

Looking for Solutions to Metal Surface Problems?

ABLE[®] **Electropolishing**
Advanced Metal Improvement Technologies



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TECHNICAL SUMMARY

Commercial applications for electropolishing have been in use since the early 1950's. Most formal research on the process occurred at that time, motivated by the growth and sophistication in electroplating technology. Today there are about 500 industrial installations nationwide, and perhaps several dozen electropolishing job shops.

Electropolishing is often referred to as a "reverse plating" process. Electrochemical in nature, electropolishing uses a combination of rectified current and a blended chemical electrolyte bath to remove flaws from the surface of a metal part.

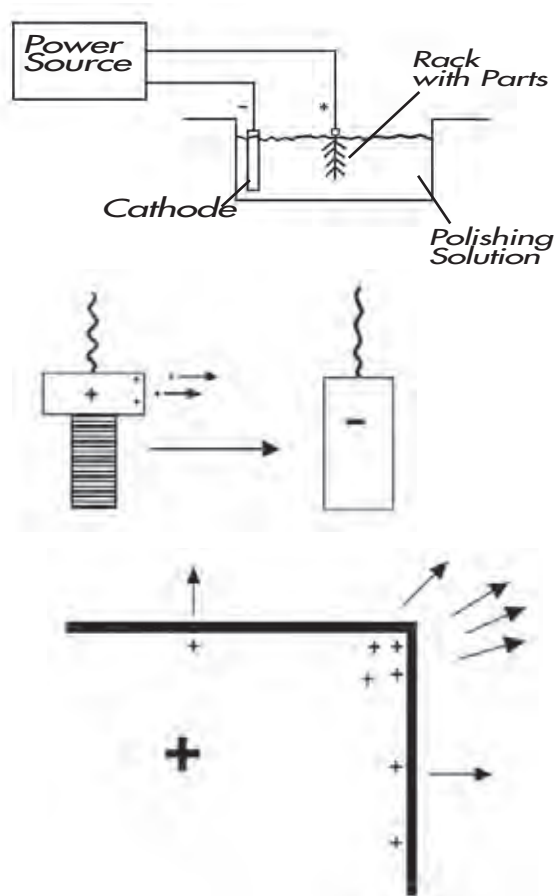
The typical electropolishing installation is deceptively similar to a plating line. A power source converts AC current to DC at low voltages. A tank typically fabricated from steel and rubber-lined is used to hold the chemical bath. A series of lead, copper or stainless steel cathode plates are lowered into the bath and installed to the negative (-) side of the power source. A part or group of parts is fixtured to a rack made of titanium, copper or bronze. That rack in turn is fixtured to the positive (+) side of the power source.

As the adjoining illustration depicts, the metal part is charged positive (anodic) and immersed into the chemical bath. When current is applied, the electrolyte acts as a conductor to allow metal ions to be removed from the part. While the ions are drawn toward the cathode, the electrolyte maintains the dissolved metals in solution. Gassing in the form of oxygen occurs at the metal surface, furthering the cleansing process.

Once the process is completed, the part is run through a series of cleaning and drying steps to remove clinging electrolyte. The resultant surface is clean and bright. In fact, the bright surface is the most identifiable trait . . . the one that helped coin the process name: Electropolishing.

While the process is best known for the bright polish left on a surface, there are some important, often overlooked benefits of this metal removal method. These benefits include deburring, size control, microfinish improvement and others. These metal improvement benefits offer great promise to design and production engineers for cost savings and product improvement.

Although the process is roughly 54 years old, substantial refinements have taken place. Many electrolytes have been developed to allow for electropolishing of a broad range of metals. These newer electrolytes, together with advanced parts handling techniques have combined to improve production yields on a wide range of metal products.



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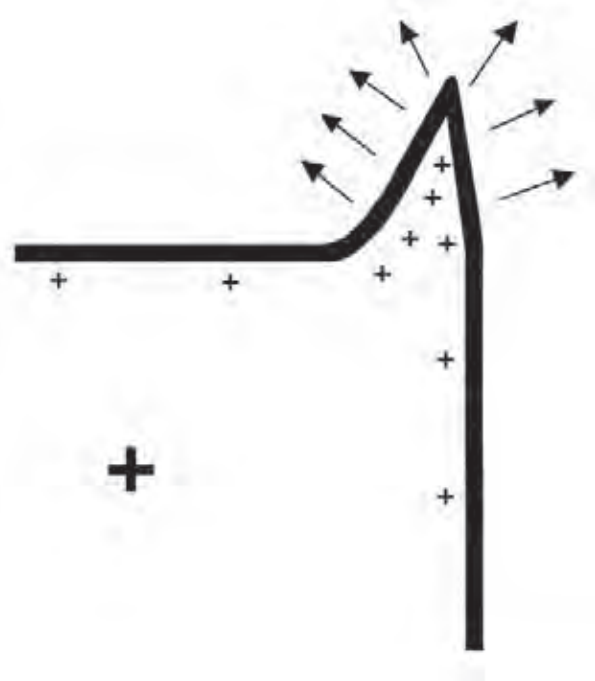
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The electropolishing process is well-suited for deburring. During the process, the transfer of metal ions occurs most rapidly on corners or edges of metal parts. Current density or concentration of electro-chemical power is greatest at high points, just as lightning is drawn to tall trees and buildings. This helps explain why plating builds metal faster on an edge or burr, while electropolishing (the “reverse” of plating) removes metal fastest at these points.

Properly controlled, the process can remove burrs from incredibly complex or fragile parts that do not lend themselves to conventional tumbling or vibratory finishing techniques. The process is best suited for parts having fine blanking, milling, broaching, lapping or grinding burrs. Since electropolishing is non-mechanical, it is important to note that the hardness of a metal part has no bearing on the burr removal. The process works equally well on a fully annealed or hardened part. This is one reason why electropolishing is often specified as a final deburring and finishing process after all fabrication and heat treating processes.

