THE FINISHING LINE

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Electropolishing of Stainless Steel

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Electropolishing has been practiced commercially for the past 50 years. The first widespread use of electropolishing was primarily to add cosmetic appeal to consumer goods such as cookware and fountain pen caps. In recent years, electropolishing has seen increasing use for engineering applications, especially in the food, medical, pharmaceutical, and semiconductor industries. This paper examines some of the ways electropolishing can be used to provide levels of smoothness, cleanliness, and corrosion resistance beyond the abilities of the finest mechanical polishing processes.

Electropolishing is the electrochemical dissolution of a metal surface to improve the smoothness, reflectivity, cleanliness, passivity, or some combination of these surface characteristics.

Micro Metal Removal

Electropolishing is a micro metal removal process, and as such, is frequently used to complement mechanical surface finishing processes such as rolling, grinding, blasting, and polishing. While the reflectivity, sparkle, and shine produced by electropolishing are obvious to the eye, some of the more subtle effects are apparent only through more sophisticated evaluations such as microscopic examination, surface chemical analysis, and in-service performance trials.

> Electropolishing can produce mirror-bright reflective surfaces that enhance consumer appeal and maintain their appearance indefinitely.

Nearly all metals and alloys can be electropolished, but in actual practice stainless steel accounts for virtually all commercial electropolishing. The inherent strength and corrosion resistance of stainless steel make it the material of choice for much process equipment and many consumer products.

Electropolishing Practice

The part to be electropolished is electrically connected to the anode (+) side of a direct current power supply, and the cathode(−) side is connected to an inert metal, typically lead. Both part and cathode are immersed in an acidic solution, and as the dc current flows through this circuit, metal is dissolved from the anodic part. Because of the tendency of electrical current to flow from points and projections, these areas are dissolved preferentially, resulting in smoothing of the surface. A viscous boundary layer that forms at the surface also contributes to the preferential dissolution of peaks and projections. The process is optimized by control of the solution chemistry, temperature, current density, and time.

Some parts can be introduced directly into electropolishing, while others may require pretreatment to remove grease, soil, or scale.

Simply shaped parts may be electropolished by using general-purpose flat cathodes, located several inches or more away from the part. Complex shapes, however, can require the use of elaborate and complex fixtures and purpose-built conforming cathodes to obtain uniform electropolishing over the entire part, or to polish selected areas.

'Tank' & 'Wand' Techniques

While electropolishing is generally considered a "tank" process, the size and shape of some parts can require other methods. Some parts, such as pipes or vessels, can themselves become the "tank" for internal electropolishing. Other parts may be so large or complex as to require the use of a "wand" technique wherein the electropolish solution and electrodes are brought to the part using a device that resembles an electrified paint brush.

Electropolishing of large parts can require dc currents of several thousand amperes, necessitating the use of heavy cables and buss, and requiring the forced cooling of parts, solutions, and electrical conductors.

Electropolishing is a relatively quick process. Typical times range from 1 to 20 minutes, although longer times are sometimes necessary. Metal removal on a plane surface is generally less than one thousandth of an inch.

Electroplating solutions are highly acidic and corrosive, requiring the use of corrosion-resistant equipment and close attention to worker safety.

Surface Improvements

Electropolishing can produce mirror-bright reflective surfaces that enhance consumer appeal and that maintain their appearance indefinitely.

Smoothness is improved by electropolishing. In terms of microinch Ra (roughness arithmetic average) numbers, surfaces are improved by about one-half; that is, a 100 microinch Ra surface will improve to about 50 Ra, or a 10 Ra will improve to 5 Ra. The exception to this occurs at very low Ra numbers where there may be no measurable improvement. In fact, very low Ra numbers can actually increase as electropolishing exposes voids or inclusions that have been smeared over by mechanical methods.

Microcleanliness is vastly improved over mechanical finishes. Even the best mirror-bright buffed finish can be seen to include smears and tears and included abrasive, oxides, and debris when examined microscopicallyby Scanning Electron Micrograph (SEM). The same surface after electropolishing may not appear different to the unaided eye, but SEM examination at 1000× shows a "featureless" surface free from foreign material and abrasive damage *(Figure 1)*. This microcleaning process partially explains the improved corrosion resistance of electropolished surfaces.

