M C P

Chemicals · Equipment · Process Technology
for
Metal Finishing

The MCP System of Electropolishing

An Overview

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The MCP System of Electropolishing: An Overview

BASIC PRINCIPLE OF ELECTROPOLISHING

Electropolishing is a process by which metal is removed from a work piece by passage of electric current while the work is submerged in a specially-designed solution. The process is essentially the reverse of electroplating. In a plating system, metal ions are deposited from the solution onto the work piece; in an electropolishing system, the work piece itself is dissolved, adding metal ions to the solution.

Figure 1 is a schematic illustration of a typical electropolishing cell. The work piece is connected to the positive (or anodic) terminal, while the negative (cathodic) terminal is connected to a suitable conductor. Both positive and negative terminals are submerged in the solution, forming a complete electrical circuit. The current applied is direct (DC) current.

The quantity of metal removed from the work piece is proportional to the amount of current applied and the time. Other factors, such as the geometry of the work piece, affect the distribution of the current and, consequently, have an important bearing upon the amount of metal removed in local areas. Figure 2 illustrates both high and low current density areas of the same part and notes the relative effects of electropolishing in these two areas.

The principle of differential rates of metal removal is important to the concept of deburring accomplished by electropolishing. Fine burrs become very high current density areas and are, subsequently, rapidly dissolved. Low current density areas receive lesser amounts of current and may show negligible metal removal.

In the course of electropolishing, the work piece is manipulated to control the amount of metal removal so that polishing is accomplished and, at the same time, dimensional tolerances are maintained. Electropolishing literally dissects the metal crystal atom by atom, with rapid attack on the high current density areas and lesser attack on the low current density areas. The result is an overall reduction of the surface profile with a simultaneous smoothing and brightening of the metal surface.

In the case of stainless steel alloys, an important effect is caused by differences in the rates of removal of the components of the alloy. For example, iron and nickel atoms are more easily extracted from the crystal lattice than are chromium atoms. The electropolishing process removes the iron and nickel preferentially, leaving an enhanced surface layer consisting of corrosion-resistant chromium oxide. This phenomenon imparts the important property of “passivation” to electropolished surfaces.

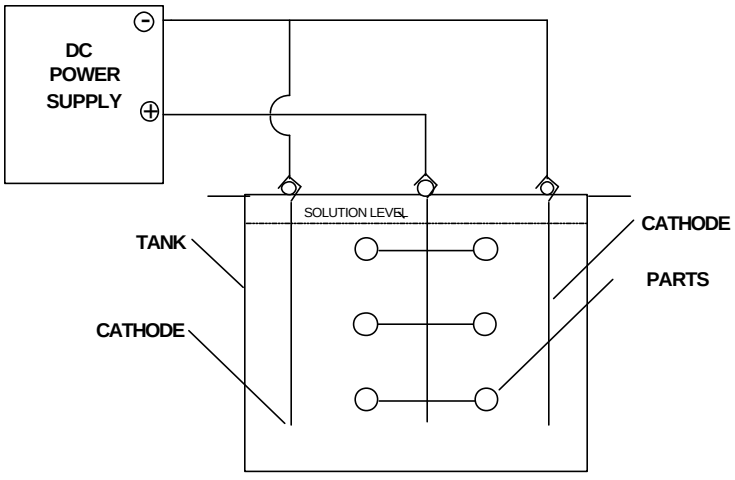
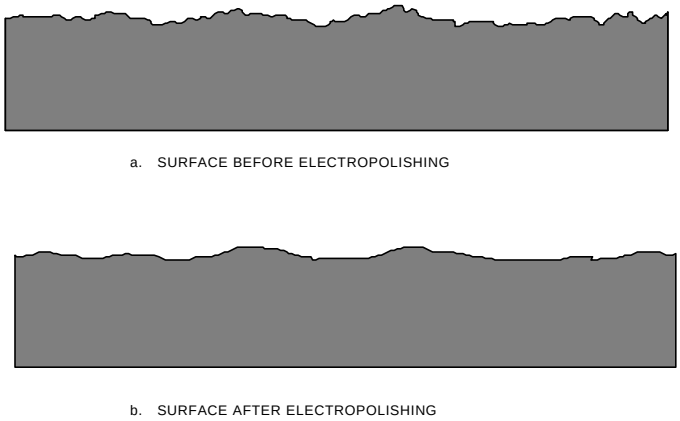


FIGURE 1 Schematic illustration of typical electropolishing system.



a. SURFACE BEFORE ELECTROPOLISHING

b. SURFACE AFTER ELECTROPOLISHING

FIGURE 2. Effect of electropolishing on surface finish.