The fact that electropolishing is a non-distorting process is often overlooked. Many metal parts produced today have critical microfinishes or are made from lighter, more fragile materials. In those cases, mass finishing techniques such as tumbling or vibra-finishing create distortion or warping, and can nick or scratch fine finishes. Electropolished parts are never subjected to stress from polishing media nor are they impinged or tumbled onto each other.

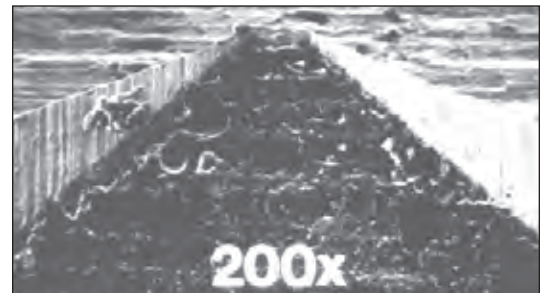
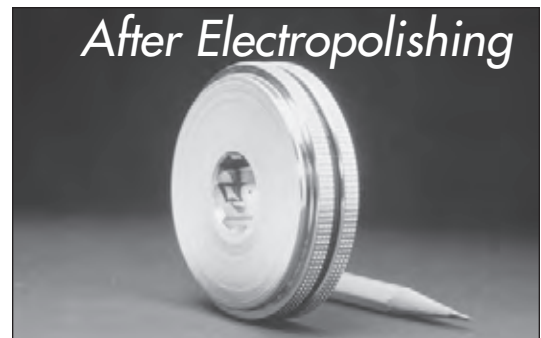
It is important to note that burr removal is limited to burr sizes of .005" or less depending on the component. Larger burrs produced in rough milling or displaced metal from drilling operations often need pre-treatment using other methods. In addition, heavy die break burrs caused by improper tooling maintenance are difficult to remove with electropolishing alone.



DEBURRING CASE STUDY 1

The part in the photo at right was made from tool steel. The entire outside surface was milled to produce a series of teeth used to grab a plastic strip and pull it through an assembly. In production, it was discovered that the teeth acted more like fish hooks; the burrs left on the teeth prevented extraction from the plastic strip, and the product got wound around the assembly.

One of the teeth, here magnified to 200X, shows clearly the burrs and displaced metal left from the multiple milling operations. The goal here was to remove the burrs on the surface without reducing the effectiveness of the teeth, nor weakening them.



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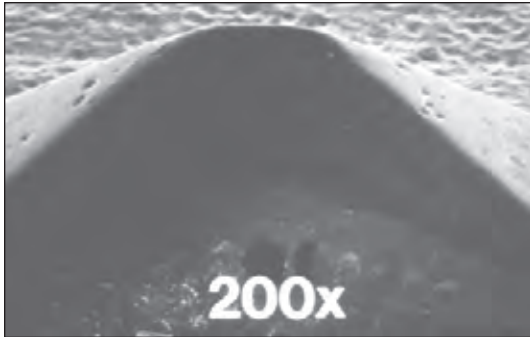
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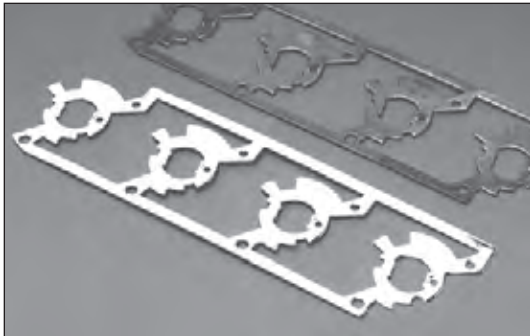
The same part was electropolished, removing .00075" from each surface. This was found to be ideal after experimenting with different amounts of material removal. At the same 200X magnification, the burrs are totally removed, with the tip of the tooth actually sharpened. Note the natural porosity of the material exposed when the surface skin was removed.



After

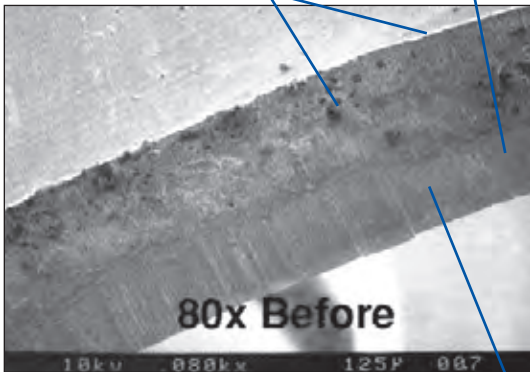
DEBURRING CASE STUDY 2

The parts in the photo are made from beryllium copper and used in an automotive pump application. Burrs along the part were creating problems in both assembly and testing. The parts were submitted for electropolishing in a lead frame condition, with 4 pieces per strip. After electropolishing, the parts were broken out for assembly.



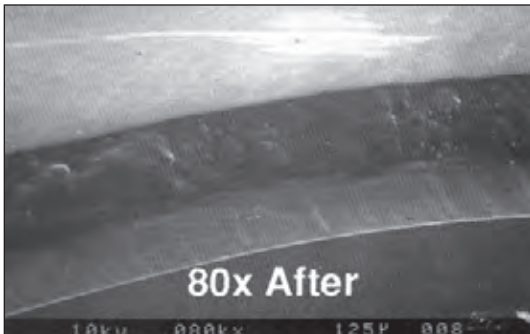
Burrs, Clinging Debris *Die Break Begins*

Under 80X magnification, the burr problem is clearly identified. As the blanking die began cutting through the beryllium copper material, the cut was clean and uniform. As the die progressed past the halfway point in the material, the copper began to shear or break away. This "die break" became more evident towards the end of the cutting process, leaving a string of burrs along one side of the part.