Electropolishing is known to improve the passivity or corrosion resistance of stainless steel. While this phenomenon may not be fully understood, there is evidence that free iron is removed from the outer few angstroms of the surface, resulting in a surface richer in nickel and chromium than the parent material, and that the chromium and nickel at the surface are more completely oxidized than occurs naturally.

Electropolishing also removes all or part of the mechanically deformed and stressed surface layer, thereby providing a third mechanism to improve corrosion resistance. This removal of a highly stressed surface layer can also improve fatigue resistance.

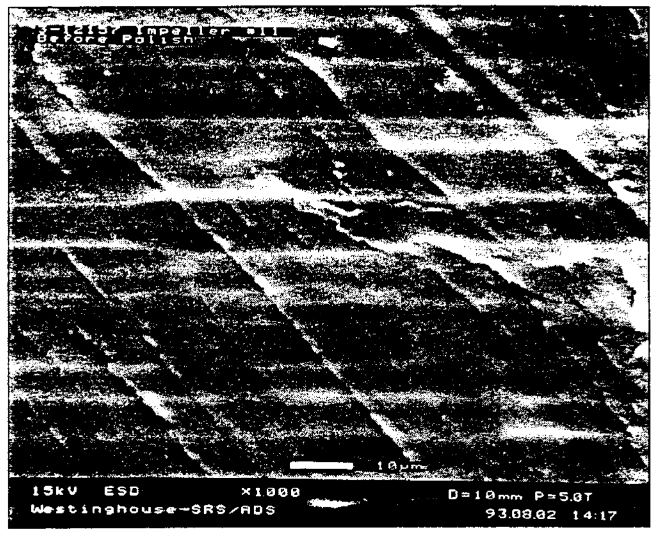
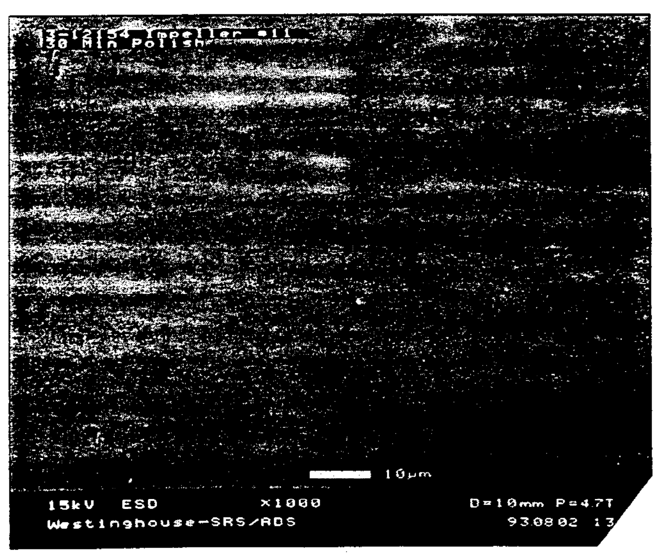


Figure 1. Stainless steel surface, as ground and before electropolishing (above) and after electropolishing (below). Scanning electron micrograph, original magnification 1000×.



Electropolishing can be an excellent tool for burr removal. In fact, there are some cases in which it is difficult to imagine any other method that would produce equivalent results.

Electropolished surfaces are more resistant to staining and contamination and are more easily cleaned. This again is due to the microsmoothed surface, which is an obvious advantage in food, pharmaceutical, and medical equipment.

Mechanical Prefinishing

Some parts can be electropolished with no mechanical prefinishing, but in many cases electropolishing is best used to complement mechanical finishing. Electropolishing operates in the micro range, smoothing and leveling defects of a few thousandths inch size. Larger defects may never be removed by electropolishing, hence the need for mechanical prefinishing.

Phase changes, alloy segregation, and carbide precipitation may become more visible after electropolishing, particularly when these changes are caused by welding and are in limited areas.

Sand, grit, or glass bead blasting generally produce surfaces too coarse to be completely smoothed by electropolishing. SEM examination of blasted surfaces after electropolishing shows the surface to be decontaminated and smoothed, but the major disturbances are still present.

Similarly, coarse abrasive polished finishes may never have all of the scratches removed. In general, electropolishing can completely smooth abrasive scratches such as those produced by 220 grit or finer. Coarser abrasive scratches will remain visible. Mechanical prefinishing finer than about 320 grit does not result in a better finish after electropolishing.

