatic configuration)
g. Powder recovery and reclaim systems: cartridge type, cyclone separators, combinations
h. Fluid beds
i. Ancillary equipment: powder transfer pumps, vibrating drum tables, deionizing generators/fans; powder clean-down apparatus

Volstatic occasionally sells powder curing equipment when supplied with other powder application equipment

3. Please provide information on powder application and recovery equipment relative to color changeovers (typical time required for color changeover and maximum number of colors that can be applied per booth or system).

DeVilbiss: Their powder system can be color changed effectively by one operator in approximately 5 minutes.

Finishing Systems: Powder collection equipment is available in three distinct formats: cartridge filter booth which FSSI specializes in, moving filter belt booth, and the conventional cyclone booth. The simplest and most efficient of these is the cartridge booth since all the recycled powder stays within the unit. This compact booth design has no moving parts other than the fan. The collector, the housing which has the dedicated color filters, is very easy to change. The filters within the collector are also easily changed when a low volume color which does not have a dedicated collector is to be recycled. The moving filter belt booth requires the changing of the belt for powder change and has extensive auxilliary equipment for screening and recycling the powder.

The idea behind the cartridge design powder recovery booth is that each recycled color has a dedicated collector with filters for that specific color. If a powder user has a multitude of colors with no appreciable volume in any of these various colors, a cartridge booth is not the proper choice of equipment. Mutliple color recovery requires a booth which uses an inline cyclone to separate each color. Naturally, the efficiency of the cyclone will vary greatly, and anywhere from 5 to 25 percent of the recycled powder will bypass the cyclone into the final filter and thus, will not be recovered. Further scrap powder is generated when the cyclone, ductwork and collection hoppers on the cyclone system are not properly cleaned during the color change.

The following are some general color change times for various types of equipment and airflow size in cubic feet per minute.

<u>Approximate time in minutes for color change by two operators</u>

Equipment model format	filter	Cartridge belt	Filter Cyclone
1,500 ft^3/min for lab or QC	5 to 10	NA	15 to 20
3,000 ft^3/min (2) manual	10 to 20	30 to 60	30 to 60
4,500 ft^3/min (2) man, (4) auto	20 to 30	45 to 90	60 to 120
9,000 ft^3/min (2) manual	25 to 35	60 to 120	90 to 150
12,000 ft^3/min (2) man, (8) auto	40 to 60	120 to 240	120 to 240

<u>Volstatic</u>: Powder color change time is dependent primarily on the size of the booth and the number of guns. Typically, a steel-construction booth and a complement of eight guns may be cleaned in about 30 minutes. Volstatic's new, patented ColorSPEEDER permits that operation to be completed in less than 5 minutes, including its reclaim system. Even faster changes may be achieved by duplicating the spray booths in a "roll on/roll off" configuration but this requires additional capital investment.

Employing cyclone separators between the spray booth and final filter sections of the reclaim system permits unlimited numbers of colors to be applied without duplication of reclaim system sections, (e.g., filter modules) and they achieve quite high recovery efficiencies of usable powder overspray (e.g., 95 to 97 percent).

4. Describe, and provide data if possible, the ranges of transfer efficiencies that are expected for each type of application equipment sold.

<u>DeVilbiss</u>: They do not have experimental data showing transfer efficiencies for this equipment, but expect it to be in the range of 20 to 45 percent depending on the technique and material being applied.

<u>Finishing Systems</u>: Transfer efficiency in powder application equipment is dependent on many factors. The most influential factor is the composition of the powder; its resistivity, particle size, particle shape, moisture content, resin chemistry and flow

properties. Other factors are gun dependent such as the efficiency of charging the powder with either internal or external electrodes, shape of the atomized powder cloud, velocity of the powder cloud exiting the discharge nozzle, and distance to the grounded workpiece.

Transfer efficiency also varies with the various types of charging methods: negative corona, positive corona and tribo charge.

The RECLAIM™ Ultra-100 brand of equipment has higher high voltage and current levels at the tip of the gun electrode than other competitive brands. The higher current allows more powder to be charged at a specific high voltage level. FSSI has an installation where four Ultra-100 guns are performing the same job as six of another manufacture on the same product. FSSI at this time does not have an interest in producing any type of friction tribo-charging application equipment.

Volstatic: Transfer efficiency is dependent on not only the application equipment, but the shape, complexity and "openness" of the parts to be coated. In addition, line speed, film thickness and powder chemistry play a major role. Volstatic equipment is generally regarded to achieve the highest direct transfer in the industry and the following are typical examples with epoxy or polyester powder at average film thicknesses of 1.5 mils + 0.5 mils:

a. "Open" parts like large frames, etc: 50 to 60 percent TE
b. "Average" line density, e.g., dense wire goods, tubular furniture, lighting fixtures, boxes and cabinetry, etc.: 55 to 80 percent TE
c. "Dense" parts or line loading, e.g., flat panels: 65 to 85 percent TE

In some special-purpose equipment, transfer efficiencies in excess of 90 percent can be achieved, but 100 percent in a spray apparatus is not achieved. (Fluid bed dipping achieves 100 percent transfer efficiency, but at higher film weights on a limited range of parts.) Proper fixturing for dense line loading is critical to achieve good transfer efficiency in any spray system.

Manual spray systems typically achieve 60 to 75 percent in Volstatic systems.

5. Please provide information on minimum and maximum coating thickness that can be achieved with each type of application equipment sold.

DeVilbiss: They believe that coating thickness is largely a function of the powder material itself, and they do not have experimental data in this area.

Finishing Systems: The coating thickness is very powder dependent. The coating can be applied very thin, 0.6 to 0.8 mils but the hiding capability and the appearance of the coating may not be acceptable, or may not offer the protection required. The thicker coatings are easier to achieve, but again it depends on the thickness at which the coating will start rejecting additional material and also the overall particle size.

Nominal coating thicknesses are generally in the range of 1.2 to 2.5 mils on selected surfaces. In areas where manual touch-up is done to an automatically painted part or on surfaces very close to the nozzle of a gun the coating can be 4.0 to 5.0 mils thick.

Volstatic: Volstatic has provided large-scale, automatic combination manual/automatic production systems achieving 0.8 to 1.2 mils average film thickness. Some systems are capable of achieving greater than 10 mils single-pass coatings on nonpreheated parts. Preheating parts greatly increases the maximum film thickness from this range. Thicknesses of 20 to 30 mils are certainly possible. Usually, automatic application systems provide the most consistent thin-film averages, with an additional 0.25 to 0.5 mil typical with manual coating. Without production monitoring, however, manual operators have been known to add a mil or more of unnecessary film weight.

6. Please provide as much information as possible on the types of spray booths (from Item 2) used for powder coating lines (dimensions, airflows, filter types, etc.).

DeVilbiss: They are not presently manufacturing spray booths for use in powder coating systems.

Finishing Systems: FSSI exclusively fabricates cartridge filter type powder booths. The airflow in all the RECLAIM™ powder booths is full height of the spray cavity whenever possible and horizontal towards the collector which is located at the end of the booth (single extended) or in the center between the manual and automatic spray stations (double extended). In cases where the booth is not extended it would have a single spray station directly in front of the collector as is the design of the laboratory booth.