Direction of Die

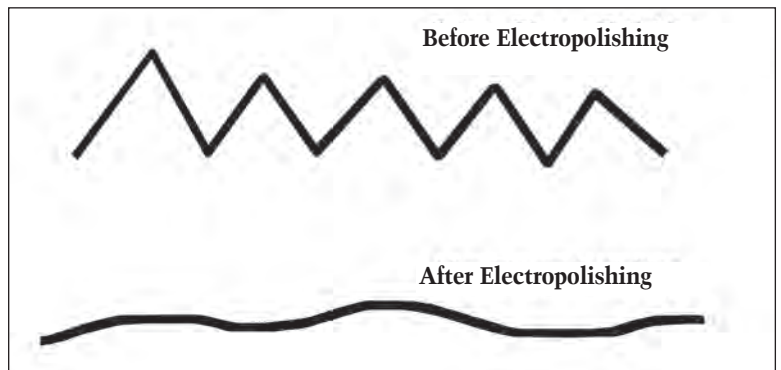
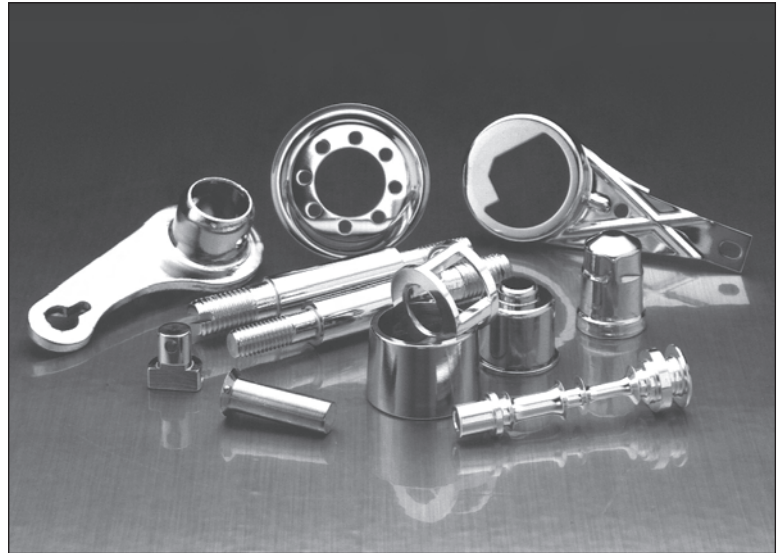
The photo at right depicts the same surfaces after electropolishing. The concentration of current allowed for greater material removal on the burrs and heavy die break, leaving most other surfaces lightly electropolished. Stock removal had to be precise to remove the burr with minimal change in other critical dimensions. The parts were left totally clean and ready for assembly.



In assemblies where contact to metal surfaces is critical, improvement of that metal surface becomes important. Virtually all metalworking operations including cutting, stamping, welding and forming serve to roughen a metal surface. When that metal surface is then forced to work in critical sealing or friction zones, product performance often suffers.

One of the traditional instruments used to measure surface roughness is the profilometer. The profilometer, using a diamond stylus to record the irregularities of the surface, usually gives a readout in microinches or micrometers. This quantifies the roughness of the surface with a larger number indicating a rougher surface. Electropolishing typically reduces these microinch values by 50%, i.e. a 16 microinch surface before electropolishing will be improved to an 8 microinch afterward.

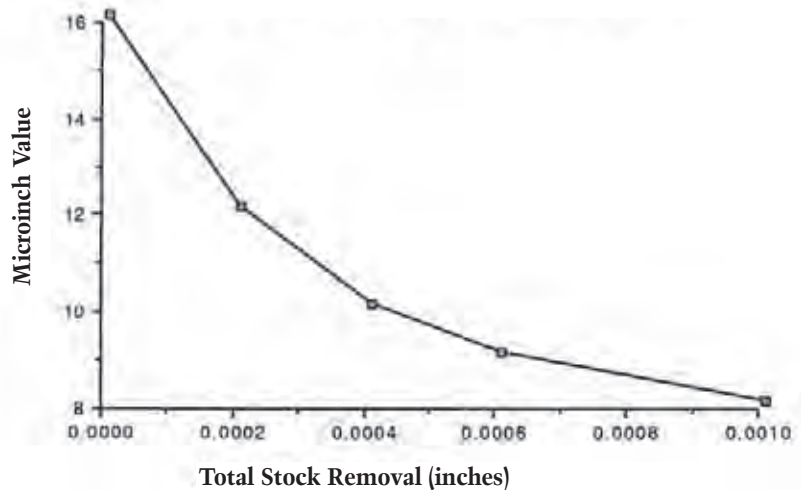
The illustration at right depicts a typical cross-sectioned metal surface. The electropolishing process allows for a concentration of current in the peaks of a surface, thereby reducing microscopic peaks and causing a leveling action. By reducing the surface peaks, the microfinish values are reduced as well.



In general terms, electropolishing when properly applied can reduce microfinish values by 50% with a removal of .0005" from each surface. This chart clearly shows that maximum benefit is achieved in this area, and that removing much more metal does not improve surface finish.

It is important to note that electropolishing is best suited for improving microfinish values on complex or fragile parts. Many other microfinish improvement methods such as grinding, lapping or harperizing are not suitable on multi-faceted parts or fragile stampings.

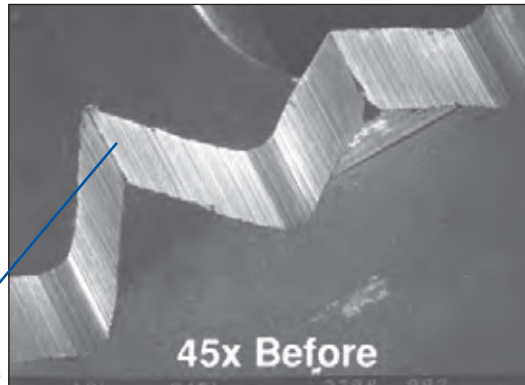
Microinch Improvement at Various Stock Removals



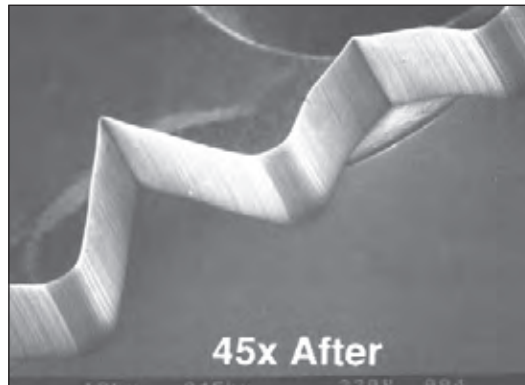
MICROFINISHING CASE STUDY

Many medical components are electropolished for improvement of surface finish. The parts on the right are made from 410 stainless steel, and heat treated for hardness. The cutting teeth are ground. The part required both an improvement in the microfinish as well as a general cleaning to remove heat discoloration and light heat treat scale.

