Powder coatings: Not just another pretty finish

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If someone told you that you could replace your existing organic finishing system with one that was completely environmentally compliant and run it at lower operational costs, would you believe him? You might respond, "I'm not interested in trying new technologies that don't have a proven track record." What if this same person told you that this technology has proved itself in thousands of installations throughout North America since the mid-1960's (Figure 1). Would that allay your fears? You might ask, "What is the performance of this new coating?" The advocate would reply, "In most cases, this type of coating has superior performance and appearance qualities when compared with all other organic finishes."

By now, you would be wondering, "What new type of miracle coating is this person talking about?" And your friend would answer wryly, "Powder coating." You would then say, "I looked at that technology years ago and determined it to be too expensive to convert, too difficult to apply, too time-consuming to change colors, and too thick for my product." The advocate would suggest that you should reevaluate this technology in light of recent improvements and cost reductions.

Although this article doesn't cover all the technical issues of the powder coating process, it does give you a general description of the materials and equipment that are unique to this process. It also outlines the advantages and dispels the myths that have been associated with this finishing technology.

FIGURE 1

Applying powder coatings onto parts in an automatic spray booth

Photo courtesy Diamond Vogel Paint & Coatings.

What are the basics of the powder coating process?

All powder coating systems must have clean, dry parts before the powder is applied (Figure 2). Normally, the parts are cleaned and pretreated with aqueous-based chemicals and then dried in an oven, although mechanical cleaning (that is, media blasting) is acceptable as well. Of course, all parts that have been powder-coated must be cured (Figure 3) by using either heat alone or a combination of heat and ultraviolet (UV) cure systems.

Powder coating materials. Powder coating is an organic finish that's divided into two basic categories: thermoplastic powders and thermoset powders.

Thermoplastic powders. These coating materials are applied as dry particulate, melted, and flowed into a smooth coating when exposed to heat (approx-

FIGURE 2

Cleaning parts in a spray washer

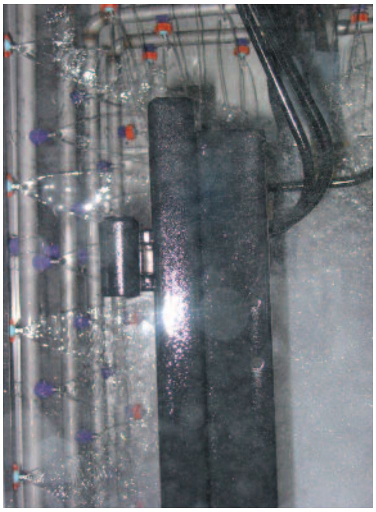


Photo courtesy Chemtec North America.

imately 300°F). After initial application and cooling, these materials will soften and flow again if exposed to heat. Examples of thermoplastic powder coatings are nylon, polytetrafluoroethylene (PTFE, or Teflon), polyethylene, and vinyl. Most thermoplastic powder coatings require a liquid primer to be applied to the part substrate to improve the marginal adhesion characteristic of these materials. These materials are normally used as functional coatings, providing corrosion protection, slip enhancement, detergent resistance, electrical insulation, and so on.

FIGURE 3

A bi-level powder coating cure oven

Photo courtesy General Fabrications Corp.

Thermosetting powders. These coatings are the most common materials used in today's marketplace. They're chosen for both their excellent functional and appearance properties. Thermoset powder coatings are applied as dry particulate, melted, and flowed when exposed to heat (above 250°F). After melting, the coating is then cured with heat or UV energy to form a densely crosslinked durable coating. However, these coatings won't soften again when exposed to heat after initial application, cure, and cooling. Thermoset powder coatings come in a variety of formulations that include epoxies, polyesters, triglycidyl isocyanurate-based (TGIC-based) polyesters, acrylics, and hybrids.

Powder coatings can be purchased in either spray grades or fluidized-bed grades. Matching the powder coating to the application method is important in achieving the desired results. For instance, fluidized beds should use fluidized-grade powder coating formulations. These formulations are normally ground coarser than spray grades, resulting in a larger particle size that will aid the fluidization of this material. Conversely, spray-grade powder coatings are ground finer than fluidized-bed grades, resulting in a smaller particle size that will pump better and is more easily atomized to achieve thinner film builds.