The capacity is figured by the sum of all the spray and product openings at an airflow velocity of 100 to 120 feet per minute.

Volstatic: Volstatic provided examples of spray booth configurations along with reclaim systems. Product maximum dimensions are not truly limited by the booth; ovens and pretreatment systems provide the practical limits for economic feasibility. The majority of Volstatic euqipment (approximately 95 percent) falls in the range of 24"w x 30"h to 72 in. wide maximum width and 312 in. maximum height, (product opening).

The filters are typically nonstatic cartridge-type in combination with two elements of monitoring safety filters afterward. Cyclone separators are often used prior to the filter to maximize filter life, improve efficiency and to allow an unlimited number of colors to be used without filter set duplication.

In some special equipment, (e.g., the Volstatic Freedomcoater) air flows are unusual and aid in the coating performance considerably.

7. List typical sizes and operating parameters for powder curing ovens (from Item 2) sold by your company.

   DeVilbiss: They do not presently manufacture or sell powder curing ovens.

   Finishing Systems: FSSI does not fabricate powder cure ovens.

   Volstatic: Volstatic normally works with oven manufacturers for the supply of these products. The product openings match or exceed the booth product openings (see question 6) and the lengths may vary from 6 feet to several hundred feet in conveyorized systems. Powders typically cure between 325°F and 400°F with cure times between 5 minutes and 20 minutes. Infra-red radiation curing accelerates these times to as little as a few seconds in some cases and may permit curing powder on the outside of temperature-sensitive devices whose internal gaskets, seals or components could not tolerate temperatures above, say, 250°F. Some degree of infra-red curing is common on massive objects, like iron or steel castings.

8. Describe recent improvements in powder coating technology that may result in expanded or new market areas.

   DeVilbiss: Answer unknown.

   Finishing Systems: Recent equipment developments have not had significant impact on developing or expanding new markets. All the development has been in the powder material technology.

   Volstatic: The development of the ColorSPEEDER permits a true 5-minute color change without duplicate coating booths, filter modules or spray guns. This saves capital investment, floor space and permits economical "short runs" in production without wasting overspray powder. The Freedomcoater permits high production runs of parts arranged on an intergral conveyor without the need for fixturing. Automatic masking of one side of the part is a feature of this finishing technique.

   New fluorocarbon-based powders will permit the expansion of powder coating into the high-performance architect aluminum extrusion market previously limited to 2-coat liquid coatings.

9. For each type of equipment listed under Item 2, provide costs, or cost factors, that can be used to generate "typical" costs for a complete powder coating line.

   DeVilbiss: A BFA portable powder system sells to an end-user for approximately $3,700.00.

Finishing Systems: Typical costs are not easy to supply since the powder booth equipment is usually custom fabricated. The following are budget prices for complete booth equipment, powder gun and UV fire detection packages in the various airflow and product opening sizes.

Configuration		Single extended			Double extended		
Product openings	ft^3/min	Man	Auto	Cost, $	Man	Auto	Cost, $
Opening:							
2'wx4'h	4,500	2	0	29,200	2	4	54,900
		1	4	45,500	2	6	64,600
2'wx5'h	6,000	2	0	40,100	2	4	66,000
		1	6	64,100	2	8	84,600
3'wx6'h	9,000	2	0	42,540	2	8	89,500
		1	6	70,600	2	10	100,500
4'wx6'h	12,000	2	0	49,500	2	8	94,800
		1	8	85,300	2	12	114,800
3'wx6'h	15,000	2	0	56,500	2	14	131,900
		1	12	112,300	2	16	140,900
Lab model							
3'x3'	1,600	1	0	13,000	--	--	--
4'x5'	3,000	1	0	14,500	--	--	--

Volstatic: The following costs refer to equipment listed in question 2.:

a. From under $4,000
b. From under $3,500
c. Typically, around $15,000 per gun for the whole system, including booth, guns generator, reclaim system. This number varies a lot depending on the particular system and degree of automation.
d. From under $5,000 per gun
e. Very dependent on size: from under $10,000 for a self-contained 48 in.x48 in. face booth with integral reclaim system
f. Very dependent on size--see item "c" above
g. See item "c" above
h. From $500 to more than $5,000 depending on size, degree of contents and degree of integral equipment, e.g., venturi pumps
i. From under $100 and up depending on the individual pieces

As a very general guide, not for purpose of ordering, the powder applicators, delivery, and recovery equipment, including architectural interlock safety equipment for an 8-gun, 30"wx66"h automatic coating system may range from $90,000 to $125,000. It is essential to consult with equipment manufacturers, ideally more than one, to obtain usable cost estimates for finishing lines.

10. In what industries is your equipment most often used (provide a list of major customers, if possible).

<u>DeVilbiss</u>: Most of their more recent powder systems have been used in powder coating job shops and the appliance industry.

<u>Finishing Systems</u>: FSSI is involved mainly in the industrial decorative coating market. The various products being coated with the RECLAIM™ powder equipment are as follows:

- lawn and garden tractors
- snow blowers
- patio furniture
- office furniture
- pallet racking
- display shelving
- wire displays
- restaurant chairs and tables
- lighting fixtures
- propane and oxygen tanks
- garden posts
- battery chargers
- boat trailers
- rubber membrane roofing
- radiators and coolers
- stove burner liners
- navy missile housings
- truck air conditioners
- RV aftermarket equipment
- farm fans and coolers
- radiator fans
- switching gear enclosures
- oil coolers
- truck bumpers
- hardware
- TV satellite dishes
- air conditioner housings
- light poles
- school furniture
- basketball poles and hoops
- security lighting
- aluminum car wheels
- aluminum extrusions
- shop welders
- boat winches and hardware
- pole transformer housings
- floor sweepers and vacuums
- parking meters
- automotive hardware
- restaurant shelving
- range hoods
- fence fabric
- communications equipment
- multitude of job shops

<u>Volstatic</u>: In general, any product which is painted with an organic paint and which can be transported into a cure oven and which will withstand powder cure temperatures (see question 7) can and probably should be powder coated. This includes most products made of metal and many of other materials.

11. How long has your company sold powder coating equipment?

<u>DeVilbiss</u>: DeVilbiss Company has been manufacturing and selling powder application equipment in excess of 15 years.

<u>Finishing Systems</u>: FSSI has been manufacturing and selling powder recycling and application equipment since March of 1984.

<u>Volstatic</u>: Volstatic has manufactured and sold powder coating application equipment since 1960, over 29 years.

12. Do you also sell coating equipment to liquid coating users? If so, please provide information on the cost differences between the types of equipment sold for liquid and powder coatings.

DeVilbiss: DeVilbiss Company sells a substantial amount of equipment to liquid coatings users. However, since they engage in very little powder application equipment business they do not gather or maintain comparative information.

Finishing Systems: FSSI is not involved in the liquid coatings market at this time.

Volstatic: Volstatic sells a limited range of generators for private label liquid applications, including the NDT (nondestructive testing) industry. In general, productive powder coating systems are comparable in capital investment to new liquid coating systems for a given application.