Cutting Blade Tips

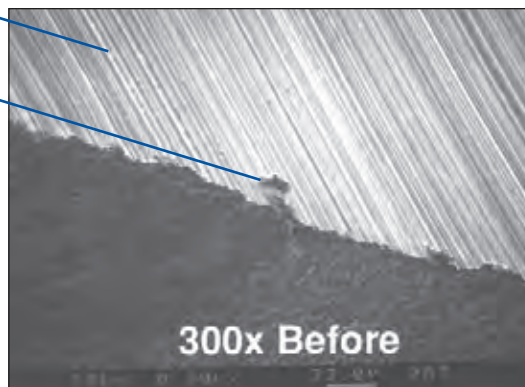


These photos show the ground cutting teeth looking downward. At 45X magnification, the grinding marks and some clinging debris are clearly evident. With .0007 of material removal, the majority of the grinding marks are "blended", while retaining a great portion of the cutting edge.

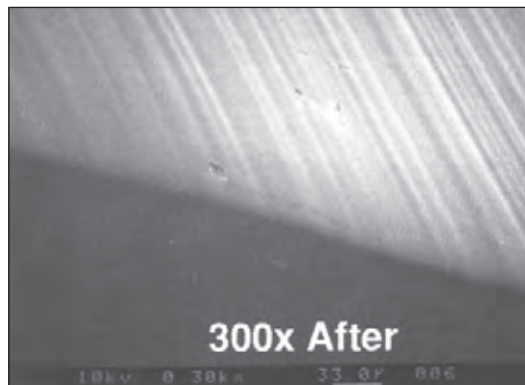


Ground Surface

Burrs



At 300X, the ground edge is further magnified to show the grinding marks and hanging burrs. The finish is approximately 16 microinch. After electropolishing, the grinding marks are reduced substantially, though still evident. Note that metal removal was better concentrated on the leading edge, completely removing the burrs and providing a smoother surface. Though difficult to measure, the finish is approximately 8 microinch. The final finish was clean, free of chemicals, scale and oxides.



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Perhaps the best known application for electropolishing is in the area of decorative finishing. While the bright finish is the trademark of electropolishing, the key benefits of the surface cleansing are much more than “good looks”. Since the process removes surface metal, virtually all surface impurities are removed as well. Imbedded scale, rust, foreign debris, oils, grinding compounds and other materials are removed as the base material is dissolved. While the resultant surface is not technically “pure” it is left at or near original mill specifications, ready for final assembly or plating.

An electropolished part has the following characteristics:

CHEMICALLY CLEAN

Since there are no grease-based polishing compounds or media that provide the polishing action, electropolished components are free of residual dust and contamination. This is especially important for parts used in vacuum, medical or pure gas/water delivery systems. Electropolished parts are often ready for final assembly in standard or clean room environments with no additional cleaning or preparation.

NON-COATING

Unlike paints, plating or teflon coatings, an electropolished surface does not peel or abrade. This is especially important where particles from coating abrasion can cause equipment malfunction or other hazards. Typical areas include food or pharmaceutical processing, high vacuum assemblies, pure gas/water systems and critical switch assemblies.

NON-DISTORTING

An electropolished finish can be uniformly applied on complex or fragile parts that do not lend themselves to other finishing methods. There is no effect on surface hardness and no stresses are introduced to the part.

STAIN/CORROSION RESISTANT

Since electropolishing removes imbedded impurities and smooths a metal surface, the resulting finish is more resistant to corrosion, tarnish or oxidation. These properties are especially evident on stainless steel, but also found on carbon steel, brass, aluminum and copper. While all these alloys are more resistant, we do not routinely recommend electropolishing as a substitute for coatings designed to protect a metal part in harsh environments.

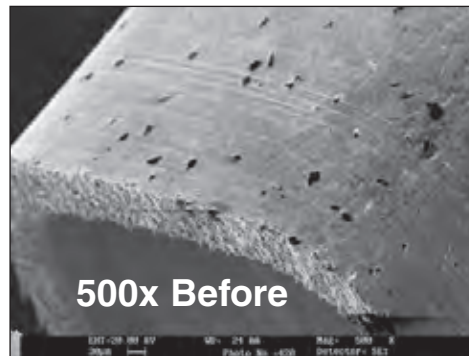
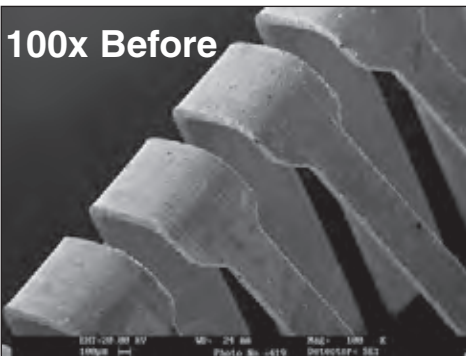
IMPROVED WELDABILITY

In critical spot weldments, electropolished components are more conductive. The improved conductivity allows better, stronger welds at lower voltage. In other welding or brazing operations, electropolished surfaces generally weld more readily with less weld splatter and surface damage.

