SUPPLEMENT TO
Powder Coating

Troubleshooting Guide: Problems & Solutions

August 2009

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Using reverse-osmosis systems to recycle used rinse water

Thomas Borcherding  TB Sales

Although powder coatings are dry, companies that apply them require large amounts of water to expedite the finishing process. Despite the fact that water was cheap and plentiful at one time, finishers now know it’s not an infinite resource that can be squandered. By using reverse osmosis (RO) and deionization (DI) technologies, finishers have found ways to reduce their water consumption. This article focuses on RO technology to recycle used rinse water. It also discusses the history of water use in the powder coating industry. It then explains how RO and DI technologies came to play a role in water treatment and how RO can be used to recycle as much as 90 percent of the rinse water used in surface preparation.

The powder coating industry demands a high volume of purified water to support production. Finishers use purified water to clean and rinse parts. Simultaneously, finishers face the need to reduce the total volume of wastewater from their plants. As companies begin to find out that many of their waters can be reused internally by containing them and then repurifying them, finishers are also finding that the process involved is so simple, it’s often cost-effective for them to reclaim the water. This is particularly true when membrane processes are used to treat water because the water recovery for reuse is extremely high, typically around 80 to 95 percent.

Water use reduction is becoming essential to the powder coating industry. Finishers have reduced their water consumption through reuse and reclaim processes that have resulted in a lowered total amount of water used. Water use reduction, if implemented correctly, translates to a reduction in cost. However, this cost saving is only one reason to reduce water use. A growing customer demand for industrial environmental responsibility has prompted several companies to develop environmental management systems (EMS) and to become International Standards Organization (ISO)1 4001 certified.

Certification in the ISO 14001 standard is partly based on the requirements of a company’s EMS to identify the environmental aspects derived from their operations, set objectives and targets to minimize significant aspects, and to commit to continual improvement. By reducing water consumption, companies have reaped many benefits. For instance, companies have been able to reduce costs, increase the efficiency of their operations, and reduce the consumption of natural resources in today’s environmentally conscious community. Finishers can make significant reductions in wastewater discharge by eliminating an unneeded prerinse step or by counterflowing rinse baths and then reclaiming the used rinse water.

Finishing businesses take water availability for granted

With regard to water and related issues, the powder coating industry is just emerging from its infancy. Powder coaters began by using water as a utility. They used water for

- Coolant
- Heat transfer
- Rinsing purposes
- Cleaning purposes
- Chemical solution preparation

During the industry’s infancy, water was relatively abundant and inexpensive. Because water was plentiful and cheap, finishers took it for granted. As the industry developed during the past 2 decades, relatively large quantities of water were used on a once-through basis. Even high-purity final rinse water wasn’t conserved, recycled, or reused in the same application. Industrial times weren’t only good, they were great. The use of water in the powder coating industry continued to grow; simultaneously, the reuse and conservation of water continued to be neglected.
Then, a change took place. Water became the target of the public eye. In addition, two other interesting results put pressure on water-related issues. First, because the industry grew rapidly and because corrosion science had a tendency to be widely misunderstood, older plants and equipment, such as washers, began to leak. Bear in mind that some of these plants were built rapidly and often with less than the most sophisticated engineering. Multiple materials came in contact with each other, corrosion resulted, and leaks occurred. Leaks, sludge, scale buildup, and plugged nozzles all caused downtime. Downtime threatened to ruin the economical aspect of powder coating.

Second, a related and even more misunderstood issue occurred with water. The amount and type of contaminants found in raw water supplies throughout the country varied considerably. Mineral hardness, bicarbonate alkalinity, and total dissolved solids (TDS) content began to affect washer chemistry. That, in turn, affected powder adhesion.

Finishers had a tendency to overlook water problems because they considered water a utility rather than a product. An industry that started out by taking water for granted had now grown to where water had become a major problem. Now, the management of water promises to dominate the next 2 decades of changes in the powder coating industry. The use of water in washers is complicated by the wide variety of materials finishers have used through the years in their water-transporting systems and by the chemicals finishers have been adding to the water to control unwanted water-formed scale or debris, biological fouling, and many types of corrosion. By adding chemicals, cleaners, phosphates, and sealers, along with the natural chemical concentration that occurs when water is evaporated, the powder coating industry is finding it necessary to staff its plants with personnel who can manage water or to outsource the job to companies capable of fulfilling this function as service vendors.

Whatever the case, powder coating operations generate water and wastewater that must be contained, managed, and disposed of appropriately. The costs associated with these processes are no longer trivial; they’re significant production expenses. Finishers can no longer make the assumption that water is an inexpensive commodity.

The first step in water and wastewater management is awareness. As companies become aware of ways to reuse their water internally by containing and repurifying it, they’re also discovering that the process is so simple, it’s often cost-effective for them to reclaim the water. This is particularly true when membrane processes are used to treat water because the recovery rate of water for reuse is extremely high, typically 80 to 95 percent. Conservation practices may be new to the industry, but they’re becoming a way of life. Companies constructing new plants are instructing their engineers to keep water conservation, reuse, and recycling in mind when drawing up designs. This trend is likely to continue.

**Reverse osmosis replaces deionization systems**

Many pretreatment systems used in the powder coating industry rely on reverse osmosis (RO) and deionization (DI) technologies for water treatment. [See “Replacing deionizers with reverse osmosis technology to purify water for multistage washers” Powder Coating, vol. 11, no. 3 (April 2000), p. 23.] However, RO is replacing DI as the technology of choice for many coaters. Although the technological advances in powder coating chemistry and related equipment are significant, the pretreatment process, where parts are prepared for coating, can’t be overlooked. This includes, as a minimum, spot-free final rinsing of the product before powder application. In addition, with many newer washers, pretreatment also includes purification of the water used in the entire washer.

RO is a relatively new technological development. The first RO systems date back to the 1970’s. In the years since then, the technology has matured. Today’s systems represent viable methods for reducing the concentration of materials dissolved in water. The technology has become applicable in widely diversified fields, including drinking water, fruit juices, waste treatment, and the production of highly pure process water for use in numerous industrial applications. RO technology uses a high-pressure pump to force water through a semipermeable membrane made of plastics. The water molecules are small enough to pass through the membrane, leaving behind the larger metal ions and mineral salts. In this manner, an RO machine can remove 97 to 98 percent of the TDS found in incoming feed water.

Early attempts to introduce RO for industrial use met with reliability and performance problems mainly associated with the high pressure required to achieve reasonable fluxes, the limits of membrane service life, the lack of operating experience, and the lack of guidelines. Following this rather questionable introduction, viable RO technology, based on a new generation of membranes and a better understanding of operating requirements, was eventually introduced in the 1980’s. The commercial introduction of RO then rapidly evolved so that today, most new and many retrofit water systems use RO instead of the traditional ion-exchange systems. Furthermore, by using specific and newly developed membranes, RO technology has worked successfully in other applications, including wastewater treatment.

In a typical five-stage washer system, such as the one shown in Figure 1, stage one uses 140°F water and alkaline cleaner to remove cutting oils and to degrease the parts. Stage two is an ambient-temperature city water rinse that continuously overflows to drain. Stage three is a surface preparation cycle using 130°F chemical solution containing iron phosphate. Stage four is another ambient-temperature city water rinse, also overflowing continuously to drain. Stage five uses a traditional deionizer for fresh DI water to achieve a spot-free final rinse. Many improvements have been made to this system design in recent years, including
replacing the final rinse water with an RO system (see Figure 2) that not only provides spot-free rinse water quality but also does this more efficiently and less expensively than the deionizer. Moreover, the continuous overflow to drain from the rinse stages can be reduced and sometimes eliminated when using RO water for the rinse baths.