APPENDIX B.

SURVEY SUMMARY: POWDER COATING MANUFACTURERS

APPENDIX B. SURVEY SUMMARY: POWDER COATING MANUFACTURERS

Seven of the nine powder coating manufactures surveyed responded to the survey. A brief summary of their responses is provided below. A list of the powder coating manufacturers who responded and a compilation of their individual responses are also attached.

Types of powder coatings manufactured

All of the respondents manufacture a variety of thermosetting powders (e.g., polyester, urethane, epoxy, acrylic, hybrid, etc.). One manufacturer also produced the following thermoplastic powders: vinyl, nylon, and thermoplastic polyester.

Color availability

All of the respondents stated that virtually any color can be matched with powder coatings. The only limitation they cited was that certain metallic effects are hard to duplicate. One manufacturer explained that, although metallic-effect powder coatings are attractive and often accepted as replacements for liquid paint, it is very difficult to match the metallic effects displayed by liquid paint at various viewing angles of the coated part.

Pretreatment steps

The respondents stated that the substrate pretreatments will vary depending upon the substrate and the performance requirements. The pretreatment step most often suggested by the respondents was a three to seven stage iron phosphate pretreatment. Five to nine stage zinc phosphate and chrome phosphate pretreatments were also listed.

Powder storage and handling

The majority of the powder coating manufacturers recommended that powders be stored at temperatures below 80°F and for a maximum of 6 months.

Minimum coating thickness

The respondents reported minimum film thicknesses ranging from about 0.5 to 1 mil. Typical film thicknesses ranged from about 1.5 to 3 mil for thermosetting powders and from 4 to 12 mil for thermoplastic powders.

Curing times and temperatures

Curing temperatures ranged from a low of 250°F to a high of 475°F for thermosetting powders, and ranged from 400 to 600°F for thermoplastic powders. Curing times ranged from 10 to 30 minutes, depending upon the curing temperature (i.e., at higher temperatures, the curing times were shorter).

Powder coating costs

Prices varied depending upon the specific formulation, the quantity ordered, the color, and the gloss level. One powder coating manufacturer stated that bright, sharp, clean colors are 20 to 100 percent more expensive than earthtones, pale shades, whites, and blacks. The price of thermosetting powders ranged from $1.75 to $12.00 per pound, depending upon the quantity ordered. The cost of thermoplastic powders was somewhat higher at $4.00 to $14.00 per pound, with the exception of vinyl powders which ranged in price from $1.50 to $6.00 per pound. One respondent stated that the "industry average" cost of powder coatings is about $2.49 per pound.

Minimum orders

Standard or "stock" powders can be purchased from the majority of the powder coating manufacturers in quantities as small as 50 lb. Nonstock powders that are custom-manufactured for specific customers usually have minimum orders from 1,500 to 5,000 lb. One manufacturer stated that, for all of their powders, the minimum order is 200 pounds.

End users

The powder coating manufacturers supply a variety of markets including major home appliances, metal furniture, automotive, lighting, lawn and garden equipment, piping, etc.

Recent trends in the use of powder coatings

Respondents reported a 20 to 25 percent growth in powder sales each year for the past 5 years. One respondent stated that a significant number of conversions from liquid to powder have occurred because of regulations pertaining to the disposal of hazardous wastes. Other reported trends are increased user sophistication (i.e., 95 percent or greater material utilization efficiencies), consistent thin films, and long-term testing prior to the use of powder.

Recent developments

The following developments in powder coating technology were reported by the respondents:

- high transfer efficiency powder application equipment
- capability to apply thinner, more uniform films
- more economical powder reclaim systems, facilitating more rapid color change
- new powders replacing porcelain in the appliance and bathroom industries continue to be developed
- development of new thermosetting fluorocarbon powders for use in architectural industry
- powder coatings now available for cure as low as 250°F

- powder and application equipment is available for coating coil or blank stock
- powder coatings now exist for coating a variety of plastics, both in mold and out of mold
- metallic look powders which <u>approach</u> chrome appearance are recently available
- less batch-to-batch variation with powders
- powders now have better weathering systems for exterior exposure

2 Attachments

LIST OF RESPONDENTS: POWDER COATING MANUFACTURERS

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Mr. Douglas Bach
Manager of Marketing and Operations
The O'Brien Corporation
Power Coatings Division
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(713) 641-0661

Mr. Trevor Mason
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Spraylat Corporation
3465 South La Cienega Boulevard
Los Angeles, California 90016
(213) 559-2335

Mr. John Kish
Customer Service Coordinator
FERRO Corporation
Power Coatings Division
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SURVEY RESPONSES: POWDER COATING MANUFACTURERS

1. Company name and address; contact name, title, and telephone number. (See Attachment 1)

2. Types of powder coatings manufactured (vinyl, acrylic, polyester, hybrids, etc.)

EVTECH: Polyester, urethane, epoxy/polyester, epoxy, acrylic.

Glidden: Epoxy, epoxy/polyester hybrid, polyester urethane, polyester, acrylic, (all thermosetting materials).

Morton Thiokol: We currently manufacture thermoplastic and thermoset organic powder coatings as follows:

Thermoplastic: vinyl, nylon, thermoplastic polyester.
Thermoset: epoxy-all types, hybrid, urethane polyester, TGIC polyester, acrylic.

O'Brien Corp.: Epoxy, epoxy-polyester hybrid, urethane-polyester, and TGIC-polyester. No thermoplastic types are produced.

Spraylat: "Secura" epoxy, "Secura" hybrid, "Secura" polyester TGIC, "Secura" polyurethane. All available in various gloss levels, textures, structures and nonmetallic, metallics.

FERRO Corp.: Epoxy, polyester, hybrid, and acrylic.

Lilly: Thermoset powder coatings in the epoxy, hybrid, TGIC polyester, and polyurethane chemistries.

3. Describe limitations on color availability.

EVTECH: Colors formulated to meet customer requirements.

Glidden: There are virtually no limitations on color availability. It should be noted that while attractive metallic effects can be achieved, metallic particles will generally not orient (flop) the same as they will in low viscosity liquids. It is difficult to match the exact metallic "flop" in different systems. This is not only a powder problem but a problem between various viscosities or solids levels in liquids. This is often mentioned as a powder limitation.

Morton Thiokol: Virtually any color can be matched in any coating type. We have 95 stock colors.

O'Brien Corp.: Virtually any color can be produced in solid colors. Clear coatings and pigmented transparent colors are also available. The one area in which we are limited by current technology is that of metallic-effect coatings. Metallic-effect powder coatings can be produced which are very attractive, and, in many cases, enjoy very favorable reception as replacements for liquid paint. However, it is extremely difficult to match the metallic effect displayed by liquid paint at various viewing angles of the coated part. Usually, this difference is not objectionable if the powder coated part is not placed in close proximity to a part coated with liquid paint, or does not require touch-up with liquid paint. However, for applications such as automotive topcoat, powder metallics are not yet direct replacements for liquids.