ELECTROPOLISHING PROCESS REQUIREMENTS

Electropolishing is accomplished in a series of wet processing steps using specially designed tanks, similar to electroplating or anodizing. The parts to be polished are mounted on a rack or jig which is moved from tank to tank. The three major process objectives of the electropolishing process are:

METAL PREPARATION:	To remove all oils, lubricants, shop dirt, fingerprints, oxides, scales, and other contaminants from the surface. Suitable methods include vapor degreasing, alkaline and/or acid cleaning, spray washing, sanding, wire brushing, and other types of mechanical steps.
ELECTROPOLISH:	To smooth, brighten, deburr, passivate, stress relieve, improve surface profile, hygienically clean, reduce friction, increase corrosion resistance. To remove and recover electropolishing solution.
POST TREATMENT:	To remove chemical residues or byproducts of electropolishing and to assist drying.

Electropolishing is similar to other metal finishing processes in terms of design, operation, and control. Each of the major objectives listed above may require a number of steps to accomplish the desired result, depending the condition of the surface and the metal history. The typical flow chart for a stainless steel electropolishing system is shown in Figure 2.

ELECTROPOLISHING PROCESS REQUIREMENTS, continued

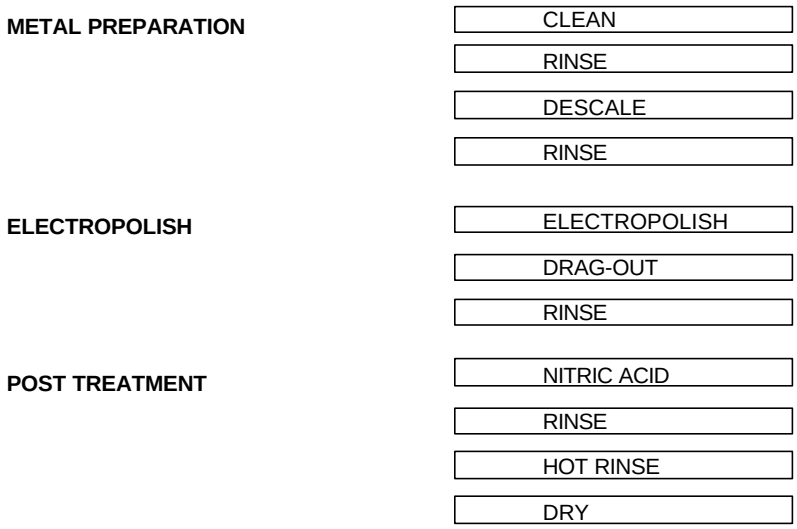


FIGURE 3. Schematic diagram illustrating the normal sequence of steps used to electropolish stainless steel.

Electropolishing systems require rinse water to remove solution from the parts after each chemical operation. These rinses usually flow to drain, and are subject to Federal, State, and Local regulations affecting discharge to public sewer treatment systems. Most modern electropolishing systems now incorporate evaporative recovery and/or multiple rinse technologies to minimize the amount of rinse water used. MCP can furnish simple waste treatment packages guaranteed to meet the current restrictions.

Electropolishing baths generate both hydrogen and oxygen gases, producing an acid mist which must be ventilated to meet OSHA requirements. Other solutions in the line, such as cleaners and pickles, may also require ventilation to meet these regulations. MCP can furnish installed ventilation systems constructed entirely of PVC, which meet or exceed such regulations.

High quality surface finishing also requires some analytical effort to ensure that solutions are chemically balanced. MCP will furnish analytical services free of charge to its chemical customers in good standing; however, each customer should also budget space, equipment, and reagents for the chemical controls needed to achieve the desired finish specification.

Special equipment may be needed to ensure that quality criteria specified by the end-user are being met. Many end-uses require only visual examination of the parts to evaluate brightness, luster, or clarity of the finish. Others may require sophisticated instrumentation to determine surface profile, degree of passivation, surface layer composition, or other specified performance characteristic.

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WHAT ARE THE BENEFITS OF ELECTROPOLISHING?

Electropolishing produces a number of favorable changes in a metal part which are viewed as benefits to the buyer. All of these attributes translate into selling advantages depending upon the end-use of the product. These include:

Brightening
Burr removal
Total passivation
Oxide and tarnish removal
Reduction in surface profile
Removal of surface occlusions
Increased corrosion resistance
Increased ratio of chromium to iron
Improved adhesion in subsequent plating
Reduced buffing and grinding costs
Removal of directional lines
Radiusing of sharp edges
Reduced surface friction
Stress relieved surface
Removal of hydrogen

Electropolishing produces the most spectacular results on 300 series stainless steels. The resulting finish often appears bright, shiny, and comparable to the mirror finishes of “bright chrome” automotive parts. On 400 series stainless steels, the cosmetic appearance of the parts is less spectacular, but deburring, cleaning, and passivation are comparable.