**Recycling rinse water requires separation**

How do you recycle the used rinse water without overflowing it? To recycle the rinse water, you need to separate the used rinse water into a bulk storage tank so that you can repurify it. This stored water can now be continuously circulated through a series of filters, each specifically designed to remove certain impurities such as iron, mineral hardness, chlorine, organics, turbidity, suspended colloidal particulates, and dissolved salts. Figure 3 shows the whole washer RO system design. The system is similar to the RO system discussed previously, but with the addition of two more storage tanks, you can now separate the used rinse water returned from the washer and collect the concentrate waste stream from the RO machine for reuse.
your five-stage washer. Typically, the final 10 percent is sent to an evaporator or other means of disposal when you need to meet zero-discharge requirements. This system works well when the TDS of the used rinse water can’t exceed a concentration of 200 milligrams per liter (mg/L). The final concentrate to the evaporator will then stay below 800 to 1,000 mg/L, which in many instances is still cleaner than the raw water (city water) that you started with.

In summary

This article has discussed the advantages of RO technology as well as the advantages of incorporating RO into a new system design. The concept of having a whole washer RO with reclaim offers several advantages. For example, the whole washer RO system

- Recycles as much as 90 percent of used rinse water
- Reduces dumping and the need to recharge chemical stages with more chemicals
- Eliminates scale buildup on heat exchangers
• Reduces sludge buildup
• Provides a spot-free final rinse
• Increases finish quality by increasing powder adhesion

Consider these benefits and find ways to incorporate RO technology into your finishing process. This way, you’ll be making economical as well as ecologically wise decisions.

Endnotes
1. International Standards Organization, located at 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland; 011-4122-749-0111, fax 011-4122-733-3430; Web site is at [www.iso.ch]. ISO 14001 is the international standard for environmental management systems.

2. The Water Quality Association (WQA) provides detailed information about the quality of water supplied by municipal water systems in the US. For more information, contact the organization at: WQA, International Headquarters and Laboratory, 4151 Naperville Rd., Lisle, IL 60532; 630/505-0160; Web site is at [www.wqa.org]; E-mail address is [info@mail.wqa.org].

Editor’s note
For further reading, see articles listed under the Surface preparation headings in the “Index to Articles and Authors 1990-2008,” Reference and Buyer’s Issue, Powder Coating, vol. 19, no. 9 (December 2008) and check the Powder Coating Web site at [www.pcoating.com].

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Peridium powder coatings offer excellent application and performance characteristics. Our state-of-the-art technology allows for tightly controlled particle size distribution that provides extremely good first pass transfer, edge coverage and smoothness. We are behind you with every project you work on. Professional yet personal, unparalleled service and support, expert color matching, reliable inventory, and rapid response.
Metal Rehab Technologies sees rapid growth with Keppel Seghers’ help

Metal Rehab Technologies, Inc. is a custom metal cleaning service dedicated to environmentally compliant cleaning technologies. A Texas based company, located in Arlington, Texas; Metal Rehab began business by developing new and environmentally responsible chemical systems to remove organic coatings and rust from metals and rapidly became a premier service provider in the antique and classic car market nationally.

As the company grew, it became evident that other technologies must be added in order to meet additional market demands. Requirements for a new technology were:

1) must meet all local, state, and federal mandates and guidelines
2) must have a short cycle time
3) must be able to remove a wide array of coatings
4) must handle large numbers of small items in addition to larger ones
5) must be safe and relatively easy to operate
6) must be reliable.

After a great deal of research into various thermal and non-thermal processes and devices, Marietta, Georgia, based Keppel Seghers’ Fluidized Bed Technology became the obvious choice for meeting all criteria. A system was purchased and quickly proved to be all that was expected. This system rapidly and completely removed plastics, rubber, paint and an array of coatings from metal surfaces with no damage to the metal substrates. Because of a sophisticated control system for controlling temperature, it even cleaned spring steel with no degradation to physical characteristics. Short cycle times allowed pick up and delivery of paint line fixtures within a wide radius and led to servicing many other industrial applications.

Keppel Seghers’ Fluidized Sand Bed promoted rapid growth for Metal Rehab, and as a result a second larger system was recently purchased, adding increased capabilities and new markets to service.

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Keppel Seghers’ fluidized bed saves money for Valmont Industries

In 2006, Jerry Croy, Valmont Industries Elkhart Indiana's powder coat supervisor, was aware that grounding problems were affecting the efficiency of his powder coating operation. The weight of the product required tempered steel hooks. Environmental issues eliminated chemical stripping and concerns over losing temper prevented thermal cleaning methods. Valmont resorted to using a hammer to physically clean the hooks by chipping powder from grounding points.

Jerry's search led to Keppel Seghers Inc. to determine if their fluidized bed was the answer to his hook cleaning. He found their FluidClean offered a quick, efficient and environmentally friendly solution to Valmont's stripping needs. With a temperature differential of less than 10º F throughout bed, the FluidClean was able precisely control to cleaning temperature. The cleaning cycle was less than one hour and hooks could go directly from the fluidized bed back to the paint line.

Upon purchasing the FluidClean and new paint guns, Valmont documented reject rates and powder wastage before and after installation of the FluidClean and was surprised by the results. The estimated decrease in powder wastage would yield an annual savings of over $160,000 with a significant decrease in paint related rejects.

An additional benefit was the elimination of the labor intensive hammering a grounding point. According to Charlie Gray, the group leader whose job it was to create the grounding point, "as far as I'm concerned, this is the best money we ever spent."
The Boss just told me that our fixture stripping is not keeping up with our line speed and he wants a cleaning solution that is quick, economical, and environmentally friendly. Did I mention it needs to have low labor, operational, and maintenance cost?

IMPOSSIBLE

Not really. The Keppel Seghers FluidClean meets all those requirements.

The Environmental friendly FluidClean has an average cycle time of less than 45 minutes for powder coat stripping giving our customers the opportunity to strip every 2-3 passes through the line. Labor and operational costs are minimal and the operation is low maintenance.

As the organics are destroyed in the flame zone, there is no waste stream and this product meets strict emission standards for both hydrocarbons and particulate matter. The hot fluidized sand not only removes and destroys the organics but also removes most of the ash residue.

Have us prove the above by calling us for a free test cleaning.

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www.keppelseghersusa.com
In 2006, The Toyota Motors Malaysia Special Projects Department of Assembly Services needed to find a single cleaning unit that could handle all their stripping needs. The size and number of fixtures to be cleaned presented a real challenge. The method chosen had to be able to clean several types of paint from skids, grates, and a wide variety of paint fixtures. The system chosen also needed to have low operating costs and be environmentally friendly.

After careful consideration of available cleaning methods, the choice became clear, the Arena Scirocco. The Scirocco (A) 127 D selected by Toyota Malaysia was the largest Suspended Solids Reactor in the world used for stripping, with an internal size 6 m x 1.75 m x 1.1 m. This size and the efficiency of the Scirocco allowed them to provide a single cleaning system for all their needs: paint booth grids, production tools, and body skids. To optimize the efficiency of loading an extra automatic loading system was delivered which gives the ability to prepare several loads in advance which are automatically loaded in sequence reducing idle time of the equipment.

The quick cycle times, 45 minutes for grates (120 @ 2 kg of cured paint on each), 60 minutes for skids (3 skids per load), and 40 minutes per load for over 1,000 assorted fixtures allow the cleaning to keep up with the production schedule and not become the production bottleneck.
How’s your first-pass transfer efficiency (FPTE) these days? If it’s poor, or worse yet, you don’t know what FPTE is, then you need to read this article. It discusses factors that limit or reduce FPTE in powder coating systems and focuses on ways to improve it.

Sometimes, you read an article and it’s so familiar—as though you’re the one that the story was written about because your situation is identical to the one in the story. Well, this is one of those articles, and now is the time when some light can be shed on improving first-pass transfer efficiency (FPTE) in your powder coating operation.