Spraylat: Most colors are available with only a few exceptions. Special finishes have some limitations when considering resin.

FERRO Corp.: The only restrictions on color is the use of pigmentation that has been chosen as a high risk safety hazard (ex. free-floating metals).

Lilly: Generally, any color available in liquid industrial finishes is also available in powder coatings. There are some limitations in matching liquid coatings in metallic formulations.

4. Describe the substrate pretreatment steps that are recommended or required.

EVTECH: Three stage iron phosphate or five stage zinc phosphate depending on product requirements.

Glidden: Substrate pretreatments vary significantly based on substrate and performance requirements. These will be the same requirements as for liquids, however.

Morton Thiokol: All powder coatings require a clean, dry substrate. Further pretreatment is dictated by coating performance requirements; i.e., to achieve long-term corrosion resistance five stage or longer iron or zinc phosphating is typically used.

A. Thermoset Powders

1. Ferrous substrates
   a. 3-7 stage iron phosphate with a chrome or nonchrome final rinse.
   b. Cleaning followed by shot blasting.
   c. 5-9 stage zinc phosphate.

2. Nonferrous substrates
   a. 3-7 stage iron phosphate with special additives
   b. Chromates
   c. Chrome phosphates
   d. 5-9 stage zinc phosphate (for galvanized primarily).

B. Thermoplastic powders

1. As above.
2. Nylon and vinyl may require a primer depending on requirements.

O'Brien Corp.: Minimum recommended pretreatment is usually 3-stage iron phosphate. For applications which require a high degree of corrosion protection, 5 or 7-stage iron or zinc phosphate is recommended. In applications which are strictly decorative and used in a mild environment such as the interior of a home, vapor degreasing, alkaline cleaning, or solvent washing may be adequate.

Spraylat: Thorough cleaning and degreasing. When higher specifications have to be met, a chromate or phosphate coating should be applied to the substrate.

FERRO Corp.: Generally, a good quality powder finishing system should have a minimum of 5 stages; however, there are some coaters using 3 stage systems for their quality requirements. A 7-stage operation will be used if physical requirements, such as resistance to salt spray, are extremely demanding. Example of a typical 5 stage (zinc or iron phosphate): cleaner/rinse/phosphate/rinse/sealer.

Lilly: A clean metal substrate is required before electrostatic application. For products exposed to interior environments, a three-stage pretreatment is generally required (washer/phosphate, clear water rinse, and another rinse or sealer). For products exposed to an exterior environment, a five-stage process is recommended. This consists of a power wash, a rinse, an iron or zinc phosphate, a clear water rinse, and a seal.

5. Describe any powder storage and handling procedures that are recommended.

EVTECH: Storage conditions should not exceed 80°F for prolonged periods of time.

Glidden: Our standard recommendation for powder storage is that the product be stored at 80°F maximum. The time depends upon the specific formulation but in no case is less than 6 months with our commercial products.

While the 80°F is a good general recommendation, it is not mandatory. We have some inventory areas as do some of our customers where there is no warehouse temperature control. Just as many liquid paints should not be stored in extremes in temperature, discretion should be used in storing powder.

There are two fundamental mechanisms where powder can be unstable: (1) chemical reaction, and (2) physical melting (sintering/blocking).

The first is dependent upon the chemistry of the particular formulation. More reactive systems can advance with heat. Many formulations will be extremely stable, however. While it is very difficult to generalize in this area, it would be our estimate that 75 percent of product sold have good stability in this area.

The second is applicable to all solid plastic materials. Depending upon the melting point of the formulation, the particles will begin to stick together under some conditions of elevated heat. Again, it is extremely difficult to give quantitative absolutes. Because of the excellent insulating properties of a container of powder, a package stored at an elevated temperature could take weeks and even months for that temperature to reach all areas of the powder. Powder is routinely shipped across the country and through the desert in standard trucks without deleterious effects.

Morton Thiokol: Typical powder coatings require ambient storage (80°F at 50 percent relative humidity is ideal). Some special fast cure materials require cold storage.

O'Brien Corp.: We recommend storage in a cool enviroment (75° or less) for a period of 6 months, although many applicators routinely store powder for longer periods without experiencing any difficulties.

Spraylat: Dry storage, 6 months recommended maximum, stored at not more than 77°F. Particular attention should be paid to storage where adverse climatic conditions are possible.

FERRO Corp.: Power storage and handling procedures:

a. Climate controlled room for storage of powder coatings;
b. Proper rotation of stock;
c. Protection clothing and proper respirator; and
d. Carefully read all M.S.D.S. information supplied with the product.

Lilly: Lilly recommends that powder be stored at less than 80°F. Powder coatings have a shelf life of 6 months from date of shipment, if properly stored.

6. Are your powder coatings compatible with all typical application devices? Discuss any known exceptions.

EVTECH: Compatible with all powder coating application equipment.

Glidden: Our powder coatings are compatible with all powder coating application concepts. Of course, these materials cannot be sprayed through liquid guns. Applicable powder equipment must be employed.

Morton Thiokol: Morton powder coatings are used in all known types of powder application equipment.

O'Brien Corp.: Our coatings are designed to apply through electrostatic spray guns, triboelectric guns, electrostatic fluidized beds, or conventional fluidized beds. On occasion, formulations or process conditions may require alterations to yield acceptable performance on specific types of equipment, and such alterations are generally successful.

Spraylat: Electrostatic, hand or automatic spray. Most products can be formulated for use in fluidized bed.

FERRO Corp.: VEDOC powder coatings are typically compatible with all application equipment. However, particle size distribution and/or a post-additive may be required to insure peak performance.

Lilly: Generally, powder coatings are applied by the electrostatic application method. Another way of applying powder coatings is electrostatic fluid bed.

7. What is the minimum coating thickness that can be obtained with your powder coatings? What is the "typical" coating thickness?

EVTECH: Minimum thickness 0.7 mil to 1.0 mil depending on specific color. Typical coating thickness 1.5 mils.

Glidden: Film thicknesses requirements vary significantly. We have ongoing commercial operations applying powder in thickness ranging from 0.7 mils to 1.3 mils. Other applications in the electrical industry average 15 mils. The ability to maintain consistent and low film thicknesses depends significantly on application line design and control. While liquids experience rejects through "runs and sags" when thickness is too high, powder is more forgiving. Operators tend to apply powders heavier to take advantage of this flexibility.

Morton Thiokol: We have thermoset powder coatings that can be applied as thin is 0.5 mils. Typical thermoset film thickness range is 1.5 to 3.0 mil. Often thickness can be controlled to ±0.2 mil.

Thermoplastics are usually applied 4 to 12 mils thick.

O'Brien Corp.: In "real world" conditions, it is unusual to find coatings applied consistently under 1 mil. In a laboratory situation, coating thickness of under 1 mil may be obtained with acceptable appearance, but it is very difficult to maintain this film thickness on a large-scale application line. My opinion on "typical film thickness" is that it is in the 2 to 3 mil range for most applicators.

Spraylat: Coating thickness of 1 mil is possible but a thickness of 2 ±0.5 mils is typical.