Powder application techniques. Powder coatings can be applied by using either fluidized-bed techniques or spray techniques. When choosing an application technique, you need to consider the following:

- Does the coating need to be functional, decorative, or both?
- How much film thickness control is needed?
- What is your production rate?
- How many color changes do you need to make?
- Are there Faraday-cage[1] areas on the parts?
- What is your product size?
- What is your desired coating quality?

Careful consideration of these issues will determine which application method makes the most sense for you.

Fluidized beds have been used to apply powder coatings to parts since the 1950's. This method can use thermal attraction or electrostatic attraction to deposit the powder particles onto a given part. If you want to apply thick-film functional coatings (that is, more than 10.0 mils), then thermal attraction is your best bet. Here you preheat the part to above 350°F and dip it into a fluidized bed of powder coating. The heat attracts the particulate to the part and may partially melt it onto the sur-

FIGURE 4

Powder coating hoppers

Photo courtesy Nordson.

FIGURE 5

Corona-charging spray guns

(a)
Manual

(b)
Automatic

Photos courtesy Nordson.

face. Final melting and full cure of thermoset powder coatings occurs when the part is further heated to the prescribed metal temperature. With thermoplastic powder coating, the part is further heated to achieve the desired surface smoothness, texture, or both. Film thickness is controlled in this process by the heat of the part and the time the part is in the fluidized bed.

Electrostatic fluidized beds use ionized air to charge the powder particles, which are attracted to a grounded and cool part transported either above the bed or into the bed. Varying the time in the bed and the charge on the powder particles controls the film thickness on the part. After the parts are coated, they need to be heated to melt/flow the material and, in the case of thermoset powder coatings, to fully cure.

Spray application techniques for powder coatings can be broken down into several categories: corona-charging guns, tribo-charging guns, flame-spray guns, corona-charging bells, and tribo-charging discs. All of these methods require powder to be pumped from a vibrating box feeder, fluidized hopper, or gravity hopper. The pump uses compressed air to draw powder from the box or hopper (Figure 4) through the use of the venturi principle, which propels it to the spray device via a powder feed hose. Both powder volume and transport speed can be adjusted at the spray apparatus control panel. Atomization of the powder particles occurs at the spray device where the particles are deflected, spun, directed, or air-atomized into a well-dispersed cloud. The powder within this cloud is electrostatically charged or melted in the case of the flame-spray gun. The powder particles are then attracted to a grounded part to form a continuous film between 1.0 mil and 10.0 mils thick, depending upon the desired application constraints. Film thickness tolerances can be controlled to ±0.20 mil in a well-designed and closely controlled process.

Corona-charging guns (Figure 5) and bells use an electrostatic generator that creates an electrostatic field between the gun and the grounded part. The powder particles accept the electrostatic charge as they penetrate this field and are attracted to the grounded part. Electrostatic voltages are adjustable at the control panel up to 100 kilovolts. The current within this field can approach 80 microamperes. Some units have automatic feedback systems that vary voltage to maintain a constant current within the electrostatic field. This leads to more consistent film thickness control and makes it easier to powder coat complex shapes. Corona guns are most commonly used today to coat a variety of products. The powder pattern with guns is achieved by using conical deflectors, fan spray tips, or pneumatic atomizers. Selecting the right pattern control device will allow for large well-dispersed patterns useful in coating flat areas or narrow and focused patterns designed to penetrate recessed areas.

Corona bells are used in applications in which large flat areas need to be coated at a high rate of speed. If you have to spray a lot of powder in a short period of time onto a relatively flat surface, then these are the preferred application devices. Typical bell applications are automotive car bodies and appliance outer shells. The charging technique is the same as the one used in corona guns, with similar effect.

Tribo guns (Figure 6) and discs use frictional charging techniques to charge the powder particles. Powder particles develop this charge by the rubbing action caused by meandering charging/transport channels molded into the gun/disc body. These channels are normally much longer than those used in corona equipment to ensure that each powder particle has had an opportunity to accept a tribo charge caused by the rubbing action between these channel surfaces and the particle. The amount of charge imparted on the powder particles is directly related to the materials sprayed and the composition of the channels along with the duration of frictional contact between the particle and the channel surface. These powder application devices are more suited to overcoming Faraday-cage problems than corona-charging application devices because they don't use electrostatic fields to charge the powder particles.