Solutions are available to electropolish most common metals. Notable exceptions include cast alloys of zinc, aluminum, brass, bronze, and carbon steel. Investment cast stainless steels may also be difficult to electropolish to a satisfactory finish unless parts are solution annealed after heat treating. In general, only the 200 and 300 series stainless steels, certain tool steels, copper, and some single-phase brass alloys can be electropolished to mirror finishes. The principal effects on other types of metal are deburring, smoothing, improvement of surface finish, and increased adhesion of plated coatings.

Electropolishing produces a combination of properties which can be achieved by no other method of surface finishing. Mechanical grinding, belting, and buffing can produce beautiful mirror-like results on stainless steel, but the processes are labor intensive and leave the surface layer distorted, highly stressed, and contaminated with grinding media. The passivation methods commonly employed produce clean, corrosion resistant surfaces, but do not achieve the bright, lustrous appearance obtained by electropolishing. The corrosion resistance of electropolished stainless steel exceeds that of standard passivation processes.

Electroplating can produce extremely bright finishes, but the finish is a coating which can chip or wear off. Electroplated surfaces may also exhibit hydrogen embrittlement which must be stress-relieved in a separate step. Neither passivation nor electroplating can accomplish burr removal.

Processes are available for chemical deburring and brightening of steel and stainless steel, but these methods cannot match the surface improvement produced by electropolishing. The corrosion resistance produced by such processes is decidedly inferior to that produced by electropolishing.

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SPECIFICATIONS FOR ELECTROPOLISHING

Specifications for electropolishing vary with the end use of the parts. A knowledge of the end-user's requirements is of great importance in designing an electropolishing line and the process control system. MCP process control methods are designed for a spectrum of quality assurance applications ranging from simple deburring to the most demanding ISO 9001 requirements.

The simplest requirements for electropolishing are for a “clean, bright, cosmetically attractive” finish. Results are judged primarily by appearance. Other common specifications require a specified level of deburring without regard to cosmetic appearance. Inspection techniques vary from simple snagging tests with woven or knitted cloth to microscopic examination of the burrs. These applications may be satisfied with a relatively simple approach to the electropolishing equipment and process.

Processes for passivation are defined by the American Society for Testing Materials (ASTM). ASTM specification A380 covers various methods of chemical passivation, detailing the sequence of operations and the test methods to be followed. A more recent publication, ASTM A967-99, expands the scope of A380 to include electropolishing as a means of passivation. ASTM specifications may be obtained by download from the Society web site at www.astm.org. The Federal specification QQ-P-35C formerly used as a guide for passivation of stainless steels has been superceded by the ASTM specifications.

The use of electropolishing to improve surface finishes for vacuum, semi-conductor, and cleanroom applications continually becomes more sophisticated. Many end-user specifications now include scanning electron microscope (SEM) at 1000X to 10,000X. Surface profiles in the range of 3-5 R_a are frequently specified, and research efforts continue to strive for methods to achieve even finer finishes. Electron spectroscopy is used to define the composition of the surface oxide layer in terms of the ratio of chromium to iron. Atomic force microscopy is also being used as a tool to define electropolished surfaces. Ultraclean gas systems may require limitations in the parts per billion range for outgassing from the polished surface. Detailed specifications can be downloaded from the semiconductor trade association web site, www.sematech.org.

ESTIMATED COST OF ELECTROPOLISHING

CAPITAL INVESTMENT

Electropolishing equipment is available in a wide range of types and sizes. Materials handling systems may be manual or automatic, depending upon the requirements. MCP encourages the use of complete process systems to produce the highest quality finishes. Partial systems are furnished, if the complete process is not needed to achieve the quality objectives.

The smallest complete systems furnished by MCP are the “Console” series units. Console units contain precleaning, electropolishing, and post-treatment modules, and are suitable for small-scale production, pilot plant, or experimental work. Such systems vary in size from 5 gallons to 25 gallons tank capacity, with costs ranging from about $22,000 to about $48,000. Console systems consist of a series of recessed tanks, enclosed in a stainless steel and polypropylene cabinet, with all internal plumbing and wiring installed. The ventilation system consists of a plenum chamber with air intake slots and an exhaust stack for connection to an existing fan and ductwork. Waste disposal equipment is not included with the “console” series.

MCP “Standard” Electropolishing Eystems are designed for nominal tank capacities of 60, 100, and 150 gallons, referred to as Models 1060, 10100, and 10150, respectively. Each model consists of 10 tank stations, covering Precleaning, Electropolishing, and Post Treatment modules. The Standard Systems can be equipped for zero discharge of the electropolishing solution through the use of optional evaporative recovery units.