Some mill finishes produce excellent electropolish results without mechanical prefinishing. The general-purpose bright cold-rolled 2B finish will electropolish bright, smooth, and clean, although any nicks or scratches from handling and fabrication will need mechanical prefinishing to produce a uniform electropolished finish. The 2B finish is actually preferable to mill finishes No. 3 or No. 4, which are produced by relatively coarse abrasive of 50-150 grit and on which the polishing lines will remain visible.

Hot rolled finish No. 1 will electropolish bright, but will show many of the depressions and undulations resulting from the hot rolling and descaling processes. To produce a mirror finish on hot-rolled and pickled finish No. 1 would require multiple passes with succeedingly finer abrasives prior to electropolishing.

Weld Prefinishing

Weld prefinishing prior to electropolishing can be a particular problem. Depending on the weld techniques and the skill of the welder, there can be voids and inclusions that can never be removed without exposing more of the same defects. Top-quality welds, on the other hand, can often be satisfactorily electropolished with no prefinishing.

Electropolishing can be an excellent tool for burr removal. In fact, there are some cases in which it is difficult to imagine any other method that would produce equivalent results. Burrs inside very small drilled, pierced, or tapped holes are an example. Electropolishing can remove these burrs, and because of the preferential removal of projections, can remove them without altering dimensions *(Figure 2)*.

Burr removal can require mechanical prefinishing. A pierced hole, for example, may have a burr perpendicular to the surface. Such a burr may be too large to be removed by electro-

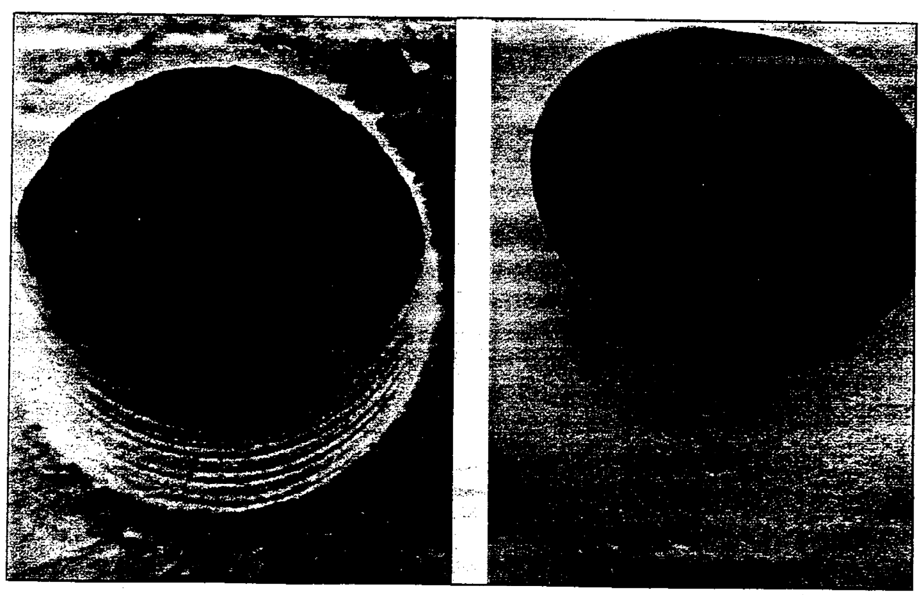


Figure 2. Drilled hole 0.003" diameter, before and after electropolishing. (Scanning electron micrograph, original magnification 1000X).

polishing. A mechanical operation such as belt lapping can be used to remove the majority of the burr, leaving a small, sharp burr in the hole, and this burr can be removed by electropolishing. The burrs most amenable to removal by electropolishing are those that are small, sharp, and difficult or impossible to remove mechanically.

Electropolishing is also a valuable tool for producing fine radii, for example where two ground surfaces meet. Electropolishing can remove any fine burr and leave a small but definite radius. Electropolishing can be used as a precision machining method where it is necessary to remove a very thin layer of metal to achieve a precise dimension with a fine surface finish.

Electropolishing vs. Mechanical Polishing

Electropolishing and mechanical polishing are more complementary processes than they are competitive processes.

Removal of significant stock or larger imperfections requires mechanical polishing. Mechanical polishing of large volumes of identical items can be more highly automated than electropolishing and can have lower unit costs. Mechanical polishing itself may not require the use of hazardous chemicals.