FERRO Corp.: Based on applications, coating thickness specifications are maintained at ranges of 0.8 to 1.0 mils; custom coaters environment ranges from 2 to 3 mils.

Lilly: The minimum coating thickness currently being applied by customers of Lilly is 0.8 to 1 mil. The typical coating thickness is approximately 1.8 to 2.2 mils.

8. Please provide information on the range ("low," "typical," "high") of curing times and temperatures that are required for the types of powder coatings identified in Item 2.

EVTECH:

Low:	30 min. at 275°F (epoxy)
Typical:	20 min. at 375°F (all others)
High:	5 min. at 400°F (epoxy)
	10 min. at 400°F (all others)

Glidden: Minimum cure requirements can range from 250°F and 30 minutes to 375°F and 30 minutes.

Morton Thiokol:

	Low	Typical	High
Epoxy	250°F	350° to 400°F	475°F
Hybrid	275° to 300°F	350° to 400°F	450°F
Urethane polyester	350°F	390° to 400°F	425°F
TGIC polyester	300°F	350° to 400°F	475°F
Acrylic	275°F	350° to 400°F	450°F
Nylon		475° to 600°F	
Vinyl		400° to 600°F	
Thermoplastic polyester		400° to 600°F	

O'Brien Corp.: Cure schedule.

	Epoxy, hybrid, polyester	Urethane
Low	275°-350°F/8-20 min	350°-400°F/8-20 min
High	350°-425°F/8-20 min	375°-425°F/8-15 min

Spraylat: Low cure products are available with curing schedule of 330°F, 10 minutes peak metal temperature. Standard cure is 365°F, 10 minutes peak metal temperature. Polyurethane and other low gloss products have a cure of 400°F, 10 minutes peak metal temperature. By increasing the curing times a lower cure temperature can be achieved.

FERRO Corp.: Cure schedule:

	Epoxy	Polyester	Hybrid	Acrylic
Typical	375°F/15 min	375°F/15 min	375°F/15 min	375°F/20 min
Low	300°F/15 min	360°F/30 min	325°F/30 min	360°F/30 min
High	425°F/10 min	425°F/15 min	425°F/10 min	425°F/15 min

Lilly: The typical thermoset powder coating cures at 400°F for 10 minutes (or an equivalent bake based on time and temperature). However, coatings can be formulated to cure at temperatures of 275° to 300°F for approximately 20 to 30 minutes, contingent upon substrate thickness.

9. Please provide information on the price range for each type of powder coating identified in Item 2.

EVTECH: Prices vary depending on specific formulation from $2.50 to $5.00/lb.

Glidden: Again, price can vary significantly within any generic type based on formulation specifics. The following generalities can be made:

Type	Cost, $/lb
Epoxy	2.40
Polyester/epoxy hybrid	2.20
Polyester urethane	2.35
Polyester	2.65
Acrylic	3.00

Price is only one piece of the economic equation, however. Please refer to attached discussion on economics for further information. Price for pound of our products can range from $1.75/lb to over $10.00/lb with the average being in the $2.50/lb area.

Morton Thiokol: Price is very dependent on color with bright, sharp, clean colors being 20 to 100 percent more expensive than earthtones, pale shades, whites and blacks. Quantity also plays a role in cost.

Epoxy	Less than $2.00/lb to $12.00 lb
Hybrid	Less than $2.00/lb to $12.00 lb
Polyesters	Less than $2.00/lb to $12.00 lb
Acrylics	Less than $3.00/lb to $12.00 lb
Vinyls	$1.50/lb to $6.00 lb
Nylon	$4.00/lb to $14.00/lb
Thermoplastic polyester	$4.00/lb to $14.00/lb

O'Brien Corp.: It is very difficult to identify prices only by chemistry due to the differences in pigments and additives required for each formulation. For the purpose of this survey, they assumed white, high gloss coatings with a specific gravity of 1.6 to 1.54 produced in quantities of 21,000 pounds at a time. (Prices listed were considered confidential.)

Spraylat: Supply prices depend on quantity ordered, type of resin system, gloss level and finish required.

FERRO Corp.: Information on pricing by chemical class is proprietary, but the industry average is $2.49/lb.

Lilly: The average selling price for powder coatings varies according to specific gravity and color. A pastel color in a hybrid chemistry would sell for approximatly $2.30 [per pound] based on a 4,000 pound production.

10. What is the minimum order (quantity) of each type of powder coating that can be purchased by your customers (excluding samples or trial orders)?

EVTECH: 5,000 pound minimum order for shipment over a 6 month period for nonstock products; 55 pounds for stock or standard products.

Glidden: Their general position is that they do not pursue single orders of powder less than 1,000 lb in size. Most of their products are custom manufactured for a specific customer. While their company does not engage in a stock color program, many other U.S. powder coating suppliers do with quantities as low as 50 lb being commercially available.

Morton Thiokol: Stock materials are available in 55 lb quantities. Nonstock thermoset powders are available in 1,500 lb quantities. They have "small lots" capability. This means that any coating type can be manufactured in 100 to 1,500 lb quantities.

O'Brien Corp.: For products produced to a specific customer requirement, 1,500 pound minimum. For existing products in stock, 50 pounds.

Spraylat: Minimum orders are for 200 pounds of individual products.

FERRO Corp.: Minimum order quantity is dependent on overall customer volume but, a typical minimum is 2,000 lb per color and/or chemistry.

Lilly: Minimum orders are 50 pounds for stock products and 2,000 pounds for a custom color match and manufacturing.

11. Please provide as much information as you can on the end users of your powder coatings (i.e., list of major customers; major market areas - automotive, large appliance, metal furniture, etc.; new market areas).

EVTECH: Automotive, appliances, metal furniture, lawn and garden equipment.

Glidden: We market our material into several markets which we have segmented as:

Major home appliance:	Washing machine tops and lids, spinner baskets, cabinets. Dryer drums and cabinets. Refrigerator shelves, liners, and cabinets. Air conditioner cabinets. Hot water heaters, etc.
Automotive:	Primer surfacer, anti-chip, trim parts (door handles, etc.), under-the-hood parts (cannisters, oil filters, air cleaners, etc.), wheels--aluminum and steel.
Architectural:	Aluminum extrusions, building panels.
General industrial:	Electrical, lighting fixtures, office furniture, lawn and garden, and fixtures.

Morton Thiokol: They supply all powder coating markets including:

Furniture--all coating types
Automotive--all coating types
Appliance--epoxy, hybrid, polyester, acrylic
Lawn and garden--all coating types
Lighting--all coating types
Electronic--all coating types
Pipe and rebar--epoxies

New market areas include in mold coating of SMC, coil coating, and blank coating.

On request, they can supply individual customer contacts in any market area.

O'Brien Corp.: O'Brien is strongest in the general industrial finishing market, including both custom coaters (job shops) and original equipment manufacturers. We do not actively pursue the major appliance market. We do have a presence in the automotive market (OEM and aftermarket), as well as the metal furniture and office equipment market.

Spraylat: Decorative and functional coatings for a wide range of manufacturers and custom coaters.