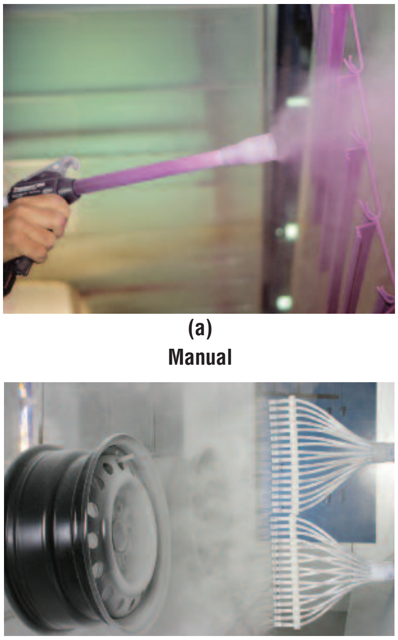
Flame spray powder coating equipment is typically used to coat large objects with thermoplastic powders where using an oven is impossible. This equipment ignites liquefied petroleum gas (LPG), or other combustible gasses, at the gun tip where the resultant heat combines with thermoplastic powder pumped by compressed air from a feed hopper. The heat melts the powder as it is propelled to the part surface, resulting in a continuous protective coating (8.0 mils to 10.0 mils thick) that is both durable and highly corrosion resistant. Flame-spray devices are used to apply protective thermoplastic powder coatings to very large parts, such as water tanks, tanker railcars, and bridges.

Powder spray booths and recovery systems. Powder spray booths differ from liquid spray booths in their filtration techniques and fans. In liquid systems, simple, and relatively coarse, filters stop paint droplets while the solvent fumes are exhausted from the plant airspace. Powder booths use much finer filters than liquid booths to stop small powder particles and, in most cases, return the air back into the plant airspace. Because the filters are finer and hold some of the waste powder onto their surface, the fans used in powder booths are typically rated at a higher static pressure than those used in liquid booths.

All powder coating booths are designed to accomplish the same goals: containment of the powder particulate

FIGURE 6

Tribo-charging spray guns



(a) Manual

(b) Automatic

Photos courtesy Nordson.

within the spray booth and separation of this particulate from the airstream by using filters for reuse or disposal. Some spray booth designs, which use contained and separate collection systems, require that enough air be introduced into the spray area to ensure a safe condition. Furthermore, all powder booths that return the booth air back to the plant airspace must use final filters capable of removing particulate down to 0.3 micron. This fine filtration will ensure that all safety codes for personnel areas are enforced, while the returned air will eliminate any air make-up requirements.

Powder booths come in three configurations: cartridge (Figure 7), cyclone (Figure 8), and filter belt. Cartridge booths use paper or fabric cartridges in a collection system to separate the powder particles from the containment airstream. Cyclone booths use cyclone(s) to remove most of the powder particulate before it's further cleaned by a cartridge collector. Filter-belt booths use a rotating internal fabric belt to separate the particulate from the airstream while a separate collection device vacuums the belt clean. Selecting which booth is best-suited to your particular application is accomplished after careful consideration of many factors:

- Colors to be sprayed or collected
- Color change time requirements
- Floor space available
- Additional safety devices needed (segregation dampers, explosion vents, and explosion ductwork)

Because the filtration techniques used in powder coating are so efficient, collection of the overspray powder material for reuse is a definite advantage to this process. Sometimes the amount, and subsequent value, of the overspray powder material is so small that collection for reuse isn't prudent. In these cases, powder coatings can be disposed of, in most cases, as non-hazardous materials. Systems that reuse overspray powder material incorporate sieves and fresh powder replenishment devices to ensure properly conditioned powder material necessary for consistent product quality. (See Figure 9.)

Powder booths come in all shapes and sizes. Batch-type booths, in which products are manually transported into and out of the booth, can be small bench-top designs or large walk-in booths capable of containing 20-foot, or larger, parts. Conveyorized booths, in which products are automatically transported through the booth, are available in standard sizes or custom designs. These booths can be designed to be compatible with chain-on-edge (Figure 10), powered-overhead (Figure 11), or power-and-free-overhead conveyor systems. Equipment suppliers offer limitless booth designs that can accommodate high- or low-volume production requirements for just about any size product.

FIGURE 7

Cartridge spray booth system

Photo courtesy Gema USA.

FIGURE 8

Cyclone spray booth system

Photo courtesy Gema USA.

FIGURE 9

A powder coating spray booth sieve and hopper system

Photo courtesy Deimco Finishing Equipment.

FIGURE 10

A chain-on-edge conveyorized powder coating system

Photo courtesy Deimco Finishing Equipment.