The basics need to be thoroughly understood first

Understanding what FPTE is and how it affects your overall paint operation and bottom line is important, especially in these days of lean manufacturing. Usually powder coating involves a one-coat application, and overall transfer efficiency (TE) is high (90 to 95 percent) when reclaiming the powder. This is impressive compared with the reclaimability of other types of coatings. Compared with liquid systems, the cost savings when using powder coating systems are considerable in both TE and waste production.

Powder coatings are generally applied electrostatically. The powder is given a + or - charge when it passes through a charged corona field. As the powder passes through this charged field, it picks up the charge and is attracted to the closest ground—the part. Most of the powder will be attracted to the part, and the rest will fall into a collection hopper where it can then be resieved and reused.

The specific gravity of powder is actually the ratio of the weight of a given volume of powder to the weight of an equal volume of water. FPTE is the ratio of the amount of powder coating actually deposited on the substrate the first pass by the spray guns compared with the amount of powder coating directed at the parts to be coated that isn’t deposited on the part. Your powder coatings manufacturer should have provided you with the specific gravity information for your powder coating on a product specifications worksheet. Table 1 shows you how many square feet (sq ft) of coverage you’ll get with certain specific gravities and mil thicknesses.

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<th>Specific gravity</th>
<th>1 mil</th>
<th>2 mils</th>
<th>3 mils</th>
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Powder coverage. To calculate how much it will cost you to coat parts, use the following formulas:

**Formula 1:**

\[
192.3 \times \text{(Specific gravity of the powder)} \times \text{(mil thickness)} = \text{Sq ft of coverage at 100\% TE}
\]

Actual TE will be less than 100 percent. Use your estimated efficiency.

**Formula 2:**

\[
\frac{\text{Sq ft of coverage at 100\% TE}}{\text{TE}} = \text{Actual coverage}
\]

To calculate the total cost of the powder needed for a job, use the following formula.

**Formula 3:**

\[
\frac{\text{Total sq ft to be covered}}{\text{Actual coverage}} = \text{Total pounds (lb) of powder needed}
\]

\[
\frac{\text{Total lb of powder needed}}{\text{Price per lb}} = \text{Cost for job}
\]

**Example 1:**

If the specific gravity of a powder is 1.5 and you plan to put 3 mils of powder onto a part at 70 percent FPTE, you will cover 29.91 sq ft for each pound of powder you spray. Calculate the amount of sq ft you need to coat, divide by 29.91 sq ft, and you’ll get the amount of powder you need to use for the job. Simply multiply that number by the cost per lb.

**Example 2:**

If the specific gravity of your powder is 1.6 and you plan to apply the powder at 2 mils, the chart says that you will coat 60.1 sq ft at 100 percent FPTE. At 50 percent FPTE, only 30.05 sq ft will be coated.

**Many factors can affect FPTE**

Of all the strategies available for reducing pollution (air, water, and waste) and costs from a coatings shop, TE probably provides the most benefits. Several factors affect TE to a smaller or greater extent. (See Table 2.) We’ll discuss the more important factors. Keep in mind that powder spray booths are designed to effectively contain oversprayed powder, efficiently reclaim oversprayed powder, improve TE, and create a safe, clean, and comfortable operating environment.

**Electrostatic corona.** High- or low-voltage cables are two basic ways that the voltage source is currently applied to the tip of the corona-charged powder spray gun. The type of cable depends on whether the high-voltage generator is an external or internal power supply gun. Both come in negative or positive polarity. Generally, coronacharging uses a negative polarity on the electrode as negative polarity produces more ions and is less prone to arcing than positive polarity. Positive polarity guns are generally used when sprayingnylons or touching up with a tribocharging system.

**Powder spray guns.** The two major gun categories are manual and automatic. Manual guns can be used in stand-alone units, in applications not requiring automatic guns, or with automatic systems that are generally used for difficult-to-reach part areas, complex parts, or both. Because the hand painter uses the spray gun for long periods of time, the flexibility, weight, efficiency, and durability of the spray gun are important. When considering the added mass of the hose and cable, keep in mind that most applicators will hold the hose and cable with the other hand so that only 3 or 4 feet of hose and cable weight are added to the gun.

In addition, depending on where the hose and cable are attached to the gun, the added weight may or may not improve or degrade the overall balance of the gun. This can be important when considering TE because the coater’s arm may tire due to the extra weight carried by an internal gun system, which may degrade efficiencies as the day progresses. The external corona gun is by far the most common type in use today. It provides good uniformity and TE.

If you feel your equipment is not performing adequately, ask your equipment supplier to bring a DC-voltage test.
tem, defeating the efficiency.

Too little or too much air introduced within the hopper. Too little or too much air uniformly across the fluidizing membrane, which in turn provides uniform fluidization throughout the exterior of the feed hopper. More fluidizing airflow is not better when dealing with TE. Too much air or nonuniform distribution of air will result in extremely violent fluidization in certain areas. As a result, efficiency of the powder pump will be reduced causing the powder pump to draw air and reduce the proper powder flow rate. The fluidization needs to be carefully monitored for each type of powder introduced within the hopper. Too little or too much airflow will potentially give surges within the system, defeating the efficiency.

**Nozzle design.** The gun and nozzle design is a major influence in achieving FPTE. This comes into play where the air velocities are low and where the powder is well-dispersed. This is when the nozzle design matters. The two most widely used nozzles are the deflector-pattern and the flat-spray nozzles. Both are available in various patterns and shapes. The flat-spray nozzle is more directional than the deflector type and has a well-defined pattern. The deflector-pattern nozzle has a soft well-dispersed pattern and has the appearance of a liquid bell. Many other types of nozzles are available, but these two types account for 90 percent of them in today’s powder coating systems.

**Hoppers.** A fluidizing hopper-feeder with level control is probably the most overlooked and underrated device of any powder system. These systems have three key features:
- Level control
- Fluidizing plenum
- Venting

**Level control.** A good level control will enable the fluidizing feeder to maintain a consistent powder and feed height.

**Fluidizing plenum.** The fluidizing plenum distributes the air uniformly across the fluidizing membrane, which in turn provides uniform fluidization throughout the exterior of the feed hopper. More fluidizing airflow is not better when dealing with TE. Too much air or nonuniform distribution of air will result in extremely violent fluidization in certain areas. As a result, efficiency of the powder pump will be reduced causing the powder pump to draw air and reduce the proper powder flow rate. The fluidization needs to be carefully monitored for each type of powder introduced within the hopper. Too little or too much airflow will potentially give surges within the system, defeating the efficiency.

**Venting.** A powder feed hopper is like a pressure vessel. The feed hopper can receive powder from three to four or more venturi transfer pumps. These pumps are a simple air-transfer type, and the air pressure from these pumps and the fluidizing bed below must be relieved from the hopper feeder. The best way to remove the excess air is through a direct vent design. This design relieves internal pressure.

**Powder pump and fluidizing flow rate.** The purpose of the pump is to supply powder to the gun at a uniform and constant rate. Powder pumps use a venturi principal to deliver powder from a supply hopper to the powder spray gun. The lowest flow rate possible is the ideal condition for FPTE while still maintaining coverage through each gun. Consistent high-charging efficiency is controlled by the gun output. The more powder passing by the gun electrode, the less chance each powder particle has to pick up the maximum charge. More powder flow is not better when dealing with TE. Adding additional guns to keep outputs low is better than reducing the number of guns and increasing the output of each gun. Remember, TE is achieved through proper charging of the powder applied to the part.

**Process controls and monitoring devices.** Process controls and monitoring devices can enhance the operating efficiency of your powder coating system. When you look at FPTE, consider a system in which the guns are triggered on at all times and the space between the parts is equal to the part size. The highest achievable FPTE will be no more than 50 percent because 50 percent of the powder sprayed goes into the air.