FERRO Corp.: Major market areas: automotive, appliance, and lighting. New potentials: functional, architectural, and plastics.

Lilly: Primary market thrust is in the general metals finishing market. Major customers include manufacturers of small appliances, fabricated wire goods, electrical meters, and audio-visual aids.

12. Discuss current or recent trends in the use of powder coatings. Compare sales of powder coatings in 1988 vs. 3 years ago and 5 years ago (for your company and nationwide, if known), also compare by major market areas.

EVTECH: Powder coatings have grown in excess of 20 percent per year in volume for the last 4 years in the United States.

Glidden: Since 1983 powder has been growing at a 20 to 25 percent annual compounded growth rate. Our growth has paralleled the industry in this time period.

Morton Thiokol: Total powder coating sales in the USA should exceed 120 million pounds for 1989. This is nearly double the figure for 5 years ago. The Powder Coating Institute can provide somewhat accurate yearly totals.

The automotive and appliance markets currently use a total of approximately 30 million pounds of powder annually. The annual metal furniture market usage approaches 20 million pounds. Growth in these markets, as well as those listed in No. 11, comes from converting liquid coaters to powder. This growth is expected to be 15 to 20 percent a year through 1995.

As the powder market grows, a significant overall trend is increased user sophistication; i.e., 95 percent or greater material utilization efficiencies, SPC, incoming QC, consistent thin films, long-term testing prior to use of powder.

O'Brien Corp.: Business has increased over the last few years.

Spraylat: Operation not started until July 1987. Therefore, no previous history.

FERRO Corp.: Growth has averaged 15 percent per year for the last 5 years. Major market areas have seen a growth rate of 15 to 18 percent per year over the last 5 years.

Lilly: Lilly has been manufacturing powder coatings for the last 2½ years. During the past 5 years, a growth rate of approximately 20 percent has been realized in the powder coating industry. A significant number of conversions from liquid to powder have occurred in the last year because of Federal and State environmental regulations pertaining to the disposal of hazardous wastes. Most manufacturers converting to powder have a payback period or return on investment of approximately 2 years.

13. Discuss recent developments in powder coating technology that may result in expanded or new market areas.

EVTECH:

1. High transfer efficiency powder application equipment
2. Capability to apply thinner, more uniform films
3. More economical powder reclaim systems facilitating more rapid color change

Glidden: Several new developments are taking place. One is the use of powder as a "blanks" coating.

New materials replacing porcelain in the appliance and bathroom industries continue to be developed.

We are in the early stages of introduction of a thermosetting fluorocarbon powder. This product is aimed at the architectural industry which currently uses liquid fluorocarbons because of their excellent durability and UV resistance. We anticipate these products to be equal to or superior to these liquids and see significant market acceptance.

Morton Thiokol:

- Powder coatings are now available for cure as low as 250°F.
- Powder and application equipment is available for coating coil or blank stock.
- Powder coatings now exist for coating a variety of plastics, both in mold and out of mold.
- Metallic look powder coatings which approach chrome appearance are recently available. Also metallic powder coatings can now match most liquid appearances.

Generally any organic liquid coating performance can now be equalled by organic powder coatings.

O'Brien Corp.: Developments in powder coating technology have tended to be more evolutionary than revolutionary in recent years. Advances have been made in the areas of more consistent products with less batch-to-batch variation, tighter controls on raw material streams, better weathering systems for exterior exposure, materials with better application properties, and materials which may be applied at lower film thicknesses. Progress has also been made in offering a wider range of metallic-effect coatings, and lower bake temperatures for heat-sensitive substrates such as plastics. The ultimate effect of all this is to move the use of powder coatings from an art to a science, thus establishing powder coating as a viable finishing technology which is applicable to a broad segment of the industrial finishing industry. This has been a significant factor contributing to the rapid growth of the powder coatings market in recent years, and should continue in the near term.

Spraylat: No major changes in recent years.

FERRO Corp.: The development of power coatings for plastics may be the next new market area.

Lilly: New markets are opening daily because of improvements in the application equipment and powder coatings. Lilly is now able to develop powder coatings that can be applied at an average dry film thickness of 1.2 mils and achieve complete opacity. The industry is working on the improvement of metallic formulations, low cure powders and different generic types that should open new markets in the next few years.

14. Do you also sell liquid coatings? If so, can you provide the names of customers that are using liquid coatings to coat identical products to those being powder coated by other customers?

EVTECH: No.

Glidden: Yes, we are a major supplier of liquid coatings. Many of our customers use powder and liquid for similar applications. One example would be in the major home appliance segment when some manufactures use powder for the coating of cabinet enclosures and others use liquid.

Morton Thiokol: Morton's Powder Coatings Group also markets liquid primers and touch-up paints for powder coatings. A sister company, Bee Chemical, markets liquid coatings. We service similar markets, often together.

O'Brien Corp.: O'Brien sells coatings for trade sales (house paints, etc.) and automotive refinish coatings, but no liquid coatings which could compete directly with powder coatings.

Spraylat: Yes, in applications where powder cannot be used i.e., plastics and rubbers.

FERRO Corp.: No, Ferro Corp. does not sell liquid paint.

Lilly: The parent company, Lilly Industrial Coatings, manufacturers liquid coatings.

APPENDIX C.

SURVEY SUMMARY: POWDER COATING USERS

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Four of the nine powder coating users surveyed responded to the survey. A brief summary of their responses is provided below. A list of the powder coating users who responded and a compilation of their individual responses are also attached.

Powder coating experience

The number of years each respondent had used powder coatings ranged from 9 to 17 years, with an average experience of about 12 years.

Types of items powder coated

Two of the four companies only coat products that they manufacture themselves. A third company only coats items manufactured by other companies, and the fourth company does both. The types of items coated by the four respondents included laboratory casework, medical examination tables, pumps, valves, plumbing fixtures, chemical processing equipment, computer equipment, food processing equipment, window frames, playground equipment, electrical equipment, and aerospace parts.

Similar or identical liquid-coated products

Two of the respondents also use liquid coatings to coat products that are identical or similar to products that they powder coat. They both preferred powder coatings for the following reasons: (1) thickness control is better, (2) finish control is better, (3) coverage is better and there are fewer parts rejected for areas not covered, (4) cleanup is very simple and easy with powder; there are no chemicals required to cleanup with powder, (5) powder-coated parts are more durable and can withstand strong cleaning agents and, (6) powders are easier to handle and apply. One of the respondents commented that, although it was more costly for him to use powder coatings, the powder coating was necessary to fulfill product requirements. The other respondent stated that his company would prefer to powder coat all of their items, but it was not cost effective for them to change all of their engineering prints and documentation at this time.

Color availability, changeover time, and powder reclamation

The number of different colors of powder coatings applied at each facility ranged from 3 to 40. The company that only used three colors required about 20 minutes to change colors and usually changed colors about once a day. The same company was also able to recover 95 percent of their powder overspray (the overspray is collected in a filter and run through a sifter prior to reuse to insure its cleanliness and uniformity).