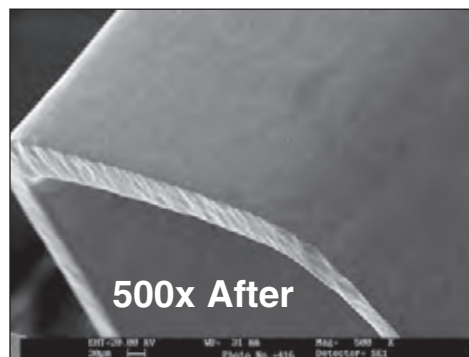
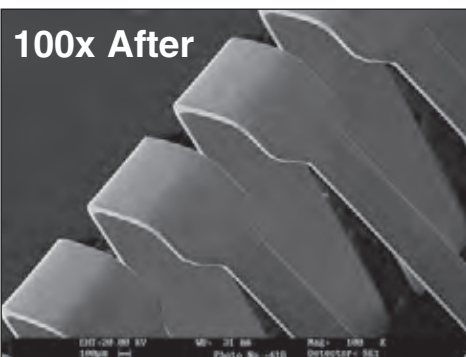


ULTRACLEANING CASE STUDY

This part is fabricated from a beryllium/nickel alloy, used in a switch application. The ribs are cut by wire EDM, formed to shape, followed by heat treat. The customer was looking to remove surface and imbedded contamination from both the EDM process and subsequent handling.



Under 100X and then 500X magnification, the delicate ribs show obvious contamination, burrs, and recast materials on all sides and edges. Because of the soft alloy and very critical shaping, this part did not lend itself to any mechanical cleaning for fear of warping or distortion. Additionally, critical dimensions eliminated the possibility of chemical etching, which often has widely varying stock removals.



By carefully controlling material removal, all critical surfaces were completely cleaned of surface and sub-surface contamination. The amorphous layer was removed as well, exposing the true base metal. In this and similar cases, electropolished parts will pass strict clean room standards. Additionally, in high stress/high cycle switch applications, the removal of stress cracks extends product life (see case histories in de-stressing).

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One of the fastest growing applications for the process is to enhance corrosion resistance on a wide variety of metal alloys, specifically stainless steel. Electropolishing is fast becoming a replacement process for a long established treatment: Passivation.

Passivation is a chemical process that has been used for years to help restore contaminated stainless steel to original corrosion specifications. Passivation is routinely specified by engineers because of the many sources of contamination. The intent of passivation is to create a chromium rich surface that is resistant to corrosion. However, the process originally was preceded by a pre-cleaning process known as pickling. Prior to the 1970's, "pickle and passivate" was a two-step process. The pickling solution made up of a very hazardous hydrofluoric acid was used to dissolve imbedded steel flecks and other impurities. The passivation solution was then used to create a corrosion resistant film. It was the combination of these two processes that allowed stainless steel to resist corrosion.

With the passage of the Clean Water Act and subsequent changes in OSHA regulations, virtually all companies have dropped the pickling process, while maintaining passivation baths. And while pickling has slowly disappeared from American industry, corrosion problems on stainless have correspondently increased.

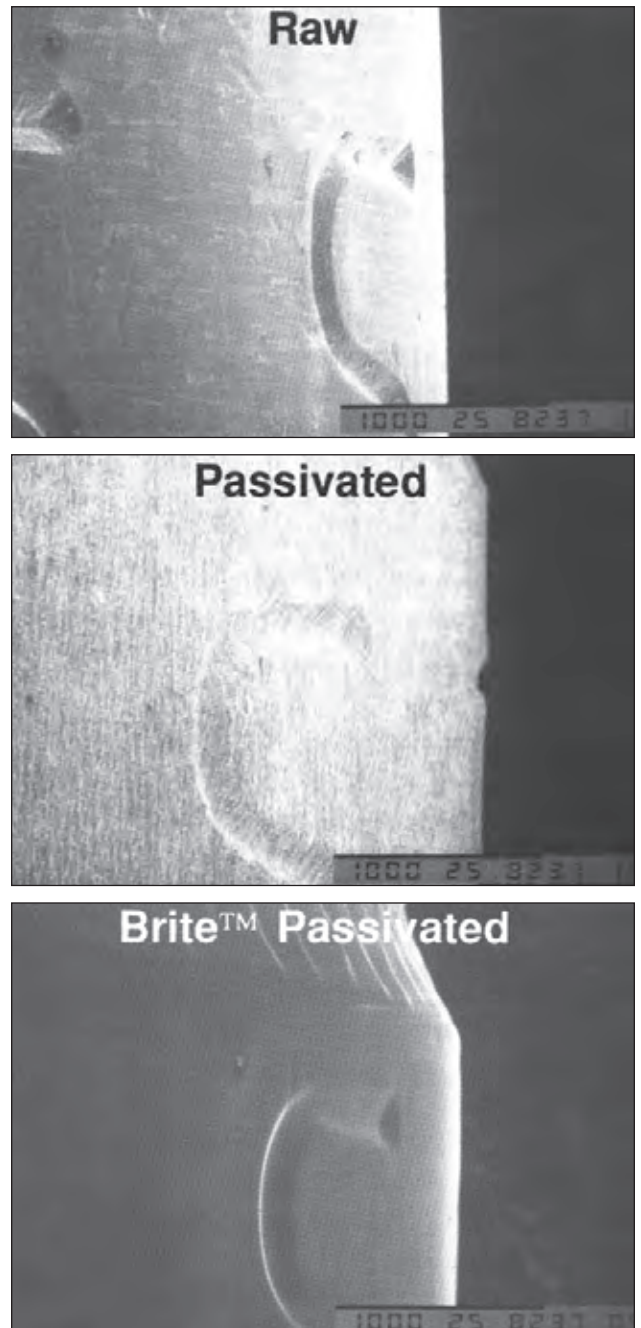
The electropolishing process has long been a substitute for the "pickle and passivate" specification. Since the process removes surface metal, all surface impurities are removed as well. Heavily contaminated surfaces such as machined parts, welded or brazed assemblies or other components that typically respond poorly to passivation alone are good candidates for electropolishing. Unlike pickling or passivation, all stainless alloys including the 400 series, precipitating grades, 303 and 416 stainless steel can be processed without distortion, flash attack or hydrogen embrittlement.

Just as electropolishing is used to enhance corrosion resistance on stainless steel, it offers corrosion resistance on other alloys as well. Many companies use the process to delay or retard the corrosion properties of copper, brass, aluminum and carbon steels. On these and other alloys, the removal of surface skin and impurities enhances the corrosion resistant properties of the component. For components needing light corrosion resistance that cannot afford an expensive plating operation, electropolishing may be a solution.