System history has shown that the FPTE will vary from 20 to 60 percent of the times the guns are spraying with known parts in front of the guns. Depending on gun triggering, however, your overall FPTE could improve from 20 to 60 percent. An added benefit of automatic gun triggering is the capability to adjust the spray duration to either reduce heavy edges on parts or increase wrap on parts.

**Booth canopy design.** The design of the powder coating booth contains oversprayed powder within the booth. Because the powder is applied via an electrostatic charge, and our goal is high FPTE, we want the powder to be attracted to the part and not to the booth. To achieve this, the booth canopy or the area around the automatic guns should be constructed with a low or nonconductive material. This will allow the electrostatic field emitted by the guns to attract the powder to the part and not to the booth wall.

**Airflow factors.** The spray zone, defined as the area where the powder is applied, can be disrupted in many ways, disturbing TE. Some sources of disruption include the air-make-up units, open doors, and outside weather conditions. The parts in a powder booth require a consistent air velocity enveloping them. If the conditions mentioned previously exist, disruption of the air envelope could occur and contamination would result. The air movement within powder spray booths is much more important than it is in liquid coating booths. This is due to the powder particle make-up. It takes very little outside air disruption (and sometimes inside disruption) to dis-
turb the proper airflow within a powder booth. Planning and placement of equipment is a top priority for controlling contamination.

Gun-to-booth-wall distance. One canopy issue that will affect FPTE and good housekeeping is the distance of the gun tip to the booth canopy behind the gun. The powder gun should be at least 12 inches inside the booth so that the electrostatic field is attracted to the part and not the booth canopy.

Gun-to-part distance. The distance between the parts you’re coating and the gun tip will affect your TE. Many variables with gun placement depend on line speed and part specification. Generally, start at 8 inches to 12 inches away from the part.

Booth airflow. Uniformity in spray booth airflow is one key application variable. Again, you must remember that more powder flow is not better when dealing with TE. In any booth type, you’re looking for powder containment. Too much airflow will draw the powder away from the parts being coated. Many coaters try to overcompensate with a higher powder flow rate and less FPTE.

Humidity. Both humidity and temperature can affect the performance of a powder coating system. The powder system should be installed within an environmental room if possible to give you application consistency because any change in temperature and humidity may affect fluidization, filter efficiency, filter service life, and powder charging capabilities. The temperature of the environmental room should remain at 68°F to 80°F. Relative humidity should remain at 45 to 60 percent.

Water and powder do not mix when the intent is to spray as a dry powder. Exposure to excessive humidity can cause the powder to absorb either surface moisture or bulk moisture. This causes poor handling, such as poor fluidization or poor gun feeding, which can lead to gun spitting, surging, and eventually feed-hose blocking. High moisture content will certainly cause erratic electrostatic behavior, which can result in changed or reduced TE and, in extreme conditions, altered appearance or performance of the cured coating.

Maintaining proper humidity is also critical in controlling contamination and film thickness within a powder sys-

em. Maintaining a clean environment should be of the utmost importance. Fibers and dust that float around an area need to be controlled, and the best way to do this is with humidification. Attaching moisture (humidity) to the particles will help make them heavy so that they drop out of the air. In fact, it has been observed in many shops, that when it rains, dirt levels are usually lower.

Employing several methods, which include spray coils, spray nozzles, rigid media humidification, steam injection, atomizing nozzles at the burner, and ultrasonic humidification, can control humidity. It should be noted that to a certain degree, each of these methods could contribute to
particulate contamination. This should really be considered when choosing a method to control humidity.

In addition, dry air increases static electricity. The dryer the air, the higher the static charge. Maintaining proper humidity levels will reduce the static electricity that can cause a part to act as a magnet to attract and hold contamination. This is similar to electrostatic painting when a charge is used to apply powder to a part for better TE. Contamination will do the same thing when it is charged with static electricity. It will attach itself to the part to be powder-coated and once attached, will be difficult to remove. Increasing the humidity in the air reduces static charge and thus reduces particulate contamination. In a powder coating application area, this is even more critical because of negative airflow to the booth, which pulls in outside air thereby producing a cloud that will hang in the application area. Low relative humidity will decrease the attraction of powder, yielding low film thickness and requiring a voltage increase to maintain the appropriate coating. Fluctuations in humidity will also affect the film-thickness consistency.

**Ground.** Part grounding is extremely important. An ungrounded substrate will attract the charged powder to a certain point. Eventually, it begins to repel the charged material, which affects your FPTE.

Many shops continue to allow their racks, hooks, or both to remain within the powder coating system long after they have lost the capability to properly ground the parts being coated. Usually, this is done for the following reasons:

- It involves more personnel to actually clean or take off hooks and racks.
- It costs more to send out the racks for cleaning.
- Employees aren’t trained to identify problem racks and hooks.
- Management thinks that production output outweighs the time necessary to clean racks and hooks.

Grounding rods should be placed at both ends of all booths and be attached at the conveyor if used. Many booths use grounding copper, or rub bars, within the booths themselves, and while this can help ensure that you have an optimal ground system, it usually produces more debris from them than they are worth, and they take more time to clean. In some instances, the ground isn’t any better with these rub bars than without them. Again, properly cleaned hooks and racks will efficiently provide adequate ground for the powder system.

**Powder coatings.** Some of the physical and chemical properties of the powder coating you use can affect FPTE. Not all powders are the same. Some powders work better with some gun brands than others.

**Reclaim powder.** The larger the powder particle on the metal surface and the higher its charge, the stronger the electric field between the particle and its mirror image.

The fact that larger particles experience a stronger attraction to grounded metal provides one explanation for an orange-peel effect on thicker layers of powder coatings.

The lower charges of smaller particles may not be sufficient to create an attraction force strong enough to retain the particles on top of the already deposited powder coating layer. The result will be lost efficiency within the system and reduced appearance to the part being coated. Powder fines don’t charge well. This is why you should use at least a 50-to-50 ratio of virgin-to-reclaim powder in your feed hopper.

**Totally integrated systems produce the greatest efficiency**

You can achieve the greatest application efficiency if you apply powder at the highest TE possible at all times. It may even be economical to spray to waste by increasing the TE of the application equipment.

The value of FPTE can’t be underestimated. Achieving the highest TE involves more than a powder gun. In fact, it involves a totally integrated system. In some cases, a piece-meal system may look like a powder coating system; however, its overall performance, operating cost, quality, and system efficiency may fall short of a totally integrated powder system’s efficiency.

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Bob Utech is owner of a consulting company called Powder Visions and is a former member of the magazine’s Editorial Advisory Board. The former Minneapolis area resident has designed and installed numerous coating systems for businesses large and small during his years in the powder coating industry. He also was a powder coating instructor at Dunwoody Institute in Minneapolis and is author of A Guide to High-performance Powder Coatings. He attended Normandale College, Minneapolis, and has an associate degree in criminal justice.
This article outlines some of the most effective methods and techniques to track and control the powder coating application process, and reduce the reject rate through continuous improvement. The article analyzes control variables on a typical conveyorized powder coating system.

Process control in a powder coating shop begins with a general understanding of the overall process and the variables that can affect the overall system and its performance. A number of control techniques can be used by line operators to keep the powder coating system in check.

A powder coating system includes separate processes working in sequence to achieve a common goal—a quality, cost-effective finish. A successful powder coating company is made up of various processing components functioning together in harmony much like organs within the human body. Like the human body, the health of the overall finishing operation depends on the quality of the components that operate within it. Following is a breakdown of the components in a powder coating system and their control features.