The remaining three respondents apply 20 to 40 different colors. One of these companies is able to change colors in about 25 seconds and these changeovers are made several times an hour; however, they do not reclaim any of their powder overspray. A second company changes colors 7 to

10 times a day in about 15 minutes. This company also does not reclaim any powder overspray. The third company changes colors one to four times a day depending upon the volume of each color, and takes 15 to 20 minutes to change. They also have the capacity to reclaim about 35 percent of the overspray, depending upon the volume of parts being run, the particular color, the cost of the materials, and the configuration of the part being coated.

Powder types and application equipment

The power coating users apply a variety of different powders including epoxy, PVC, nylon, polyester, Teflon, Ryton and Kynar. All of the respondents use electrostatic spray guns to apply their powders. One company also uses a fluidized bed; however, only nylon powders are used in the fluidized bed. The number of "lines" at each plant ranges from one to three lines with 1 to 4 booths per line. Both manual and automatic spray guns are used.

Coating Thickness

The thickness of the powder coatings applied at the responding facilities ranges from about 1.5 mils to 125 mils. However, three of the four respondents reported thicknesses of 4 mils of less.

Curing requirements

Required cure temperatures and times of about 350°F to 375°F and 15 to 20 minutes, respectively, were typical. One company had a maximum cure temperature and time of 750°F and 8 hours.

Converting from liquid to power coatings

Only one of the four respondents converted from conventional liquid coatings to powder coatings. This company switched from liquid to powder due to requirements that the coatings be resistant to strong chemicals. One result of their switch is that they are able to offer their customers fewer colors and the film thicknesses have increased; however, because the greater film thickness covers irregularities in the substrate, they tend to have fewer rejects.

"New" powder coating facilities

Three of the four respondents were "new" powder coating facilities (i.e., they did not convert from liquid to powder coatings). These companies selected powder coatings rather than liquid coatings for the following reasons: (1) greater durability of powder coatings when subjected to strong cleaning agents, (2) powder coatings offered a nonpolluting process, (3) powder coatings performance versus paint was impressive, (4) powder is less labor-intensive, and (5) powder coating can be done using less expensive employees. All of the respondents reported that their powder coating system either met or exceeded their expectations.

Capital and operating costs

The capital cost of each plant's powder coating system ranged from $150,000 to $200,000. One company estimated the cost of powder coating to be -0.058 per square foot of coated product.

Limitations associated with powder coatings

Two of the respondents cited the following limitations that prevent them from applying powder on other products: (1) special colors would require development by the suppliers, and therefore, those items requiring special colors are not done as powder coating, (2) special effects such as spatter texture may pose problems; however, texture powders are available if satisfactory to customers, (3) orange peel appearance on some powder-coated items, and (4) excessive buildup in corners of enclosures. Another respondent stated that his company would prefer to powder coat all of their items, but that it is not cost effective for them to switch over at this time.

2 Attachments

Attachment 1

LIST OF RESPONDENTS: POWDER COATING USERS

Mr. Keith M. Long
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American Sterilizer International
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Montgomery, Alabama 361104
(205) 277-6660

Mr. David Tice
Superintendent, Maintenance
Hamilton Industries, Inc.
1316 18th Street
Two Rivers, Wisconsin 54241
(414) 793-1121

Mr. Jeffrey S. Yahn
General Manager
Erie Advanced Manufacturing
3150 West 22nd Street
Erie, Pennsylvania 16506
(814) 833-1711

Mr. Dale A. Gumm
Owner
Tuscon Spraying Technology
628 E. 20th Street, Building D
Tucson, Arizona 85719

Attachment 2

SURVEY RESPONSES: POWDER COATING USERS

1. Company name and address; contact name, title, and telephone number. (See attachment)

2. How long has your company used powder coatings?

   AMSCO: 12 years

   Hamilton Industries: ~12 years, increased use 2 years ago

   Erie Advanced Manufacturing: 17 years

   Tucson Spraying Technology: 9 years

3. List the items that your company manufactures that are coated with powder coatings.

   AMSCO: Surgical light parts, surgical table parts and sterilizer control panels.

   Hamilton Industries: Laboratory casework, medical examination tables, institutional

   Erie: They only coat items manufactured by other companies; they are a "custom powder coater."

   Tucson Spraying Technology: Electrical components.

4. Do you apply powder coatings to products manufactured by other companies? If so, please list the item you coat.

   AMSCO: No

   Hamilton Industries: No

   Erie: Yes. Pumps, valves, plumbing fixtures, chemical processing equipment, computer equipment, hospital equipment, food processing equipment, window frames, playground equipment, and electrical components.

   Tucson Spraying Technology: Electrical components, aerospace.

5. Are there identical (or similar) products coated by your company with liquid coatings? If so, please provide a comparison of advantages and disadvantages of the two coating types (include factors such as cost, performance, ease of application, etc.).

   AMSCO: Yes, some similar parts are liquid coated. Powder is preferred for the following reasons: (1) thickness control is better with powder, (2) finish control is better, (3) coverage is better and there are fewer parts rejected for areas not covered, (4) cleanup is very simple and easy with powder; there are no chemicals required for cleanup with powder, (5) powder-coated parts are more durable and can withstand strong cleaning agents, and (6) powders are easier to handle and apply.

Hamilton Industries: Yes, identical products in their laboratory casework line are finished with liquid coatings; advantages of powder coating are: (1) cost of powder coating is greater than cost of liquid coating, but the p.c. performance is better and fulfills product requirements, (2) powder coatings are easier to apply.

Erie: No

Tucson Spraying Technology: Powder coating is more cost effective than liquid coating; less EPA problems, less rejects with powder coatings.

6. How many different colors of powder coatings are applied?

AMSCO: Three different colors applied

Hamilton Industries: 22 different colors applied

Erie: 20 different colors applied

Tucson Spraying Technology: Approximately 40

7. If several colors are applied, how much time is required for a color changeover? How often are changeovers made?

AMSCO: 20 minutes to change colors, ~1 color change per day

Hamilton Industries: Colors are changed in ~25 seconds; change overs are made several times an hour

Erie: 15 to 20 minutes between changes; changes are made one to four times a day depending upon the volume of each color

Tucson Spraying Technology: We can color change in 15 minutes. We may change colors 7 to 10 times daily.

8. How many "lines" are used to apply powder coatings? How many booths and spray guns per line?

AMSCO: One line with three spray booths (one spray gun per booth)

Hamilton Industries: Three lines; one line has four booths and five operators, another line has one long continuous booth and five operators, the third line has two booths and two operators

Erie: Three conveyor lines; one has four auto guns and one manual gun (two booths); another has one manual gun or a fluid bed (one booth), and the third has one manual gun (one booth). They also have four batch coating areas that each uses one manual gun.

Tucson Spraying Technology: Two job shop booths.

9. What type of application equipment do you use to apply powder coatings? What types of powders do you apply?

AMSCO: Powder is applied using Nordson Paint equipment; they use three powder coating suppliers: (1) O'Brien Corp., (2) International Paint, and (3) Morton Thiokol, Inc.

Hamilton Industries: Electrostatic spray for all but a small percentage which is applied via fluidized bed; coating types are epoxy (electrostatic) and nylon (fluidized bed).