Several popular grades of stainless steel cannot be passivated due to low levels of chromium and nickel. When these stainless steels are passivated by routine methods, the resultant flash attack actually weakens the base material and does irreparable damage to the part.

The parts pictured on the right are made from type 303 stainless steel. After a series of machining operations, the parts needed to be de-contaminated to remove imbedded steel and other impurities.

Under 40X magnification using the scanning electron microscope, you can see the passivated part is actually rougher, due to the chemical attack of the 303 stainless steel by normal passivation. In contrast, the Brite passivated part is smooth and clean. By carefully monitoring the amount and rate of metal removal, Brite passivation dissolves the surface skin and its impurities, including impinged steel flecks and other contaminants.



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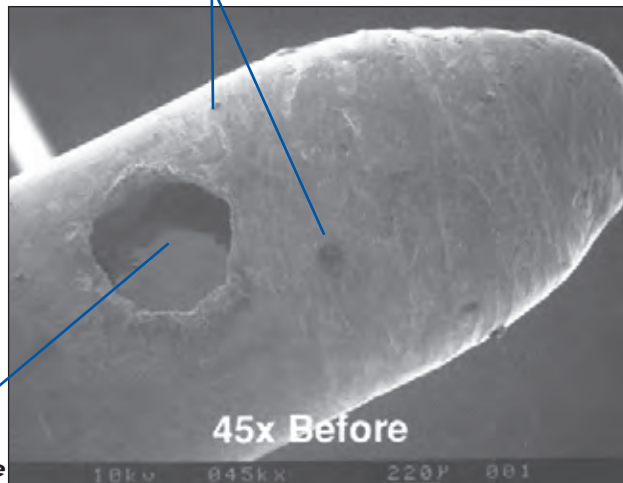
BRITE PASSIVATING CASE STUDY

This assembly is used in a fluid measuring system. Made from a combination of brass and 304 stainless steel, the tube is press-fit and brazed into the brass body. Subjected to use in a variety of corrosive environments, the stainless finish needed to be both chemically clean and highly resistant to corrosion. Since the brazing operation itself is a potential contributor to corrosion, the part had to be finished as an assembly.



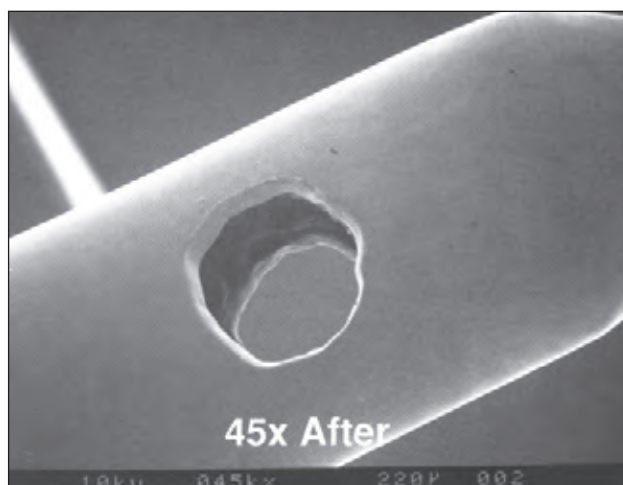
Under 45X magnification, the end of the tube with laser-cut through hole is pictured. The surface under this magnification is quite irregular, with various surface imperfections and imbedded particles. A sizable burr and loose fragments of material are located at the hole area.

Imbedded Particles



Laser-Cut Hole

After electropolishing, all imbedded impurities, loose burrs, and virtually all surface blemishes are removed. By removing both foreign debris and sub-surface cracks, corrosion is delayed beyond standard mill specifications. The part was left without residual coatings and ready for final assembly.



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In the past several years, advancements have been made in electropolishing technology that has allowed metal removal to be controlled to within .0001". This control over stock removal together with the ability of the process to work on complex geometries has opened new applications in part sizing. On complex or fragile components where final sizing is difficult or expensive, electropolishing can be an economical procedure. Sizing can be of special importance in the following areas:

SCRAP RECOVERY

Parts made oversize by operator or machine error, growth from heat treating or other unexpected cause can be brought to finish size with electropolishing. While secondary grinding, lapping or other processes are often used to reduce an oversize part, most of these processes are useless once a part is in finished form or already hardened. Sizing can be performed regardless of hardness and the process will preserve most part geometries. Bores or holes can be enlarged while simultaneously reducing thicknesses on other surfaces or journals.



Many parts are sized through electropolishing. Virtually all alloys including carbon steel, brass, aluminum, copper, Inconel, Monel, Hastelloy, molybdenum and stainless steel are successfully electropolished.

PRODUCTION SIZING

Many fragile stampings or machined parts do not fit into traditional sizing operations because of the potential of damage, special tooling or introduction of surface stresses or contaminants. Parts requiring critical final sizing that do not fit well under these circumstances are excellent candidates for electropolishing. In addition, short lots or prototype runs are often sized economically as compared to secondary machining or grinding operations where long lead times or high set-up costs are a concern.

MATERIAL REDUCTION

High tolerance stampings or blankings made from special ordered raw material should be considered. In these cases, the extraordinary costs and lead times in getting special thickness material can be avoided by ordering standard gauge material slightly thicker than final requirements. The parts can be blanked or formed as normal, and electropolished to final thickness. The reduced material costs and delivery times of the standard material often more than cover the cost of the electropolishing operation.

SPECIAL MACHINING

Parts requiring unique or special tapering, precise weight control or simultaneous deburring and sizing are often electropolished. The process is well-suited for bringing special "matched set" components to specific size or weight often at less cost than other traditional metal removal processes.