In conclusion, electropolishing accomplishes more than improved smoothness and appearance. It also produces microclean and microsmooth surfaces that are corrosion and contamination resistant. ■

At **http://www.globalmfg.com** on the Internet's World Wide Web, SME maintains a site called the Global Manufacturing Network, one of the world's most important databases devoted exclusively to manufacturing technology.

Chairman's Message

Dear Member:

This is the first of a determined effort on the part of the AFP/SME Board of Advisors to communicate with the membership. Your new Board met recently at SME Headquarters in Dearborn, Michigan. One of the key points on our agenda was to respond to the 1997 Presidential Charges, which include:

- Create a report detailing the major trends in the finishing industry,
- Support a truly international AFP/SME Board of Advisors, and
- Support development of the AFP/SME Home Page.

In future issues of *The Finishing Line* and at the Finishing '97 Show this May 19-22 in Rosemont (Chicago), there will be clear evidence of support in these projects, along with others.

We are very interested in providing international members representation on the Board. We're looking for individuals who can represent the European and Asian finishing industries. Interested members should contact AFP/SME at (313) 271-1500, ext. 544, or fax to (313) 240-8255, Attention: Cheri Skomra, AFP/SME manager.

The AFP/SME Board highly recommends that you attend Finishing '97 in Rosemont. The gains for you will be to:

- Stay current by networking with colleagues and other finishing experts,
- Update your knowledge on the latest processes at the conference,
- View state-of-the-art equipment and materials at the exposition, and
- See the first demonstration of AFP/SME's Home Page.

You gain all this for a small effort on your part. I look forward to seeing you at the AFP/SME booth.

Gary K. Sweet

Gary K. Sweet, CMfgE
AFP/SME Chairman

tion methods. Chrysler made major changes in paint formulation, equipment, and employee training to improve finishing operations while reducing VOC emissions. The automaker also developed a combination spray-booth/oven that helps paint products faster. Lowenstein, a large contract seating manufacturer, developed a new coating system using waterborne stains and a UV top coat to reduce VOC emissions from over 125 tons per year to less than 50 tons. Gabriel made changes in coating materials to reduce VOC emissions by 20%; this customer-driven manufacturer also makes over 60 color changes in an eight-hour shift. Industry experts Gerry Schneberger and Frank Hussey examine the way increased transfer efficiency lowers VOC emissions and the

worldwide trends toward green manufacturing. The video (order code VT571-2969) is priced at $240; $225 to SME members. To order, call SME Customer Service, 1-800-733-4SME(4763).

Advanced Polymer Sciences (Avon, OH) announces availability of a 20-minute videotape outlining the capabilities of Siloxirane, the basic, patented polymer used in the company's product line of coatings. The video compares the properties and chemical structure of Siloxirane with epoxies, phenolics, rubber, and stainless steel. When heat cured, Siloxirane-based coatings are used to protect surfaces from corrosion, abrasion, and high temperatures in a variety of applications from railroad tank cars and shipping containers, to emission stacks and ducts and heat exchangers. With ambient curing, Siloxirane is used to coat steel structures, concrete, and containment areas such as floors, loading docks, and other high wear surfaces. Call (800) 334-7193.

Literature

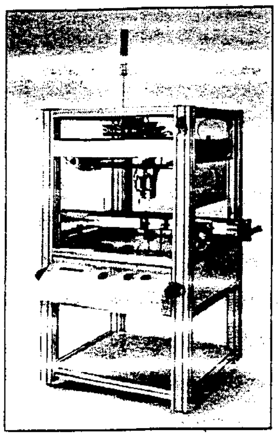
Engineers' Guide to Cleaner Production Technologies presents technological advice for solving environmental problems in five areas: cleaning and degreasing, paints and coatings, metal finishing, chlorinated solvents, and coating removal. Editor Paul Randall is a chemical engineer with the US Environmental Protection Agency in Cincinnati, where he leads engineering research and technical support for pollution prevention research. The book is intended as an aid to practicing engineers responsible for process improvements to reduce or eliminate wastes into the environment. For each technology, the book addresses its pollution prevention benefits, operating features, applications, and limitations. Processes and equipment are well illustrated with schematics, and extensive reference data are provided in tables and figures. The book is 240 pp., softcover, $85, available from Technomic Publishing Co (Lancaster, PA). Toll-free number in US and Canada is 800-233-9936.

