

# **M C P**

**Chemicals · Equipment · Process Technology  
for  
Metal Finishing**

**The MCP System of Electropolishing**

**General Process Steps**

**Charlotte, NC  
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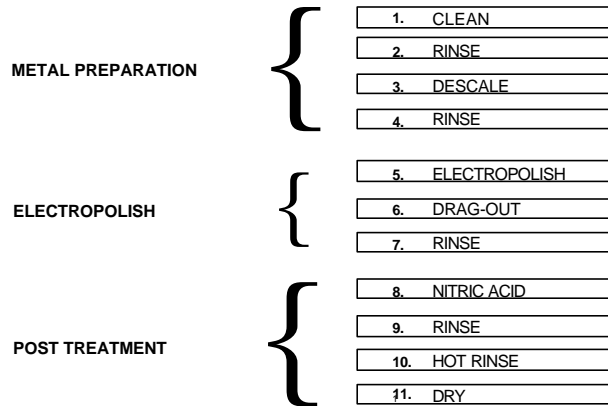
# THE MCP SYSTEM OF ELECTROPOLISHING

## GENERAL PROCESS STEPS

**INTRODUCTION:** To obtain high quality electropolished finishes on most stainless steel alloys, it is necessary to process the work through three major operations:

1. METAL PREPARATION: To remove surface oils, greases, oxides, and other contaminants, which interfere with the uniformity of electropolishing.
2. ELECTROPOLISHING: To accomplish the desired smoothing, brightening, and/or deburring of the metal, followed by re-capture of the electrolyte to minimize waste treatment.
3. POST TREATMENT: To remove residual electrolyte, to remove by-products of the electropolishing reaction, and to dry the metal to prevent staining.

Each of these major operations may consist of several tank stations to accomplish the desired result. The typical flow chart is shown in the following schematic diagram:



### STATION 1. ALKALINE SOAK CLEAN

The purpose of the alkaline soak cleaner is to remove any oil, grease, shop dirt, fingerprints, or similar films left on the parts after manufacture. Surface contaminants present on the parts during electropolishing can lower the quality of the resulting finish, particularly for critical applications such as medical, pharmaceutical, and semi-conductor products. Once the parts are removed from the cleaner, care should be taken to avoid unnecessary contact with the hands or process equipment.

Alkaline cleaning proceeds by a combination of chemical and physical reactions involving displacement, flotation, penetration, wetting, emulsification, and saponification of the contaminants. All of these reactions are sensitive to both time and temperature; therefore, care should be taken to make sure the cleaning conditions fit the properties of the soil to be removed. Some soils may require little or no alkaline soaking; others may require substantially higher temperatures, soaking times, and chemical concentrations to achieve cleanliness.

Cleanliness should be considered one of the cardinal principles of all metal finishing operations. Improperly or inadequately cleaned parts are a frequent source of rejects. Alkaline cleaners are relatively cheap insurance, compared to the cost of rework. Cleaning baths should be maintained by:

1. Periodic additions of cleaning compound to maintain sufficient alkalinity, wetting agent, and performance, as determined by on-site testing.
2. A preventive maintenance schedule to dump and remix the solution before cleaning problems can affect the quality of the work.

Alternative cleaning methods include organic solvent cleaning and vapor degreasing; however, these methods seldom leave a water-wettable surface, and some alkaline cleaning may be required to remove any residue from the organic cleaner.

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### **STATION 2. COLD WATER RINSE**

A rinse tank serves two primary functions in a metal finishing system:

1. To remove by dilution the chemical residue from the previous operation, and,
2. To act as a barrier to prevent drag-in to the following operation.

As the alkaline cleaner solution is removed from the parts, the concentration of alkali in Station 2 gradually increases. At some concentration, the alkalinity of the water dragged out of the rinse by the parts will have a serious neutralizing effect on the acidity of the descaling solution in Station 3. In order to minimize the effect of this drag-out, fresh make-up water must be fed to Station 2 on a continuous or regular intermittent basis.

The volume of water required to establish satisfactory equilibrium must be determined experimentally. Estimates of the volume and flow rate of water required to establish equilibrium can be approximated by using a method described in the MCP process manual. Typical flow rates for rinse tanks range between 1 and 3 gallons of make-up water per rinse tank per minute of operation.

The volume of water used in rinsing must be limited to avoid overwhelming the capacity of the waste treatment system. Some common methods of water volume control include the use of counterflows, spray rinses, drag-out tanks, conductivity instruments, flow orifices, intermittent valves, etc.