Compressed air

Clean, dry air is essential for overall quality in the powder coating system. The air compressor breathes life into the equipment, allowing the powder to flow through the powder feed and recovery equipment. Compressors simply take air and compress it, moisture and all. As a result, the moisture must be removed before the air can be used in the powder coating system.

Poor air quality causes clogged equipment, wet powder, and a contaminated finish. A properly designed and well-maintained air filtration system ensures good air quality and helps maintain healthy powder delivery and recovery. As a final safeguard, you should place a filter at the air-supply hookup to the powder gun. Generally, this is a 5.0-micron filter in a glass canister that can be easily checked visually for moisture, oil, or other contaminants.

Conveyor and racks

A well-maintained conveyor and racking system is also an important part of maintaining control in the powder coating system. Materials handling by racking represents the circulatory system of the powder coating process. Periodic cleaning and proper lubricating can’t be overemphasized.

The efficiency of the overall system is greatly affected by proper electrostatic ground and smooth delivery of parts from one process to another. Automatic lubricators are available for conveyor systems and are worth the investment for new system construction.

Surface preparation

The leading cause of rejects in the finishing industry today is inadequate surface preparation before coating. Unbalanced chemical concentrations, bad rinse water, clogged or misdirected nozzles, and other factors left unattended will certainly cause rejects, regardless of topcoat quality. If allowed to operate unchecked, the surface preparation system would turn from a valuable asset to a huge liability in a short time.

A properly done control and maintenance program dramatically reduces rejects caused by failures in surface preparation. System control variables include the following:

- Time
- Temperature
- Concentration
• Impingement

You can titrate your pretreatment solution to determine concentration strength and easily keep track of it through statistical process control. Regular testing and immediate recording of results allow the system to operate in a tight range of parameters as determined by your pretreatment chemical supplier.

Surface preparation systems require a good deal of maintenance for a variety of reasons, including extended equipment life, quality performance, and efficient operation. In each stage, the pumps, nozzles, and burners also need proper attention. The objective is to deliver parts with clean, dry surfaces and proper phosphate coating weights to the powder coating booth as quickly as possible.

To meet this objective, a few guidelines should be followed. A maintenance schedule and logbook should be kept to track the regularity of additions of make-up water, chemicals, and replacement parts. This helps the systems manager determine when the next chemical change or tank cleaning is needed. Following is a list of maintenance checks for your surface preparation system:

• Check regularly for spray nozzles that are out of position, damaged, or missing as a result of fallen parts from improper racking. A misdirected nozzle from a rinse stage can overflow a chemical stage, diluting the chemical concentration in a matter of minutes.

• Check regularly for clogged nozzle orifices. Clogging increases the pressure of the unblocked nozzles. Too much pressure is undesirable. In some cases, excessive pressure causes spotting and uneven phosphate coating weights. It can also blow parts from the racking system.

• Inspect and grease the pumps regularly to ensure proper pressure to the nozzles.

• Clean pump screens daily to prevent lint from gloves, rags, and other materials from entering and clogging the pump, header pipes, and nozzles.

• Keep drains free of scale and foreign matter to prevent overflow of wastewater into the work area.

• Install interior grids to prevent falling parts from entering the holding tanks. This allows the systems operator to retrieve the parts easily between breaks. We affectionately refer to an unprotected solution tank as the Bermuda rectangle. Parts fall in and are never seen again.

• Replace air-intake filters on burners regularly to ensure clean efficient fuel consumption and maximum control of solution temperature in the holding tanks. Filter airborne contaminants from the intake airstream; otherwise, the contaminants will burn and create excessive buildup inside the burner tube, which causes inefficient heat exchange.

Most custom powder coaters process a variety of substrates. Shops that don’t have the necessary surface preparation equipment typically find surface preparation control difficult to impossible, as well as costly, labor intense, messy, inconvenient, time consuming, and troublesome. As a result, these shops often take shortcuts and sacrifice quality.

In any quality metal finishing operation, proper surface preparation isn’t optional. Historically, surface preparation has caused more premature field failures than any other segment of the finishing process. Suppliers of surface preparation chemicals and equipment offer options and solutions to many of today’s surface preparation and substrate requirements. Consult these suppliers at the time of system design and keep them in the loop throughout the start-up and service life of the system. Surface preparation is the area where most shops get into trouble at one time or another. Keep it organized, clean, and in control.

Dry-off and preheat. After cleaning and phosphatizing, parts must be dried. A postheat oven or a cure-oven section dries the substrate before powder application. Substrate temperature control at the application booth affects the transfer efficiency of the overall system. The control of part surface temperature at the time of powder application will become even more important as progress in wood and other nonmetallic applications develops.

**Powder application**

Another crucial part of the powder coating process is powder application. This involves four key areas: the powder material, powder delivery system, powder charging system, and powder collection booth.

The powder material.

Most applicators assume that all powder is fresh, new, and ready to be introduced into the process as soon as it’s received from the supplier. Unfortunately, many on-line problems occur because of improper transportation, handling, and storage of the powder material. In addition, powder that has been in house for a time may lose some of its desired properties. For example, powder that has passed its expiration date, or has been exposed to heat for a time, may exhibit some or all of the following:

- Poor fluidization
- Agglomerated particles
- Reduced gloss
- Excessive orange peel or textured appearance
- Pinhole formation

To ensure that all materials received are of good quality, the applicator should check the date of manufacture at the time of delivery. It’s also a good idea to do first-in first-out, or FIFO, inventory control. The manufacturing date, lot, and box numbers are clearly marked on each powder box (sometimes in code) and should be included with job processing information for each order processed. This
information is valuable when tracing a powder-related problem.

Powder received near its expiration date should be checked for quality before introducing it to the finishing system. A simple preproduction check can give finishing line personnel valuable insight to possible powder-related problems before on-line rejects occur.

**Powder delivery system.** Powder delivery is the process by which clean, dry air is carefully mixed with the proper ratio of powder and delivered to the gun tip via the feed pump and hose at just the right velocity. Adjusting the fluidizing air, the flow-rate air, and the atomizing air at the gun control console determines powder delivery. Each air source affects the air-to-powder ratio at the gun tip. For example, the fluidizing air mixes the air and powder in the feed hopper.

To ensure proper powder dispersion without clumping, screen powder into the hopper. The flow-rate air adjustment uses venturi air to create a vacuum in the feed pump, which forces air and powder from the feed hopper into the feed hose. The atomizing-air control introduces more air directly into the feed hose at the pump to increase air volume and velocity and change the powder cloud pattern at the gun tip. Each of these controls plays an important role in the transfer efficiency of the powder delivery system.

**Powder charging system.** This system depends on the powder charging system. To understand the powder charging system, you need to have a basic understanding of electrostatics. Many articles are available on this topic (see the Editor’s note at the end of this article). It’s a good idea to develop a good understanding of how electrostatic attraction differs from other forms of electricity.

Powder applicators should be trained by application equipment suppliers in the proper use of the control variables and maintenance details required to keep the guns operating at their peak. Applicators should also understand that more isn’t always better when it comes to powder charging and delivery.

The charging of powder particles isn’t magic. Some people find the electrostatic attraction of powder particles to metallic and nonmetallic surfaces as somewhat mysterious. In the negative coronacharging system, an electrostatic generator creates a charging field. The intensity of the electrostatic charge is related to the control console setting that reads in kilovolts (kV). Proper adjustment and control of the charging system and adequate grounding are essential for the highest first pass transfer efficiency. You need to con-
cation personnel and to keep the powder and air ratio safely below the lower explosive limits.

The objective is for the operator to control the environment in the application booth in such a way that the powder is efficiently attracted to the part. To do this, operators must be trained to properly operate and maintain the collection equipment (and all other powder coating equipment).

