Process Specification for Electropolishing of Corrosion-Resistant Steel

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3/28/02  
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<table>
<thead>
<tr>
<th>VERSION</th>
<th>CHANGES</th>
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<td>Baseline</td>
<td>Original version</td>
<td>1/14/99</td>
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<td>A</td>
<td>Reviewed for accuracy, changed EM2 references to ES4, removed MMPTD references</td>
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1.0 SCOPE

This process specification establishes the technical engineering requirements for electropolishing of corrosion-resistant stainless steel alloys. Electropolishing of aluminum, copper, or titanium alloys is not permitted. This specification is not intended to be used for electropolishing of parts with internal surfaces, such as tubing. In addition, this process specification is not intended to be used to electropolish parts with faying surfaces or deeply recessed areas where internal cathodes cannot be effectively applied.

2.0 APPLICABILITY

This specification applies to electropolishing treatments for use on austenitic, ferritic, martensitic, and precipitation-hardening corrosion-resistant steel alloys. In addition, it applies to heat and corrosion resistant materials, including cobalt and nickel alloys. When this electropolish process is used, passivation is not required. Also, electropolishing may be used in lieu of etching prior to dye penetrant inspection.

3.0 USAGE

This specification shall be called out on the engineering drawing by using a drawing note that identifies this process specification. A sample drawing note is:

<table>
<thead>
<tr>
<th>ELECTROPOLISH PER NASA/JSC PRC-5009.</th>
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Metal removal by this electropolishing process shall be between 0.0002 in. and 0.0005 in. per surface. If a different range or tighter tolerances are required, the engineering drawing must specify the range of material removal that is acceptable. For example:

<table>
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<tr>
<th>REMOVE 0.0002 TO 0.0004 INCHES OF MATERIAL PER SURFACE</th>
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Note however, that depending on the location of the electrodes, the surface that results from less material removal may have more of a matte finish than a uniformly shiny surface.

Designers should be aware that the operating parameters of the electropolish process are somewhat dependent on the geometry of the component. A separate test coupon from the same material lot as the production part(s) must be provided for the process qualification (see section 7.0). For extremely complex parts, a test article that is more detailed than a flat coupon will be required and should be negotiated with the manufacturing facility.
4.0 REFERENCES

The following documents were used to develop this PRC. Documents listed are assumed to be the current revision unless a specific revision is listed.

AMS 2759/9  
*Hydrogen Embrittlement Relief (Baking) of Steel Parts*

10107-70972D  
*General Process Specification for Electropolishing of Corrosion Resistant Alloys, Oceaneering Space Systems*

SOP-007.1  
*Preparation and Revision of Process Specifications (PRCs)*

JPG 8500.4  
*Engineering Drawing System Manual*

MAO103-308E  
*Electropolishing, Rockwell International*

MS 150.4  
*Manufacturing Specification for Electropolishing of Corrosion Resistant Steel, NASA Marshall Space Flight Center*

5.0 MATERIAL REQUIREMENTS

5.1 PRE-ELECTROPOLISH CLEANING

The pre-electropolish cleaning step shall be accomplished using any organic solvent or non-etching detergent cleaner.

5.2 ELECTROPOLISH SOLUTION REQUIREMENTS

The electropolish solution shall be composed of a relatively concentrated acid mixture of either a glycolic-sulfuric acid or phosphoric-sulfuric acid composition. However, it is noted that a rather large number of different electropolish formulations are commercially available. Exceptions to the above acid solution compositions must be submitted to ES4 materials engineering for approval.

The specific gravity of the solution shall be in compliance with that which is specified by the solution vendor at the 170-180°F operating temperature when the recommended current density is used. The specific gravity of this solution shall be checked with a hydrometer every two weeks. Immediately after checking the solution's specific gravity, a sample of the chemical bath shall be titrated to determine the correct percentages of dissolved solids. The
electropolish solution shall be maintained between 2.5% and 3.5% iron. If these limits are not met, the solution shall be removed and replaced.

5.3 POST-ELECTROPOLISH RINSING

Post-electropolish rinsing shall use a cold water bath of either distilled or deionized water. If subsequent part finishing includes plating operations, the final rinse shall be in an acidic, cold water solution (2.5<pH<3.5) that is maintained using additions of HCl.