SIZING CASE STUDY

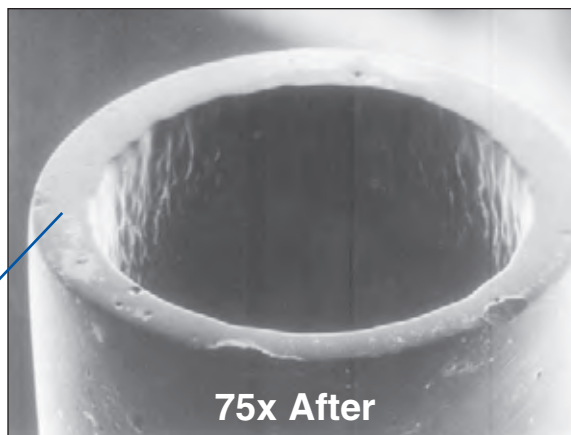
This is an end view at 75X of a surgical tube used in open heart surgery. The tube is press-fit into an analytical instrument during surgery and later disposed. The parts were previously purchased from specially ordered .0235 walled 304 stainless steel. While the special thickness material itself was expensive and hard to get, the burrs produced by the cutting operation also added to the problems of maintaining proper sizing in production.



*Cutting
Burrs*

*.025
Thickness*

The tubes were made from standard .025 material and .0015" was removed. The removal of the .0015" provided final sizing of the tube wall, and at the same time removed all burrs, clinging material and foreign debris. The tubes were left totally clean and ready for clean room purifying and assembly.



*.0235
Thickness*

75x After

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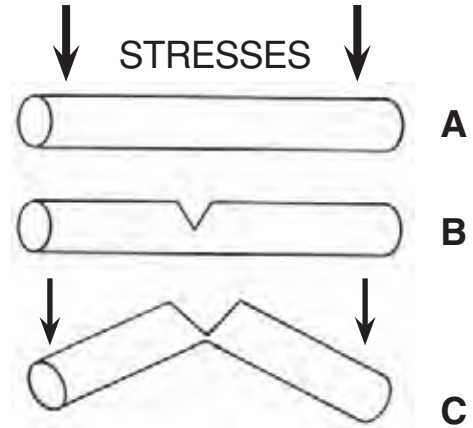


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On metal components subject to high stress and/or high cycle duties, surface finishing becomes a critical manufacturing step. Virtually all fabrication processes including forming, grinding and so forth create a wide range of compressive, tensile and other stresses as well as surface imperfections. In addition, other processes such as heat treating, vibra-finishing and even plating can induce or change metal fatigue characteristics.

One major cause of metal fatigue is the focus or concentration of metal stresses along a metal surface. As a spring is wound and unwound during use, a great deal of stress is placed on the outside surfaces. Imperfections or stress risers channel or focus those stresses creating a condition ideal for failure. This is known as "notch effect", and is best illustrated at right. These illustrations depict a metal bar subject to flexure stress. If the bar were notched as in B, those same flexure stresses would allow the same steel bar to bend. On springs, stampings and other fabricated metal components, the combination of stresses and imperfections caused by fabrication and heat treatment often create fatigue problems.



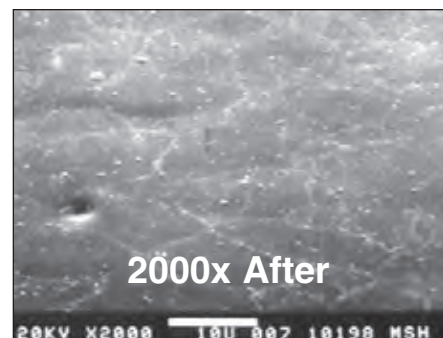
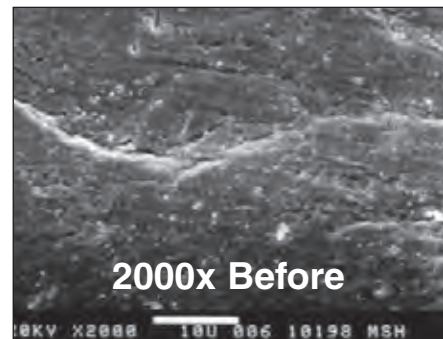
By removing surface metal, electropolishing helps to solve metal fatigue problems from two perspectives. Many surface stresses occur within the first .001" of a component's surface. The various tensile, compressive and other stresses are removed or reduced with the removal of .001" of metal. Unlike shot peening, vibra-finishing and other processes, electropolishing does not introduce new or different stresses that can adversely alter metal fatigue characteristics. More importantly, removal of the surface skin also reduces or eliminates stress risers caused by heat treating, decarburization and microscopic scratches, tool marks and grinding checks. It is the combination of these two benefits that allow electropolishing to improve metal fatigue.

DE-STRESSING CASE STUDY 1

These parts are c-springs made from beryllium copper. Used in a high cycle switch application, the c-springs were failing prematurely. The parts were submitted for electropolishing attached to the lead frame, to speed processing and lower electropolishing costs.

Under 2000x magnification, a surface crack caused by stresses in the forming operation is clearly evident. Flexure stresses on the c-spring while in the assembly were thought to concentrate in these cracks, causing a total fracture of the spring.

Under the same magnification, the same surface after electropolishing. With removal of .0005", the surface crack was greatly reduced. By making the surface more uniform, the flexure stresses were more uniformly spread over the surface, thereby extending spring life. Additional stock removal to .001" or more would further smooth the surface, though not to add proportionally to the spring's life.





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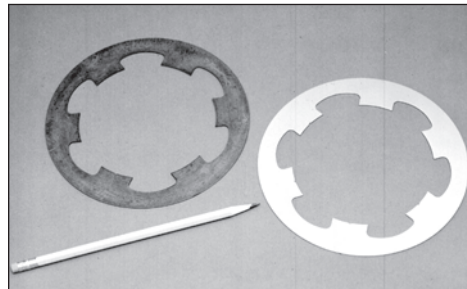
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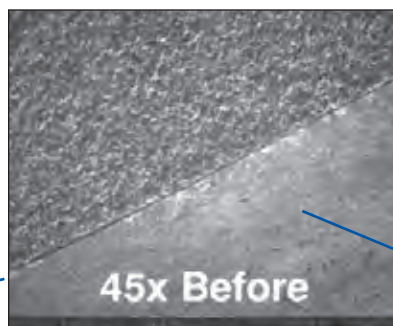
DE-STRESSING CASE STUDY 2

A fast growing area for De-Stressing is on parts fabricated using wire EDM. These parts are fabricated from carbon steel and are used in a transmission application. The plates were heat treated and later coated with other materials. The parts were fracturing during normal use, and the problem was traced to the surface left from the EDM operation.