Powder containment for reuse is optional and highly recommended whenever possible. Many powder users are now realizing the financial benefits of collecting powder for reuse. With the advanced technology in the design of collection booths, equipment manufacturers have given operators controls with which to increase or decrease the air draft. This is useful for tasks such as booth cleanup.

**Powder curing**

Thermosetting powder coatings must reach a certain temperature for a determined amount of time for the powder to properly cure. Your suppliers should give you the recommended time and temperature for curing each powder coating. Different powder formulations require different cure temperature and oven dwell time.

When exposed to heat, the powder melts, flows, gels, and finally cures. The dwell time in each of the four stages of cure can be altered by controlling the atmospheric temperature of the oven, the surface temperature of the substrate by preheating, or both. If the time in the oven is decreased, the temperature may be increased to ensure complete cure. Proper control of the substrate time at temperature is important. Testing should be done to find the most appropriate cure window, or time at temperature. Surface and atmospheric temperature recording devices are available to eliminate the guesswork related to substrate time and temperature.

Following are some factors to consider when determining and controlling the cure schedule for a powder coating on a part:

- Powder manufacturer’s cure recommendations (time at temperature)
- Total oven dwell time
- Atmospheric oven temperature
- Oven parameters (airflow and other heat-related oven conditions)
- Substrate composition
- Substrate mass
- Substrate geometry

Line operators, under pressure to increase productivity, occasionally increase line speeds without considering the reduced time at temperature. As a result, they are at risk of undercuring the powder coating. Undercured powder doesn’t perform to the formulator’s standards and leads to rejects or premature field failures.

**Individual job settings and controls**

Once line operators determine the system control parameters and clearly understand the system control variables, they can focus on individual jobs and applicable limitations.

One of the first issues a good line manager should focus on is determining the limiting factor. This is a single factor that will limit the rate at which a job is processed. For example, a 12-inch by 12-inch, flat, 22-gauge, cold-rolled steel part cures at a faster rate than a 6-inch by 6-inch by 6-inch block of solid steel.

The limiting factor in this case is the oven dwell time as opposed to the rate at which the parts could be cleaned or properly coated. When setting line speeds, all too often the powder application time is the only consideration. If the total process can’t perform all the necessary functions completely, quality suffers.

**Job process tracking**

Each job and part number should have a job process work sheet. For original equipment manufacturers, this is generally an important cost accounting consideration and is almost always a part of the total manufacturing process flow. OEMs record and track job processing standards for processing and scheduling purposes as well as costing. Custom coaters can use this same technique when processing repeat orders and similar parts.

Job process tracking may not be a difficult task for the custom coater with a single line. However, shops that have several lines or have systems at various locations must be able to track the status of orders in house throughout the process to effectively communicate key issues to the customers in real time.

Computers are great for job process tracking when many jobs need to be tracked simultaneously. Quality standards can be checked at various intervals and documented as the process progresses, not just when the job is complete. Often, the customer calls to find out the status of an order in process and wants the information immediately. The customer who receives accurate information regarding the progress of an order in a timely manner is much more likely to be comfortable with the finisher’s capabilities and impressed with the finisher’s professionalism.

**Job process recording**

The recording of jobs is simply a matter of developing a detailed history of jobs completed. This information is valuable to the cost accounting department and the job estimator. Job-history details can be reviewed and discussed with line personnel, thus eliminating much of the guesswork in determining the cost to process similar new jobs.

A good job estimator will review in-process data after a job to determine if the estimated production rates and material use were correct. Proper documentation, tracking, and review ensures that the company is making money.
job after job. Don’t let the profitable jobs carry the non-profitable ones. This sends a false message to the customer and doesn’t help you, the customer, or the industry in the long run.

Job process recording is also necessary when the customers require a certification of conformance. These documents and certify processing details as they’re completed and accurately list all quality control documentation. Customers are comfortable with custom coaters who can prove that predetermined quality standards are being checked throughout the process.

Conclusion

Process control in any powder coating system is a full-time job. The ever-changing variables in the system make process control a continuous challenge for the finishing line manager and system operators. Variables in substrates, equipment, powder coatings, and people require continuous monitoring to ensure quality daily.

Employees must be trained to first understand and identify the variables within the system and continue to learn about all other factors that influence quality. The equipment doesn’t run itself—an investment in education for all employees is an investment in the future success of your business. Keep your system safe, keep your system clean, and keep your system in total control.

Editor’s note

For further reading on topics in this article, see the “Index to Articles and Authors 1990-2008,” Powder Coating, vol. 19, no. 9 December 2008.

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Temperature profiling allows you to record and interpret the temperatures of your products and oven air through a conveyorized or batch oven. The data collected by a temperature profiler tells you how hot your products became and for how long, and what temperatures your products reached and at what point. This article answers the most common questions coaters have about temperature profiling and explains how analyzing profile data enables you to increase production and solve production problems.

Q: My oven is practically brand new and has the latest facilities in oven control. Why should I profile my oven?

A: You want to profile your product, not your oven. A quality cure depends on the temperature the substrate experiences throughout the oven. Although it’s important to control the exact oven temperature, knowing the oven temperature doesn’t mean you know the product temperature. This is the information you get from temperature profiling.

Temperature profiling allows you to measure product temperature in different regions of the oven and different locations on the same workpiece. Frequently, products hung at the top of the oven cure significantly more than those placed at the bottom. Thermal mass also impacts heating rates. Taking readings from various segments of a complex product or one of mixed components verifies each section has been successfully cured.

In Figure 1, two steel plates, one twice as thick as the other, are profiled through identical powder coating ovens. The results clearly show that the thicker plate—the one with higher thermal mass—heats at a much slower rate. In fact, the metal never reaches the target cure temperature of 360°F.

Q: I’m trying to compare two ovens that have totally different temperature profiles. How can I best quantify cure? Simple time-at-temperature calculations at 400°F in one oven indicate severe undercure, yet physical test results show good cure.

A: Ideally, you want to match the powder coatings supplier’s cure schedule. It guarantees optimum physical and cosmetic properties of the product. This time-at-temperature specification has been provided after extensive testing of powder-coated metal panels in a controlled laboratory batch oven under differing conditions. In a perfect world, laboratory conditions would simply need to be replicated. In practice, this is impossible. Calculating the duration at a specific temperature ignores the fact that crosslinking occurs at other temperatures. It takes time for a product to heat up and cool down, and matching exact cure temperatures can’t be done in a large-scale conveyorized oven.

The example in Figure 2 illustrates this point. Two profiles from different ovens have very different profile shapes. Because neither of them shows a dwell time of 6 minutes at 400°F, it might be assumed that the product is significantly undercured. To get an accurate analysis, the cure contributions of all temperatures must be calculated.

The most accurate way to quantify cure is to use an index-of-cure calculation. Working from cure sched-
ule data at different temperatures, a temperature-time relation can be derived based around first order Arrhenius reaction kinetics. Having derived this relation, it’s possible to sum all time and temperature contributions from the profile and calculate a single cure index value. A value of 100 indicates that the cure contribution exactly matches the powder supplier cure schedule. Higher than 100 illustrates overcure, and lower than 100 indicates undercure. In most situations, customers use physical tests to determine an acceptable tolerance range for cure index values.

In the example in Figure 2, the index values for each of the files was 101, showing that both of the ovens achieved a successful cure even though the profile shapes are totally different. The value of 101 confirms cure performance and agrees with physical test data.

Employing the index of cure simplifies life because it works independently of product size, product mass, or oven operating temperatures and is ideal for both accurate process development and quality assurance (QA) activities.

Q I’m a powder supplier, and I use my oven profiling system to prove that our product is within specifications. Customers frequently ask me to send them a color printout of the run but that can take days. Is there a quicker and easier way to send them the data?