Theoretically, the time required for rinsing is a function of the flow rate of make-up water and the initial and final concentrations of contaminants. The practical choice of a rinsing time may consider other observed factors, such as the clarity of the solution, the color of the rinse water, or the removal of floating foam, to estimate the equilibrium point. In general, alkaline cleaning solutions are difficult to remove completely by rinsing, and often require neutralization to ensure removal.

The importance of rinsing to the success of a metal finishing operation should not be underestimated. Inadvertent mixing of solutions through drag-in of incompatible chemicals is a common source of quality problems in metal finishing.

### **STATION 3. ACID DESCALE**

The purpose of the Acid Descale is to remove light oxidation from the work and to neutralize the alkaline film left by the cleaner tank. Surface oxidation present on the parts during electropolishing can affect the quality of the resulting finish, particularly for critical applications such as semiconductor, medical, and pharmaceutical products. Alkaline drag-in from the cleaner tank will gradually destroy the total acid content of the electropolishing bath, causing quality problems.

Scale conditions and removal methods vary widely; however, some care must be exercised to ensure that the method chosen is compatible with the electropolishing bath and the overall design of the electropolishing line. For example, nitric acid drag-in to the electropolishing bath must be prevented if spent electropolishing solution is to be returned to the manufacturing site for waste treatment. Therefore, methods incorporating nitric acid should be used as a last resort. Similarly, methods using pollutants such as chromic acid should be avoided unless provisions are made to accommodate the heavy metal in the waste treatment system. Compatible electrolytic descalers such as the Cleaner/DeOx line of products may be used with direct current to remove heat treat scales and weld discolorations. Typical process conditions are 100-120°F, at 6-12 volts, and a current density of 50-100 asf.

Oxide scales, such as welding scale, may also be removed by mechanical means. Sanding, grinding, and bead blasting of scaled or discolored areas may eliminate the need for acid descaling.

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### STATION 4. COLD WATER RINSE

The principles of operation for the acid descale rinse are essentially the same as those for the alkaline cleaner rinse. The main difference is that acidic solutions are generally much easier to remove by rinsing than alkaline residues, and lower flow rates and/or shorter rinsing times may often be used.

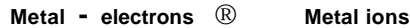
It should be noted that drag-in of fluoride and nitrate ions to the electropolishing bath may preclude return of spent electropolishing solution to the manufacturing plant for waste treatment. Therefore, some care must be taken to ensure that these ions are not permitted to reach excessive levels in Station 4.

### STATION 5. ELECTROPOLISH

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 terminals are submerged in the solution, forming a complete electrical circuit. The current applied is direct (DC) current.

The principal chemical reactions occurring at the electrical anode, that is, at the part, is as follows:



The reaction states that metal is dissolved from the anodic electrode, passing into the solution to form a soluble salt of the metal. All of the components of stainless steel, namely the iron, the chromium, and the nickel, undergo this reaction simultaneously, producing the controlled smoothing of the surface. Several side reactions also occur, creating by-products that must be controlled in order to produce the highest possible quality of electropolishing.

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 effect of electropolishing in these two areas.

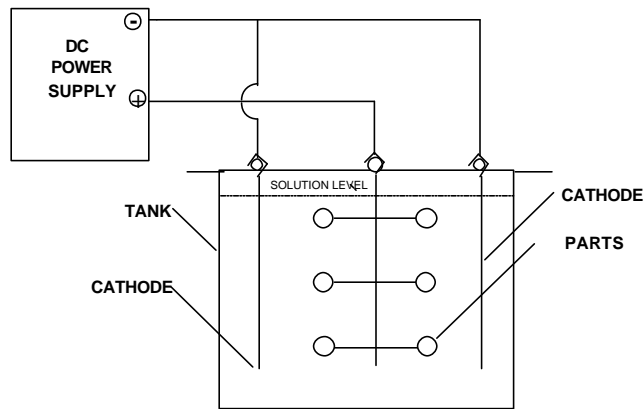
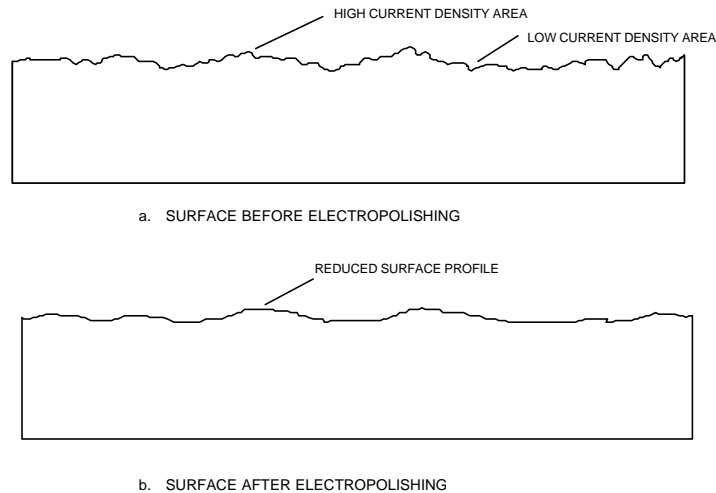