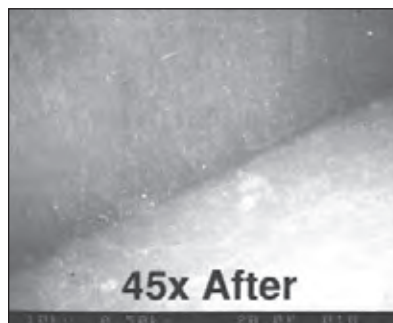


Under 45X, the inside surface appears rough. As the cutting wire moves through the material, some molten metal flows around and is re-deposited back onto the part. The "re-cast layer" is actually a false skin on the surface, creating surface cracks, stresses and alloy changes in the surface of the part. These stresses and changes ultimately caused total fracture of the part.

EDM Surface

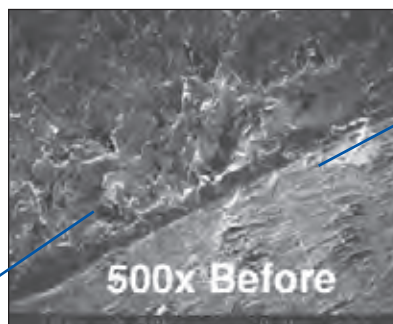


Flat Surface

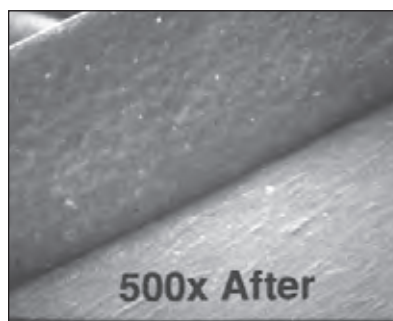


Under higher magnification, the same edge at 500x. The re-cast layer is more evident, showing a surface that is scaly in appearance, with deep fissures and imbedded impurities. Upon removal of .001" of material, the re-cast layer was totally removed, and surface stresses and alloy changes dissolved. The part was totally clean and ready for subsequent coating operations, and met or exceeded all tests.

Re-Cast Layer



Surface Fissures





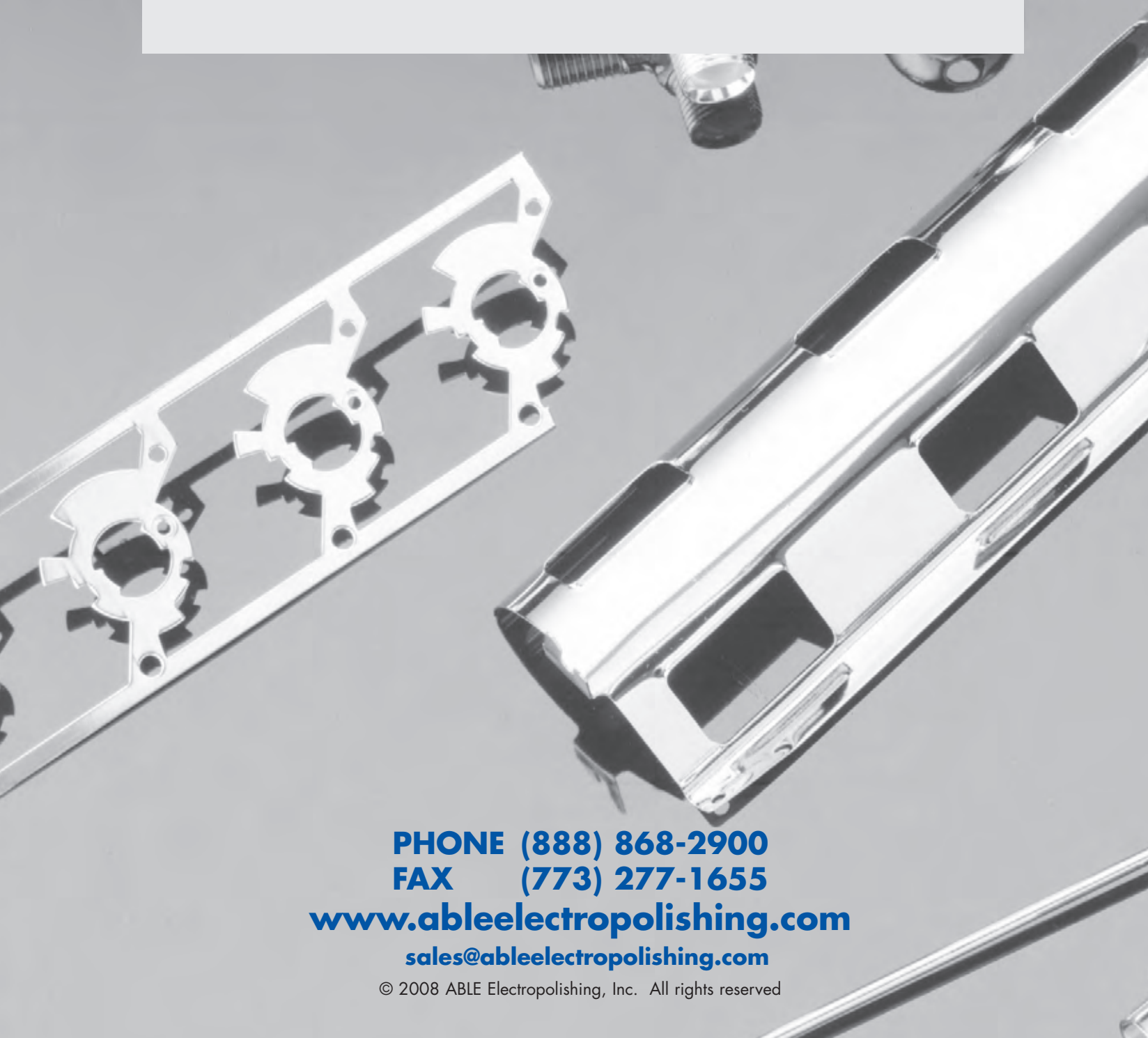
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