6.0 PROCESS REQUIREMENTS

All forming, tube flaring, machining, and heat treatment must be performed prior to the electropolish process. If stainless steels 420, 440A, 440B, or 440C are to be electropolished, they must first be annealed at 300-700°F in order to avoid pickling cracks. If components have been heat treated, they may require a wet or dry blasting procedure to remove the scale.

Parts shall be cleaned (degreased and descaled) so that a clean, uniform surface is obtained before electropolishing begins. Chemical cleaning methods other than those referenced in section 5.1 require prior approval by an ES4 materials engineer.

After cleaning, parts shall be racked with attention to the following details:

- Ample spacing to permit proper current density and gas evolution
- Rack mark placement
- Proximity to cathodes

Racked components are placed in the electropolish tank and the positive connection is made.

Specific cycles and parameters of the electropolish process are determined by the metal finishing personnel, depending on the material and nature of finish required. However, they shall meet the following general operating parameters for corrosion-resistant steel alloys:
Temperature - 120°F to 180°F (controlled to ±5°F)
Time/Cycle - 30 sec. to 8 min. (controlled to ±5 sec.)
Current Density - 1.0-2.0 amp/sq. in.

Metal removal by this electropolishing process shall not be less than 0.0002 in. nor greater than 0.0005 in. per surface. Note that if tighter tolerances are specified on the engineering drawing, this process shall meet the specified range of material removal.

Automated air or mechanical agitation shall be used whenever possible to reduce or prevent gas streaks. If automated mechanical agitation is used, it shall possess a stroke of 4-6 in., a maximum velocity of 50 ft/min horizontal, and a frequency of 15-25 cycles/min. If the electropolish bath is not equipped for automated air or mechanical agitation, the solution shall be manually stirred prior to each use.

After electropolish, the components shall be thoroughly rinsed with distilled or deionized water (meeting the requirements of section 5.3) until clean. Use of chemical brighteners as part of the final cleaning is specifically prohibited due to the potential for causing hydrogen embrittlement.

If parts are to be subsequently plated, the cleaning step must also include a spray rinse with a 150 ± 5°F deionized water source. In this case, the final rinse shall be a cold water solution (2.5<pH<3.5) that is maintained using additions of HCl.

After cleaning, the parts shall be dried using clean, dry gas or low heat. In order to prevent hydrogen embrittlement, the stainless steel parts shall then be baked out at 375°F for 8 hours, according to the requirements of AMS 2759/9.

The clean, dry parts shall be packaged in clean plastic bags or other containers, which shall be labeled with the part number or other suitable identification, unless further processing is needed. Appearance of finished parts shall conform to the requirements of section 8.0.

7.0 PROCESS QUALIFICATION

Process qualification is required using coupons for each material to be electropolished. After electropolishing, the coupons shall be examined to ensure that all of the requirements of section 8.0 are met.
8.0 PROCESS VERIFICATION

The verification of the adequate completion of the electropolishing process shall consist of a visual inspection for evidence of pitting, scale, localized material removal, preferential etching, burns, cloudy films, stains, oxidation, and gas streaks. Negative relief (grooving or undercutting) which occasionally results from electropolishing is specifically prohibited. Minor positive relief and/or minor surface discoloration is acceptable if it is at the positive connection point.

In addition, verification that metal removal is in the 0.0002-0.0005 in. per surface range shall be performed using traditional dimensional measurement techniques or go/no-go gages that are appropriate to the design. A current probe that is designed and calibrated to the metal removal that is obtained by the specific material-solution combination for a given electropolish cycle may only be used if its accuracy is demonstrated.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

All electropolishing treatments shall be performed by trained personnel. Proper training for electropolishing shall, at a minimum, be structured in such a way as to ensure that each trainee is capable of applying an electropolish process that meets this specification. Training and certification records shall be kept.

10.0 DEFINITIONS

Electropolishing Procedure by which a very small amount of metal (typically 0.0002-0.0005 in.) is electrochemically removed from the workpiece, thereby smoothing the surface and diminishing scratches, burrs, etc. It is a controllable process that is the reverse of plating.