Basic equipment costs for this type of line vary from about $43,000 to about $70,000. Precleaning, Electropolishing, and Post Treatment modules are also sold separately if the complete system is not necessary for a given situation. The cost of environmental control equipment for waste treatment and for fume removal must be added to these costs. Tank lines larger than 200 gallons are considered as “Custom” systems, and detailed pricing can be furnished upon request.

ESTIMATED COST OF ELECTROPOLISHING, continued

Automatic lines are available in the "carousel" design with programmable time cycles. These machines vary from about 8'- 12' in diameter, optimizing production by a single operator in limited floor space. Straight-line automatic machines, utilizing one or more programmable hoists, are also available for rack processing. The typical automatic process line costs $90,000 to $350,000 exclusive of installation. Waste treatment and ventilation equipment are optional.

For bulk processing of small parts, MCP can furnish the “K-Line” machine capable of polishing up to 20,000 small parts per hour. This machine is complete with electropolishing and post treatment operations. Precleaning, if necessary, must be accomplished off-line. Depending upon the production requirements, the machine costs approximately $200,000-$350,000 plus environmental control equipment. The Buyer must furnish special materials handling equipment for loading of small parts on fixtures.

Applications such as electropolishing of large tanks require use of special equipment and techniques depending upon the product to be polished and the finish specifications. Sometimes the tank can be filled with solution and used as its own vessel for polishing; in other cases, the tank is partially filled with solution and is rotated around a stationary cathode to achieve the desired finish. Internal tank finishes in the range of 0.5 R_a units are reportedly produced in this manner.

OPERATING COSTS

The cost of chemicals for electropolishing normally ranges from about 10¢ - 15¢ per square foot of work for most “clean and bright” finish specifications on stainless steels. Specification work may cost 20¢-30¢ per square foot. Electricity varies from a low of about 0.1 KWH to a high of about 0.6 KWH per square foot. The costs of labor, overhead, and certain operating parameters such as drag-out losses and waste treatment are not included in these numbers and must be added to obtain the total operating cost. Mechanical surface preparation steps, such as grinding or sanding, must also be added to the cost of the finished part.

Labor costs are generally comparable to those encountered in rack plating and may range upward from 1¢ - 5¢ per piece for small parts processed in large volumes to many man-hours of work for polishing a large vessel. Labor costs generally exceed the cost of chemicals and power; therefore, careful attention to the production rate may be extremely important to the variable cost of electropolishing.

Electropolishing solutions are normally furnished in 15-gallon or 50-gallon drums, or in bulk volumes of 1500 to 3000 gallons. Prices vary with the type of solution and with the volume purchased, but typical costs range from about $11 per gallon to about $22.00 per gallon.

COST ESTIMATES

MCP will provide a free budgetary estimate of capital costs to qualified buyers. The questionnaire form included as page 7 of this pamphlet should be completed and returned to MCP by mail or by fax to file a formal request for a proposal. The quotation request form is also available on our web site at http://www.electropolish.com.

For all proposals, the information submitted should include the part dimensions, specifications, and production requirements. In some cases, additional information such as samples or drawings of the parts to be electropolished may be requested.

The MCP consulting/seminar service is available to provide a basis for upgrading or expanding existing systems.

SEND THIS COMPLETED FORM TO MCP FOR A FREE ESTIMATE

MCP CORPORATION
6101 IDLEWILD ROAD, SUITE 134
CHARLOTTE, NORTH CAROLINA 28212
TELEPHONE 704/563-0070 FAX 704/535-4535

REQUEST FOR QUOTATION - ELECTROPOLISHING EQUIPMENT SYSTEMS

CONTACT INFORMATION

Name: _____ Title _____
Company: _____
Address: _____
City _____ State _____ Zip _____
Telephone (_____) _____ Fax (_____) _____
area code area code

COMPANY INFORMATION

President or General Manager: _____

Engineering or Production Manager: _____

Purchasing Agent: _____

Is this request for an Approved Project? No ☐ Yes ☐

New Project? ☐ Information Only? ☐

Project funded? No ☐ Yes ☐

Does plant discharge waste water to a Public Owned Treatment Works? No ☐ Yes ☐

If no, explain waste handling method _____

_____

PARTS TO BE ELECTROPOLISHED

End use of parts _____

Metal or alloy to be electropolished _____

Are parts electropolished now? No ☐ Yes ☐

In-house? No ☐ Yes ☐

Vendor? $/year _____ _____

Is there a finish specification now? No ☐ Yes ☐ What? _____

How are parts made? Cast ☐ Stamped ☐ Machined ☐ Fabricated ☐ Welded ☐

Describe mechanical finishing processes used _____

No. of parts produced: per wk _____ per mon _____ per yr _____

Approximate size of parts _____ Drawings available? No ☐ Yes ☐

Samples sent to MCP? No ☐ Yes ☐