Lean manufacturing systems have gained great popularity in recent years with powder coating systems that use spray-to-waste booths in conjunction with quick color change application equipment. These systems (Figure 12) depend upon the high transfer efficiency of the application gun to apply most of the powder onto the part, reducing the amount (and value) of the overspray powder coating. Color change can be done literally in seconds by selecting the next color right at the gun, often by using a color selector panel and a feed center where numerous colors are waiting in individual hoppers. Since the collection system is a spray-to-waste design, cleaning the booth is unnecessary.

What are the advantages of powder coating?

This article started with several sweeping statements about this finishing technology. Now I'll provide testament to these statements. I'll discuss most of the misunderstandings and myths (see sidebar) that have surrounded this technology since it has gained prominence in the past 3 decades.

Environmental issues. All powder coatings are reportable VOC[2]-free materials, and most of them are considered landfill (non-hazardous) materials. Powder coatings contain no solvents and in most cases contain no heavy metals. In fact, only zinc-rich epoxy primers are considered hazardous for their heavy-metal content. Pigments have long been heavy-metal-free to ensure easy disposal of powder coating formulations. Imagine taking your waste coating materials, spray booth filters, and gun parts, and simply throwing them away with your normal plant garbage. Powder coating end-users do just that every day in just about every municipality in North America. They may have to melt the powder to eliminate dust problems, but that normally is all the municipality requires.

Safety issues. Powder coatings are remarkably safer than normal solvent-borne coatings. Solvent fumes readily catch fire and can be a health threat to plant personnel. Powder coating materials aren't flammable but may combust in a very narrow concentration of powder and air. Insurance underwriters rate powder systems much safer than liquid systems, resulting in lower premiums. Sprayers only have to wear personal protection categorized for nuisance-dust environments as opposed to clunky respirators required for most liquid paints.

FIGURE 11

An overhead conveyorized powder coating system

Photo courtesy Deimco Finishing Equipment.

FIGURE 12

A fast-color-change spray booth system

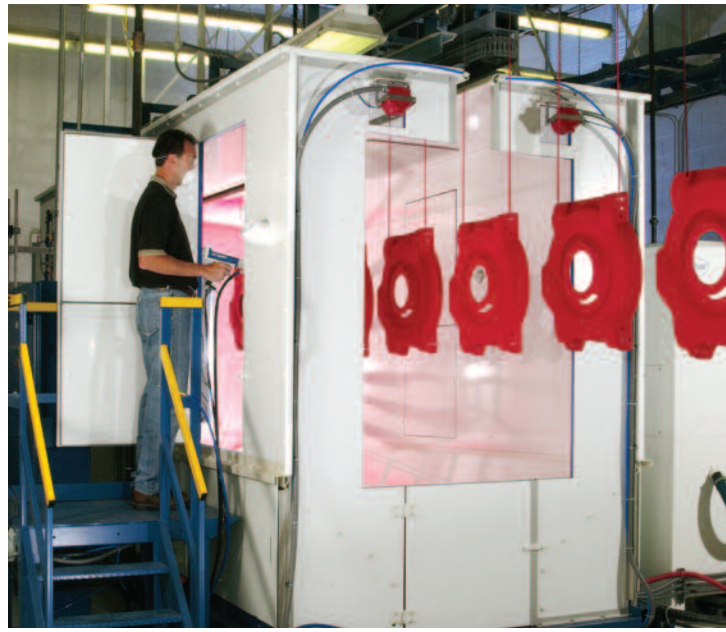


Photo courtesy Nordson.

Coating performance issues. Thermoset powder coatings have remarkably better mechanical, corrosion, and chemical resistance when compared with all other organic finishes. This is mainly due to the molecular weight of the powder coating and dense cross-linking when fully cured. Further, because of the absence of solvent, a powder coating has less porosity than liquid paint. All these conditions make powder coatings more durable (that is, harder, more impact resistant, more flexible, etc.), more corrosion resistant (up to 5,000 hours salt-spray resistance on aluminum substrates), more chemical resistant, and more weather resistant than liquid coatings. Superior coating performance properties have made powder coatings the preferred choice by designers looking for a "bulletproof" organic coating.