ZC&R (Carson, CA) offers a full color, 12-page catalog featuring standard high-performance coatings and filters. These include coatings such as anti-reflection, high-power laser, beamsplitters, hot and cold mirrors, bandpass color filters, heat and color control, metal coatings, ITO and index-matched ITO, thin film polarizers, covert filters, and fluorescence filters. Graphs illustrate the performance of each coating and a description of output specifications is given. Call (310) 513-6319.

Physical Vapor Deposition (PVD) has expanded significantly as more manufacturing and fabrication techniques and miniaturized products broaden the demand for vapor-deposited materials. PVD equipment and technology are poised to capitalize on a variety of new products that require properties best delivered by vacuum-depositing thin films on a broad range of surfaces. *RGB-186B Thin Layer Deposition: Highlighting PVD* is a recent report from Business Communications Co. Inc. (Norwalk, CT) that traces the value of worldwide shipments of PVD equipment from $2.7 billion in 1995 to a predicted $4.7 billion by year 2000. The largest market is the microelectronics industry, which includes semiconductors, components, and flat panel displays. Shipments in 1995 were valued at $1.7 billion and will rise to $3.1 billion by 2000. PVD equipment shipments for cutting tool applications are projected to reach $161.9 million by 2000, from $112.8 million in 1995. In the industrial market sector, including automotive and aerospace, PVD shipments are expected to hit $353 million by 2000, up from 1995's $284 million. For information, call (203) 853-4266.

New Products

Specialty Coatings Systems (Indianapolis, IN) announces a new selective spray coating system, the SCS-4393, for applying conformal coatings to printed circuit boards and electronic assemblies. This new automated coating cell functions as a stand-alone coater and can also be integrated with a complete electronic manufacturing production line. The SCS-4393 provides

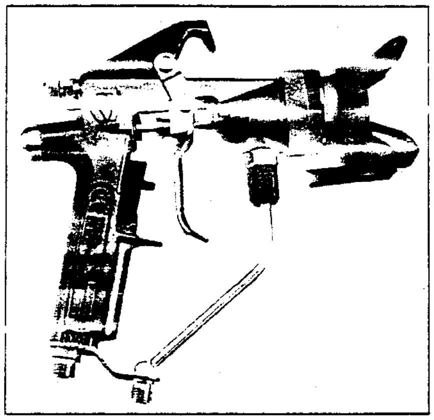


a selective coating placement accuracy of ±0.005 mm (0.0002″), permitting users to avoid masking and demasking of circuit assemblies, thus saving production time and labor costs. Coating repeatability is at least ±0.025 mm (0.001″). Of rigid, lightweight construction, it can be equipped for three- or four-axis coating application control. It includes both low-pressure atomized spray and needle dispensers on a computer-controlled transport mechanism. Call (800) 356-8260.

ITW Ransburg (Toledo, OH) introduced the Aviator™, a new electrostatic spraygun system designed to meet the needs of today's aircraft finishing indus-

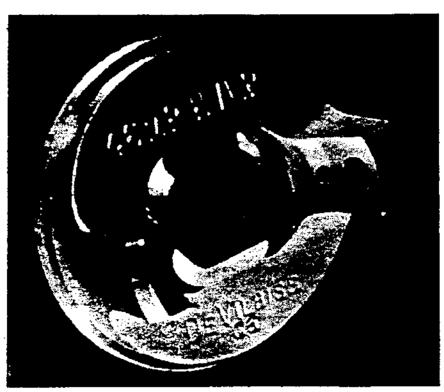
try. Engineered to meet Class 1, Division 1 requirements, the Aviator's components provide high transfer efficiency and excellent coverage by attracting more paint to the aircraft, even in hard-to-reach areas. System components include the Aviator control unit, low-voltage cable, and an electrostatic spray gun with HVLP, air spray, or air-assisted airless operation. The spray gun has no moving parts, which increases operator comfort. Call (419) 470-2000.