FIGURE 1. Schematic illustration of typical electropolishing

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**FIGURE 2. The effect of electropolishing on surface finish**

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. Iron atoms are more easily extracted from the crystal lattice than are nickel and chromium atoms. For this reason, the electropolishing process removes the iron preferentially, leaving a surface rich in nickel and chromium oxides. This phenomenon imparts the important property of "passivation" to electropolished surfaces.

The general relationship between applied current and voltage for a typical electropolishing system is illustrated in Figure 3. An understanding of the combined effects of current and voltage are key to the production of high quality electropolishing.

Electropolishing systems require rinse water to remove solution from the parts after each chemical operation. These rinses usually go 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.

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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. Some 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, corrosion resistance, reflectivity, oxide layer composition, or other specified performance characteristics.

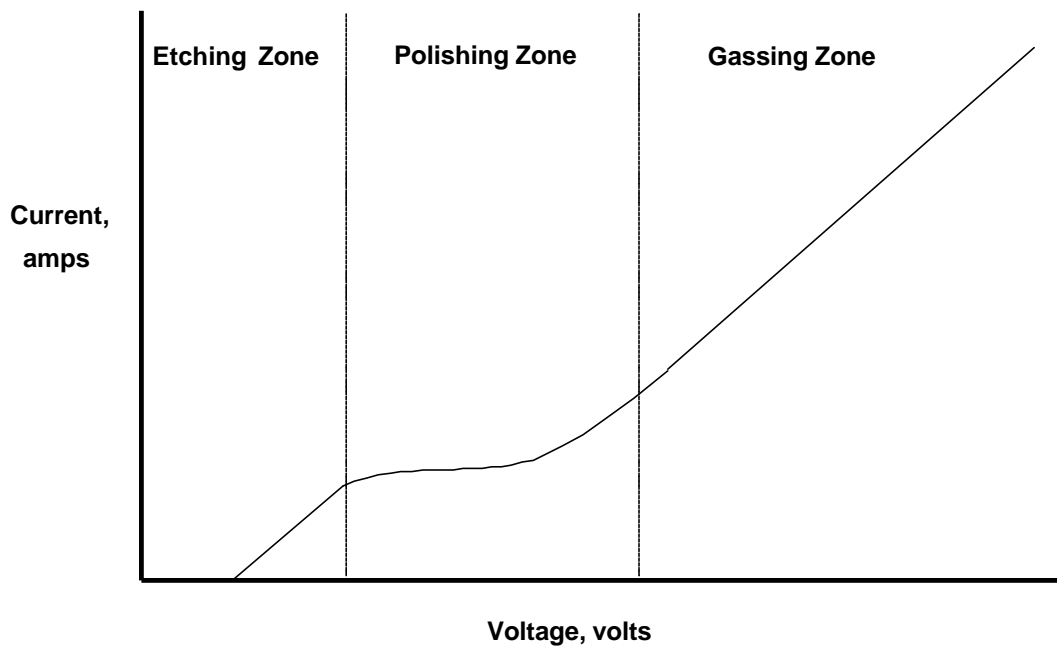


FIGURE 3. General relationship between current and voltage

## **THE MCP SYSTEM OF ELECTROPOLISHING GENERAL PROCESS STEPS**

### **STATION 6. DRAG-OUT TANK**

Station 6 is intended to capture electropolishing solution dragged out of Station 5 by the parts and to concentrate the dilute electropolishing solution for recycling or for disposal as spent electrolyte. Drag-out tanks may be used as drip tanks, equipped with spray nozzles, or used as immersion tanks.

The equipment normally consists of a tank with appropriate electric immersion heaters or steam coil for evaporation of water from the dilute electropolishing solution. This arrangement may be augmented with a thin-film evaporator which uses a packed chamber and forced air circulation to increase the rate of water removal. Evaporation rates of 10-20 gallons per hour may be obtained with the thin-film evaporator.