Operational cost issues. Powder coating processes are cheaper to operate than other organic finishing processes. The most significant cost savings is realized in lower coating material cost. Powder coatings are cheaper and can cover more area than just about all other organic finishes. With powder coatings, systems can be designed to accommodate denser product hang patterns allowing for higher productivity for each minute of run time compared with liquid systems. Powder coatings lend themselves well to automation, reducing operational labor costs. Because most powder coatings are non-hazardous and don't contain solvents, disposal costs are dramatically reduced and spray booth make-up air is eliminated. With no make-up air requirements and lower cure oven exhaust requirements, the powder coating process requires less energy to operate than liquid coating processes. Lower reject rates (typically under 4 percent) experienced with powder coating systems mean you spend less time and money reworking bad products.

Proven track record. Powder coatings have been used in the North American market since the late 1960's and in Europe even longer. Although no one knows for sure how many powder coating systems there are in the US, Canada, and Mexico, some say the number is in the tens of thousands. Powder coating is the fastest growing segment of all finishing technologies without dispute.

MYTHBUSTERS

Five common myths preventing liquid-to-powder conversions

Myth #1: It's too expensive to convert to powder coating. Complete systems, including pretreatment, ovens, spray booths, and guns, cost nearly the same for either liquid coating or powder coating. This fact is undisputed. However, when you're converting an existing liquid system to powder coating, you'll need to replace or retrofit the spray booth. Also, in some cases, the existing liquid system's pretreatment equipment or cure oven can't support the demands of powder coating.

The best way to determine if the existing pretreatment equipment can be used for a powder coating process is to do a water-break-free test[1] on parts as they exit the pretreat equipment. If the parts pass this test, then the equipment can be used. Most times a change in pretreatment chemical strength or formulation will improve this process sufficiently to accommodate the cleanliness requirements of the powder coating process.

Cure ovens used in a powder coating process must provide the time at metal temperature to properly cure the powder coating. Each powder coating formulation has its own time-at-temperature requirements, but most powder cure requirements are both longer and hotter than typical liquid paints. Verification of your specific oven should be made by the powder coating supplier. If the supplier approves the oven, then you're in luck. If not, you can add an infrared booster as a very quick and easy way to gain the metal temperature in the reduced dwell time of your existing oven. Furthermore, low temperature cure powder coating formulations can be an additional method of accommodating your existing cure oven. These materials can be fully cured at lower oven temperatures or in shorter dwell times than standard powder coatings. However, these materials may not have the high performance properties your product may need, and they must be stored and used in an environmentally controlled room.

Even if the cost to convert to powder coating is higher initially, payback and return on investment (ROI) favors powder coating because of its lower operational cost when compared with liquid coating. This fact has been proved in many installations in North America; some companies have experienced 2, or less, years' payback (more than 50 percent ROI). Very few investments can guarantee that high a yield.

Myth #2: Powder coatings are difficult to apply. Powder coatings require a slightly different manual application technique than liquid paints. With liquid paints, often the gun is triggered on and off with each pass to prevent runs. Each pass by the sprayer must be made fast to reduce runs or sags. Powder coatings, on the other hand, should be applied in slow, deliberate gun motions without triggering on/off. This ensures that the powder is properly charged and deposited evenly on the surface. Because of their formulation properties, powder coatings are extremely resistant to runs and sags at film builds up to 8.0 mils thick. In fact, powder coatings are so easy to apply that most companies have difficulty preventing manual sprayers from applying too much powder on their parts. This brings us to our next myth.

Myth #3: Powder coatings are applied too thick. Powder coatings have a reputation for being thick coatings. True, powder coatings are normally applied in the 1.5- to 3.0-mil range compared with liquids applied in the 0.5- to 1.5-mil range. But this is normally due to operator error than anything else. Powder coatings have been successfully controlled in many applications to 1.5 mils (±0.2 mil). Most people are too lazy to implement the process control or to maintain the equipment to ensure this level of control. And because powder coatings are so cheap, they would rather write-off the additional coating expense than implement the controls required to maintain a tighter film thickness. This fact is further reinforced because of powder coating's resistance to runs and sags. Frankly, heavily coated parts are always acceptable (except when the coating is so thick that you can't assemble the components), and light coverage sometimes requires re-coating. So, most people err on the heavy side.

Myth #4: Color change is difficult with powder coatings. This myth always bothered me. People look at minutes to change liquid colors, which normally require flushing the guns with solvent and connecting a new pressure pot. Well, powder guns can be cleaned just as easily by flushing with compressed air and changing powder hoppers (or the powder box when using box-feeder equipment). The real problem occurs when the powder coating is reclaimed for reuse. In these systems, the reclaim equipment must either be cleaned or be changed to get ready for the next color (reclaim is obviously a benefit for powder coating), taking 15 minutes to 1½ hours, depending upon the size and amount of reclaim equipment. This may seem ridiculously long for a color change, but if you reclaim sufficient overspray powder to justify the effort, then you gain the benefit of reduced operating cost.