A To help share data between powder suppliers and end users freely, download software available from some profile equipment suppliers’ web sites. This software allows profile data to be viewed by a customer who doesn’t have a profiler or operating software. The raw data file can be e-mailed to the customer who opens the file with the viewer software and prints a basic report.

Alternatively, many commercial packages are available that can generate a PDF (Portable Document Format) of the profile report, which can be e-mailed directly to the customer and opened with an appropriate reader package.

Q My powder coatings supplier visits with a profiling system, so why should I invest in a unit of my own?

A Routine temperature profiling does much more than verify that a specific run on a specific day is within specification. By profiling regularly, you can see when variables are changing and when oven performance is deteriorating. As a result, you can identify the source of faults before they impact product quality. It is, simply put, problem prevention. The information from temperature profiling allows you to plan routine maintenance at your convenience rather than having to fix a problem at the worst possible moment during a catastrophic failure.

Don’t forget your powder supplier is interested in getting the best out of the coating, which might not be best for your process in terms of productivity or fuel consumption. How would your fuel bill change if you reduced the oven set-point by 5°F? Low cost, easy-to-use profiling systems are an excellent investment. They give you control of your process and information when you need it—with no waiting.

Q I supply automotive parts to a high-volume automotive original equipment manufacturer (OEM) who requires that I supply documentary proof from every shift that my part is cured correctly. Is there any way I can validate my process and provide documentary evidence of QA without having to send up to 60 profile reports each month?

A An excellent way of collating profile data collected over a period of time is by using statistical process control (SPC) strategies. A single one-page SPC chart (Figure 3) summarizes the variation in key process parameters both graphically and numerically with SPC indicators such as Cpk, Ppk. Your OEM can immediately see the cure is in control for a particu-
lar process because the index of cure is shown to be in tolerance for the entire evaluation period. (Editor’s note: For an article series on SPC, go to [www.pccoating.com] and click on Article Index and then Testing.)

Q Being a high-volume architectural aluminum extrusion manufacturer, I’m processing the same size and profile extrusion on one line 6 days a week. How can I make system setup easy for line operators and guarantee consistency of data run to run? Currently, I can’t always guarantee whether probes are always put in the same position.

A When powder coating the same product shift after shift, day after day, you might consider using a test piece. If designed with care to simulate production items (thermal mass and position), the test piece allows test data to be collected repeatedly without damaging production items. And repeatability is guaranteed because the thermocouples are attached to the same point on the test piece. This can save both material and time, especially if you use a two-part data logger (Figure 4). Thermocouples remain attached to the test piece and to the second half of the data logger, which stays inside the thermal barrier. At the start of a shift, the QA manager plugs the logger together. The system and test piece can then be sent through the process at the convenience of the line operator without any other setup. Triggering of the logger can be programmed to occur when the system enters the oven.

Q I’ve successfully profiled convection ovens for years but have just installed an infrared (IR) oven for a new product line. Can I use my system to monitor IR? What thermocouple type should I use?

A Profiling IR ovens is possible, but care must be taken to consider the factors affecting the heat transfer mechanism. A desirable feature of IR technology is the very rapid heat transfer possible when the metal substrate absorbs electromagnetic radiation. The degree of absorption (heating rate) is controlled by the emissivity of the surface. It’s essential that the product being tested is coated with the same powder type and color used in the production run. Exposed junction or patch probes will accurately measure the temperature experienced by the coating. They respond very rapidly to temperature change and can be coated easily. One word of warning: Gas-fired IR emitter temperatures can be very high. If polytetrafluoroethylene (PTFE) cables get too close or touch the safety cages, they can melt. Fiberglass cables can help eliminate this problem. (See Figure 5.) Stainless steel thermal barriers work well in IR ovens because they reflect IR well. If using a barrier of an alternative material, wrap it in aluminum foil (shiny side out) to get the same effect.

Q Historically, we used trailing thermocouples to measure product temperature as it traveled through the oven. Although difficult, it provided real-time temperature data. Can oven profilers be used with trailing thermocouples to do real-time analysis?

A Many profile systems can be connected directly to a personal computer (PC) to provide hard-wired profile data live. This creates issues of
safety, and using long thermocouples becomes expensive and troublesome. Telemetry is a recent development that overcomes these problems. It’s now possible to transmit data back to the monitoring PC during the process via a radio frequency signal so that data review and analysis can be done live. Data transmission efficiency varies from process to process, so you should first determine the feasibility of telemetry for your process and plant.

Q My automotive customer wants me to compare my powder cure against a cure-chart specification. This is labor intensive, and I can’t archive the results digitally without scanning the hard copy. Is there an alternative?

A Recent software innovations make it possible to generate cure-chart specifications digitally with commercial profiling software (Figure 6). The chart is a graphical cure schedule provided by the powder supplier. The green area in Figure 6 shows the acceptable cure region for a specified powder. Any point (time at temperature) within this area will satisfy cure. Profile data is automatically analyzed against this specification, requiring that at least one time-at-temperature value calculated from the profile graph falls within the cure window. All such data can be customized by the user and archived for routine analysis.

Q Time-at-temperature data is important for QA in my company, but I don’t want my line operators spending hours entering and interpreting data in order to give me a pass or fail for each run. Can this be simplified or automated for my specific requirements?

![Figure 6](image-url)
Recent software innovations make it easy to get sophisticated and detailed analysis quickly. An example is the two-tiered software with dual-operating levels. The QA manager has access to all software functionality, and it’s the manager’s job to define and create the test and analysis parameters to be used. This data is stored as a template, which can be used but not changed by operators. Line operators with password access use the software on a basic level, which tracks who did what test when. If necessary, the profile action can be simplified to checking for a green pass light. If problems are experienced, alarms go off and give the reason for failure. At this point, the QA manager steps in and uses the full functionality of the software to fault-find and provide the data to rectify the problem highlighted.

How frequently should I monitor my process?

If I were to survey the powder coating industry about this question, the answers could range from as high as six times a day to as low as only when there’s a problem.

Obviously, there are a lot of factors that influence the level of profiling needed by a user. Process engineers often profile frequently when an oven is being set up for a new product or process. Temperature profiling is a valuable tool for optimizing oven settings for optimum productivity, efficiency, and quality. Subsequent routine profiling provides process control data. Frequency is then governed by the value of the product and the desire to know that the process is in control.

After-sales service and attention to detail can be key factors in winning contracts in the competitive world of powder coating. Profile data, often in the form of a one-page report, can assure customers that you’re meeting quality and process specifications.

Are there any guidelines on how many probes I should use and where they should be placed?

The number of probes and their placement will vary significantly from process to process depending on oven size and complexity of the part being powder-coated.

In general, it’s important that you profile curing over the working area of the oven. When using an overhead conveyor, I recommend placing a probe on the highest and lowest rack positions, then at points in between. For the product itself, place probes at locations you believe will heat up at different rates. Select the heaviest and thinnest sections to check process extremes. When profiling is done for QA purposes, it’s beneficial to collect product data as well as environmental temperature. When failure occurs, it will be due to oven problems in most situations.

Probes positioned to monitor air temperatures can easily locate hot or cold spots. With an eight-channel system, you can measure four product and four air temperatures. If your process uses a flat-bed conveyor, it’s useful to do an oven survey across the width of the oven. Monitoring only the air temperature is an ideal way to check oven balance as seen in the oven thermal contour map in Figure 7.

Endnotes
1. Cp equals process capability; Cpk equals process capability index; Pp equals process performance; and Ppk equals process performance index.
2. BakeChart software by Datapaq

Editor’s note
For further reading on the topics discussed in this article, see Powder Coating magazine’s Web site at [www.powdercoating.com]. Click on Article Index and search by subject category. Have a question? Click on Problem Solving to submit one.

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This article discusses how oven design contributes to maintenance efficiency and gives specific design criteria. The article discusses the importance of oven controls and includes a list of yearly, quarterly, and monthly maintenance tasks for gas-fired and electric convection and infrared ovens.