Further concentration is accomplished by heating when the electropolishing system is not in use. Overnight or weekend heating may be necessary to concentrate the solution sufficiently for reclamation.

Electrolyte that has been concentrated to a specific gravity of about 1.60 can be returned to the electropolishing tank for further concentration. Additions of the re-concentrated solution should be made at the end of a production run, so that the bath will have time to assimilate the additions and to evaporate the excess water. Specific gravity of the solution in the electropolishing tank should be checked before production is resumed. If the metal content of the solution is too high, the re-concentrated solution should be placed in drums for disposal.

Electropolishing solutions can also be sent to a waste treatment area for disposal by precipitation and filtration of the heavy metals. It should be noted, however, that the stainless steel electrolytes normally require extensive neutralization with caustic soda (sodium hydroxide) and produce relatively large volumes of precipitate.

### **STATION 7. ELECTROPOLISH RINSE**

The rinsing of electropolishing solutions is complicated by the fact that the solutions are quite viscous and do not mix readily with water. The speed of rinsing may be increased without increasing water flow by using air spargers, spray nozzles, or counterflow rinses.

The concentration of heavy metals in the rinse water may exceed the local limits of acceptability. In this case, the system must be arranged to utilize counterflow rinses, which are concentrated in the drag-out tank. This method allows nearly 100% recovery of electrolyte, thereby eliminating the need for extensive waste treatment for heavy metals. The concentrated electropolishing solution may then be returned to Station 5 for re-use or placed in drums for waste treatment as previously described.

Care must be taken to avoid drying electropolishing solution onto the parts, as residual acid may cause staining or etching in storage. For this reason, hot rinses must be used only after all residual electrolyte has been thoroughly rinsed away.

### **STATION 8. NITRIC ACID**

The purpose of the nitric acid post-treatment for electropolishing is to dissolve the film of chemical by-products, which form as the electrochemical reactions proceed. These by-products consist primarily of phosphates and sulfates of heavy metals, and are very difficult to remove by water rinsing alone.

If left untreated, these by-products leave a milky or translucent film on the surface of the parts. After drying or in later storage, the film hardens to a crusty white residue which degrades the appearance of the finish, providing growth sites for bacteria and initiation sites for corrosion. A short rinse in dilute nitric acid at room temperature dissolves the by-products, producing work of maximum specularly. A room temperature solution of 25-30% by volume is usually effective.

## **THE MCP SYSTEM OF ELECTROPOLISHING GENERAL PROCESS STEPS**

### **STATION 9. COLD WATER RINSE**

The principles of operation for the nitric acid rinse are essentially the same as those for the other acid rinses. The main difference is that nitric acid solutions are generally much easier to remove by rinsing than alkaline residues or electropolishing solutions, and lower flow rates and/or shorter rinsing times may often be used.

It should be noted that drag-in of nitric acid to the following hot water rinse may cause staining of the parts in storage. Therefore, some care must be taken to ensure that the acidity is not permitted to reach excessive levels in Station 9.

### **STATION 10. HOT WATER RINSE**

The purpose of the hot water rinse is to eliminate the last traces of process chemicals and to raise the temperature of the metal sufficiently to cause flash drying of the parts before unranking. The principles of operation for the hot water rinse are essentially the same as those for the other single-station rinses.

It should be noted that nitric acid or electropolishing solution dragged-in to the hot water rinse from Station 9 may be dried on the work and may interfere with the finished quality. Therefore, some care must be taken to ensure that these chemicals are not permitted to reach excessive levels in Station 10. If staining develops, the hot water rinse tank should be dumped and replaced totally or partially with fresh make-up water. The levels of chemical drag-in to the hot water rinse are likely to be too low to be analyzed by wet chemical analysis. Simple methods of monitoring acidity using a pH meter, pH paper, or a conductivity instrument are recommended.

Some city and ground water supplies contain unusually high levels of hardness minerals or other contaminants, and rinsing with de-ionized water may be the only way to produce stain-free work. Water purification companies offer small package units utilizing anionic/cationic resin beds in replaceable cartridges that are useful for generating small quantities of de-ionized water. A hydrophobic rinse aid can often be used to accelerate water drainage; however, some applications will not allow a residual film on the surface of the polished metal.

Some types of parts will not dry completely with hot water rinsing. Centrifugal dryers, heated air chambers, and other types of drying stations may be needed to force rapid evaporation of residual moisture and to prevent staining of the work.