The AA Plus™ air-assisted airless spray gun from Graco Inc. (Minneapolis, MN) is designed to atomize high solids coatings at pressures up to 4000 psi. It's suited for applying lacquers, plural component materials, and protective coatings in metal and wood finishing. The



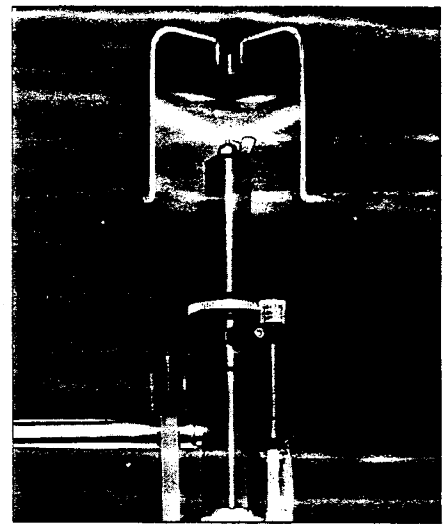
gun is readily adaptable to existing airless or air-assisted airless finishing lines without major changes. The AA Plus also features improved air caps and tips for better atomization and consistency, and an improved trigger design, requiring minimal force to activate the gun. Call (612) 623-6745.

The new GoldMax™ Air Cap from ITW DeVilbiss (Maumee, OH) was designed to meet the demands of higher solids and low-VOC materials. Identified by its gold coloring, the GoldMax air cap combination features a patented air cap, a fluid tip and needle for enhanced fluid flow and to



ensure leak-free operation, and a specially designed baffle to reduce air pressure to 10 psi maximum. Used in the DeVilbiss spray gun lines, the new air caps are being used with equal success in the automotive, OEM, plastics, wood furniture, aerospace, and metals industries. Call (800) DEV-4448.

EFD Inc. (East Providence, RI) offers its new patented 782R radial spray valve that allows automatic application of fluids



such as lubricants and adhesive activators in precise, even amounts. Output is adjustable from fine coatings to heavy sprays. In operation, a rotating air cap produces a radial pattern of atomized fluid to coat the inner circumference of cylinders having an inside diameter of 1″ up to 12″. Air cap rotation is provided by a precision dc motor. Call (888) 333-0311.

For ordering SME books and videos, verifying SME event schedules, or subscription information, call **Customer Service at 1-800-733-4SME** (4763) from 8 am to 6 pm Eastern Time, Monday through Friday. Or visit SME's Global Manufacturing Network at **http://www.globalmfg.com.**

Events

Finishing & Decorating of Plastics
May 19-20, Madison, WI
University of Wisconsin
(Call Katie Peterson, Engineering Dept., (800) 462-0876)

Finishing '97 Conference & Expo
May 19-21, Rosemont, IL
AFP/SME

Corrosion & Its Control by Protective Coatings (Short Course)
May 19-23, Bethlehem, PA
Lehigh University (Call Dr. Richard Granata, (610) 758-3574)

Paints, Plastics, & Adhesives for Automotive Usage
May 28-30, Ann Arbor, MI
University of Michigan
(Call Amy O'Connor, (313) 647-7180)

Infrared Technology: Fundamentals & Systems Applications
June 9-13, Ann Arbor, MI
University of Michigan
(Call Amy O'Connor, (313) 647-7180)

Hazardous Waste Management for Beginners
July 14-15, Raleigh, NC
August 4-5, Chicago, IL
To register, call (800) 537-2372, ext. 222

Finishing Systems Design & Operation (2 days) and Cost Analysis for Finishing Systems (1 day)
August 26-28, Toronto, ON
AFP/SME

Automotive Powder Coating
Sept. 9, Detroit, MI
AFP/SME

Spray Applications of Powder Coating
Sept. 11, Grand Rapids, MI
AFP/SME

Powder Metallurgy
Oct. 9, Pittsburgh, PA
AFP/SME

Liquid Coating Systems
Oct. 15, Detroit, MI
AFP/SME

Painting Systems for Industrial Applications
Oct. 28, Toronto, ON
AFP/SME

Finishing Systems Design & Operation (2 days) and Cost Analysis for Finishing Systems (1 day)
Nov. 11-13, Cincinnati, OH
AFP/SME

Spray Application Methods for Powder Coating
Nov. 18, Indianapolis, IN
AFP/SME

Infrared Technology & Applications
Nov. 19, Chicago, IL
AFP/SME

Advanced Powder Systems Troubleshooting
Dec. 5, Detroit, MI
AFP/SME

Painting Systems for Industrial Applications
Dec. 9, Arlington Heights, IL
AFP/SME

For additional information and confirmation of above AFP/SME dates and locations, or if you're interested in a customized coating event in your facility, contact Lisa Liverance, Technical Administrator, at (313) 271-1500, ext. 369.

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