Erie: Nordson and Volstatic electrostatic guns; all types of powders including: PVC, nylon, epoxy, polyester, Teflons, Ryton, Kynars, etc.

Tucson Spraying Technology: Nordson Equipment, many powder suppliers--primarily Morton.

10. What coating film thickness is routinely achieved on your powder coated products?

AMSCO: ~4 mils

Hamilton Industries: Average ~1.5 mil or greater

Erie: 1 to 125 mils routinely applied

Tucson Spraying Technology: 1.5 mils

11. What are the curing requirements for your powder coated products (temperature and time)?

AMSCO: All coatings baked at 375°F for 15 minutes

Hamilton Industries: Cure requirements are 350°F for 18 minutes

Erie: Minimum temperature of 350°F for 40 minutes and maximum temperature of 750°F for 8 hours

Tucson Spraying Technology: Average 20 to 30 minutes per load

12. If your powder coating line replaced a conventional liquid coating line, please provide the following information:

AMSCO: Did not replace conventional liquid coating line

Erie: Did not replace conventional liquid coating line

A. Why did you convert to powder coatings?

Hamilton Industries: Switched due to requirements for resistance to strong chemicals in their laboratory casework line

Tucson Spraying Technology: We started with powder and added liquid

B. Which components of the existing liquid line could be adapted to powders?

Hamilton: Conveyors and booths easily adapted

Tucson Spraying Technology: None

C. What additional equipment had to be added to apply powders?

Hamilton: Electrostatic application equipment and hoppers

Tucson Spraying Technology: All

D. Did product specifications have to be changed (colors, film thickness, etc.)?

Hamilton: Color offerings reduced; film thicknesses increased

Tucson Spraying Technology: Some manufacturers had to initiate a powder specification as none existed with their company

E. If you operate a coating job shop, did you lose (or gain) customers as a result of changing to powders?

Hamilton: N/A

Tucson Spraying Technology: Gain

F. Has productivity been affected? How and why?

Hamilton: Fewer rejects because greater film thickness covers irregularities in the substrate

Tucson Spraying Technology: Yes. Powder is less labor-intensive

G. Was extensive operator training required? How did training time compare with training an employee to use liquid coatings?

Hamilton: Training time was about the same for application of powder vs. liquid

Tucson Spraying Technology: Powder coating can be done by less expensive employees than liquid

H. What unexpected problems have you encountered? How were they resolved?

Hamilton: Tendency is to apply excessive film; this was overcome by zone spraying in conjunction with the use of smaller nozzles by certain operators

Tucson Spraying Technology: Pretreatment equipment is an absolute

I. What reactions have you received from customers?

Hamilton: Customers prefer powder coat; specially formulated coatings are highly chemical resistant on their products

Tucson Spraying Technology: They like the durability. They can get more product to market with less assembly damage

J. Are you pleased with your decision to convert to powder coatings?

Hamilton: Yes

Tucson Spraying Technology: We did not convert to powder, we started with powder coatings--answer yes.

13. If your powder coating line is a new facility (not a converted line), please provide the following information:

Hamilton: N/A

Tucson Spraying Technology: Although their powder coating line was a new facility, they responded to question 12 rather than 13

A. Why did you select powder coatings rather than liquid coatings?

AMSCO: Greater durability of powder over liquid coatings; their products are subjected to some strong cleaning agents in the sterile environment and powder-coated surfaces are much more durable

Erie: Selected powder coating because it offered a nonpolluting process that was competitive with paint; also, powder coatings performance vs. paint was impressive

B. Did you obtain cost quotes for powder and liquid systems? (If so, please provide copies or summarize differences.)

AMSCO: No response

Erie: No

C. Has the powder system met your expectations? If not, please describe problems.

AMSCO: Yes

Erie: Exceeded their expectations

D. Are you pleased with the decision to use powder coatings?

AMSCO: Yes, powder met expectations and is much easier to handle and apply

Erie: Yes

14. Have you encountered problems with the storage, handling, distribution, or application of powders? If so, what were they and how did you resolve these problems?

AMSCO: No problems. They only order ~2 weeks quantity of powder at a time

Hamilton Industries: Powders of limited use, which may be stored during hot weather, and may be stored for periods longer than 6 months, may produce rough surfaces. Powders should be stored in a cool area; old powder may have to be discarded

Erie: No problems

Tucson Spraying Technology: No

15. Please provide information on the capital and operating costs of your powder coating system, broken out by components if possible.

AMSCO: Total capital cost ~$200,000; this includes booths, application equipment and two ovens. Estimated cost of the powder coating ~$0.058 per square foot

Hamilton Industries: Information not readily available

Erie: Paid $150,000 for "used" coating line

Tucson Spraying Technology: We have a capital equipment investment of approximately $150,000.

16. Please describe limitations associated with powder coatings that prevent you from using them on other products. (Include items such as cost, performance, and application limitations.)

AMSCO: Would prefer to powder coat all items, but it is not cost-effective to change all of their engineering prints and documentation at this time

Hamilton Industries: (1) special colors would require development by the suppliers, and therefore, those items requiring special colors are not done as powder coating, (2) performance has improved, (3) special effects such as spatter texture may pose problems; however, texture powders are available if satisfactory to customers

Erie: No limitations. They powder coat parts from 1 inch in diameter to 4 feet long and 12 inches in diameter

Tucson Spraying Technology: (1) orange peel, (2) excessive build up in corners of enclosures, (3) color selection and availability

17. What percentage of your "overspray" is collected for recycle or reuse? How is this done?

AMSCO: 95 percent of all powder overspray is collected in a filter for reuse; the powder is run through a sifter prior to reuse to insure its cleanliness and uniformity

Hamilton Industries: None

Erie: Depends upon: volume of parts being run, the particular color, cost of the materials, and the configuration of the part being coated; they have the capacity to reclaim ~35 percent of the overspray

Tucson Spraying Technology: None

18. Are there solid waste disposal problems associated with your powder coating system?

AMSCO: None. Because 95 percent of powder is reclaimed, there is very little waste to deal with

Hamilton Industries: No

Erie: None; when they have powders to dispose, they put the powder in boxes and "cure" the powder into a hardened block to prevent problems with "dust"

Tucson Spraying Technology: None

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16. ABSTRACT

The objective of this report is to provide an overview of the current status of powder coating technology. Because powder coatings are applied as dry, finely divided particles, there are no volatile organic compounds (VOC's) released during application, and only minute quantities are released during the curing process. Therefore, the increased use of powder coatings, as an alternative to liquid solvent-based coatings, represents a significant reduction in emissions of VOC's. This report describes current powder coating materials and equipment, end uses, and economic advantages of the use of powder coatings. Included in the report are discussions of the disadvantages and potential problems identified early in the powder coating development process. The report addresses the resolutions of many of these problems.

This report is intended to be of use to State and local agencies in their evaluation of powder coatings as an alternative to coatings containing VOC's.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Powder coating technology Powder coating end uses VOC emissions reduction	Surface coating Coating systems Industrial finishes VOC's	

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