An oven is a critical component in any finishing system. Getting the best results from an oven for a particular system depends on several factors:

- The parts
- The line speed
- The plant space available

A wide variety of ovens are available today, including gas-fired or electric convection ovens, gas-fired or electric infrared (IR) ovens such as those shown in figures 1 and 2, combination IR and convection ovens, and combination dry-off and cure convection ovens. When determining the oven for your application, you need to talk with a variety of equipment suppliers.

You also need to seek recommendations from the suppliers of your powder coatings and pretreatment chemicals. These suppliers can point out areas that you need to consider when making your oven selection. For example, do you run parts that are difficult to drain after a power wash? Do you coat parts with multiple metal thicknesses that may be a challenge to cure? The suppliers can let you know what the minimum requirements are for their products to perform as expected.
Input from all sources will help you determine the right oven for your application. You also should test the parts to be doubly sure that the oven you selected performs to your expectations.

**Design criteria**

Cleanliness of the oven and the surrounding area is so important that this article starts with that topic rather than ends with it. Poor housekeeping creates about 50 percent of oven maintenance problems and downtime. Location is everything when it comes to your oven. When designing your system, therefore, you need to consider how the location of the oven is going to affect the amount of maintenance required. Interior as well as exterior oven cleanliness is extremely important regardless of your oven type.

Locating a convection oven heater, or burner, box (see Figure 3) near the powder booth area creates many problems. For example, if the oven is gas-fired, airborne powder particles can float into the combustion air blower and burner. These particles can come from sweeping up the area around the booth or from adding powder to the hopper. Eventually, the buildup of particles restricts the delivery of fan air to the burner, the quality of the flame in the burner, or both. Placing an oven near dust-generating processes, open doorways, or outside drafts creates the same burner problems. This can cause the burner to fail after several hours, or minutes, of operation. Sometimes, the burner may not light at all.

In an electric convection oven with an adjustable fresh-air vent in the heating chamber, airborne particles can enter through the vent and build up on heater elements and the recirculation fan. This reduces heating efficiency and increases operation costs.

With electric IR ovens, airborne particles that reach the emitters reduce the amount of reflection in the oven and reduce efficiency. Gas-fired-IR oven efficiency can also be greatly reduced by particles adhering to the face of the emitter.

If layout constraints force you to place the oven and burner-box components near dust-producing processes, you need to consider isolating the oven, the burner box, or the powder recovery and application areas.

You also need to make sure that the oven is as accessible as possible. For instance, if you have a flat-belt electric or gas-fired IR oven with emitters 12 to 18 inches off the top of the belt, how easily can you service the emitters? Will the belt conveyor or oven need to be disassembled to access the interior emitters? Will maintenance personnel need yoga lessons to change or service interior oven components? What can the manufacturer do to make the maintenance procedure easy and quick?

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**FIGURE 3**

Gas-fired convection oven burner box

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**FIGURE 4**

Flame safety controls

- Interlocks closed
- System error
- Flame failure
- Air failure
You also need to consider many other areas of oven design. If you select a convection oven, for example, you need to consider the number of air changes per minute offered by the recirculating fan to get an even temperature throughout the oven. You also need to review the design of the outlet ductwork, the number and type of adjustable air outlets in the ductwork to eliminate hot and cold spots, and the location of the ductwork (floor or ceiling).

If you choose electric IR, you need to determine proper emitter wavelength, watt size, and amp load. If you choose gas-fired IR, you need to consider the number of emitters, Btu’s per hour, and controls. You also need to determine whether or not your application requires zoning for the greatest efficiency.

Furthermore, parts may have been tested successfully on two different types of IR ovens. One oven may be longer than the other because of the wavelength used. You need to take that into consideration if floor space is tight at your plant.

In addition, one oven may be more costly to install and operate than the other. The cost and availability of utili-
ties in your area will be a factor in selecting gas or electric. You expect your oven to reach the design temperature and maintain that temperature. However, you need to know how long it will take the oven to reach operational temperature every morning.

**Oven controls**

In the past, locating a problem with an oven could be a difficult and time-consuming process, especially with gas-fired ovens. Thank goodness technology is moving forward to make everyone’s life a little easier.

Flame safety controls now indicate a problem in the oven (see Figure 4). If an oven with flame safety control fails, an indicator light tells the operator that the problem is in a certain part of the oven. For instance, an air failure light indicates a fan problem or an airflow switch problem. Sometimes, hours or entire shifts have been spent tracking down a problem without these indicators, only to find that an airflow switch needed adjustment.

Flame safety controls can also indicate when an interlock is open, when a pilot or main flame fails, and when a system error occurs. System errors can include a problem with wiring or welded contacts, a malfunction of the flame safety, the failure of the main fuel, a fault with the scanner, electrical interference on sensor leads, or an out-of-sequence flame.

If your oven is operating with a flame safety control that doesn’t offer troubleshooting indicators, you should replace it. You can get payback for the price of the system with the first problem by indication of where the problem is and the quick repair, adjustment, or replacement of the component.

**A preventive maintenance program**

Have a preventive maintenance program in place before oven delivery. Review the necessary maintenance procedures with the oven manufacturer. Compile a complete maintenance program. This should include a daily start-up sheet that has a dedicated section for production personnel comments. If an employee observes something out of the ordinary, it can be noted and followed up on by maintenance personnel.

A written schedule for preventive maintenance that is tied to hours, weeks, or months of production is important. As you complete the tasks, compile the reports, or work orders, along with any other nonpreventive main-

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Tenance tasks performed. You can use these completed work orders to build a history of the oven and to form the basis for a predictive maintenance program.

Several computerized maintenance programs automatically generate work orders for preventive maintenance tasks. The programs automatically generate a history of the oven from these orders. Many of the programs include areas for CAD drawings, part lists, spare parts inventory, purchase orders, and task descriptions. Whether your preventive maintenance program is on a computer or in a notebook, record keeping is a must.

Tables 1 and 2 include suggestions for maintenance schedules. You can adjust these lists to fit your particular situation. You may need to do some tasks more frequently, or you may need to add some tasks. Remember, though, maintenance and cleanliness need to be cultivated and emphasized from the first day of oven operation.

### Table 2

**Preventive maintenance program for infrared ovens**

**Gas-fired**

**Annually**

- Leak test safety shut-off valves for tightness.
- Test pressure-switch settings by checking switch movements against pressure setting and comparing with actual impulse pressure.

**Quarterly**

- Lubricate fan-bearing points on the oven.
- Inspect belts for tension, and adjust as needed. Check belts for separation or cracks, and replace as needed.
- Blow out fan motors, and remove residue buildup.

**Monthly**

- Visually inspect emitters for cleanliness.
- Clean emitters with a soft paint brush only.
- Run oven as hot as possible to burn off powder buildup if evident on heater.
- Cover emitters with plastic when cleaning oven interior or sweeping out. This will prevent dust and other materials from collecting on the catalyst surface.
- Inspect blower, and remove residue buildup if combustion air blower is used. Blow off motor, and remove residue buildup.

**Electric**

**Quarterly**

- Clean reflectors with warm, soapy water, wipe dry, and rebuff.
- Lubricate fan-bearing points on the oven.
- Inspect belts for tension, and adjust as needed. Check belts for separation or cracks, and replace as needed.
- Blow out fan motors, and remove residue buildup.
- Check output amperage to emitters with amp probe at contactor in electrical control panel.
- Check for excessive heat from back of emitters. This will indicate an efficiency loss and reflector uncleanness.

**Monthly**

- Clean reflectors with warm, soapy water.

**Weekly**

- Wipe reflectors with a soft rag.
- Visually inspect emitters for proper functioning.

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