Most people have difficulty in determining which colors they should reclaim and often reclaim colors that aren't economically justified. It's then that they complain that it takes 1 hour to change a color they're spraying for only 10 minutes. But look at the reasoning these people use: "Because powder coatings allow you to reclaim, you should reclaim every color." If you sprayed liquid paints before without the possibility of reclaiming, why would you collect every powder color for reuse? Powder should be reclaimed only if it's economically justified. If you follow this rule, the time and cost for color change will be offset by the value of the reclaimed powder. If it doesn't, then scrap the powder overspray as you would with liquid paints.

Let's not forget the newer lean manufacturing powder coating systems that perform color change in spray-to-waste booths in seconds. These systems have gained great popularity where on-demand color change is required to provide the flexibility demanded in lean manufacturing environments.

Myth #5: Color matching with powder coatings is impossible. Maybe at one time getting powder coatings in all colors was impossible, but that's no longer the case today. Some powder coating formulators boast more than 300 stock colors and textures. Other powder formulators will specially match your color in 5-pound quantities or more. This means that if you need a special color or texture in powder coating, you'll most likely find a stock material or have it custom-formulated for you. Deliveries of special materials may take a bit longer, but are normally worth the wait. True, you can't just go to your local paint store for a color-matched powder coating (at least not yet), but getting custom powder coatings in a day or two isn't so bad. Besides, that's why FEDEX is in business.

Endnote

1. A water-break-free test indicates cleanliness. Parts exiting the last rinse stage before drying will show uniform sheeting of the rinse water. If the part isn't clean, it will have a beaded surface that resembles a freshly waxed car after a good rain. From "Surface Cleanliness Tests," by Brad Gruss, *Powder Coating Pretreatment and Stripping Desktop Reference*, August 2005, p. 22.

Why do people convert to powder coating?

Although it may seem that there are infinite reasons why people convert to powder coatings, I've learned to fit them into the following categories:

- New system: Powder coating is often the choice when either the old paint system is worn out or a first-time system is being installed. This fact is proved over and over because the cost for new equipment for either powder or liquid is nearly the same. When you look at the other benefits of powder coating, the decision normally favors powder coating.
- Superior coating performance: Many original equipment manufacturers (OEMs) look to powder coatings to improve their products performance in the field. Powder coatings are well-known for their improved durability and long service life. Taking advantage of this superior coating performance can be a strong reason to use powder coatings on your OEM products.
- Marketing advantage or competitive pressure: Since powder coatings have gained more acceptance, many OEMs highlight the superior coating properties of powder coatings in their marketing literature. If you compete with an OEM who offers a powder coating finish on his or her products, you may be at a marketing disadvantage with your old, inferior, liquid-painted product. Using powder coatings will level the playing field and may give you the advantage if you're the first to use this technology in your industry.
- Environmental conformance: Powder coatings are one of the few finishing technologies that meet all EPA requirements for air and water pollution control. If you want EPA compliance, then powder coatings are the answer.
- Reduced coating cost: The applied material costs for powder coatings are typically 50 percent cheaper than that for conventional liquid paints. Energy and manpower costs are also cheaper with powder coatings. Overall, this means it can be 50 percent to 70 percent cheaper to run a powder coating line than a liquid coating line.

How do I find out more about powder coating?

There are several books on powder coating. I've edited two of them and consider them to be the most complete texts. They are *Powder Coating—The Complete Finisher's Handbook*, published by the Powder Coating Institute [www.powdercoating.org]; and *The User's Guide to Powder Coating*, published by the Society of Manufacturing Engineers [www.sme.org]. Both these publications are available on my website [www.powdercc.com]. These and other books are also available through the magazine's website at www.pcoating.com. You can also call me at 800/97-POWDER. I'll be happy to discuss your application.

Once you've had the opportunity to examine powder coatings, you'd be hard-pressed not to convert to this technology. **PC**

Endnotes

1. See the glossary sections in this issue.
2. Volatile organic compound

Editor's note

For further reading, see the "Index to Articles and Authors 1990-2018" in this issue, or search the Article Index at www.pcoating.com.

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