Process Specification for Electropolishing ofCorrosion Resistant Steel & Nickel-Based Alloys

Engineering Directorate

Structural Engineering Division

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Process Specification for Electropolishing of Corrosion-Resistant Steel & Nickel-Based Alloys

Prepared by:	Toni Griego (affiliate) Digitally signed by Toni Griego (affiliate) Date: 2026.08.10 09:46:17 -05'00'	Toni Griego Materials and Processes Branch/ES4
Reviewed by:	JOHN FIGERT (affiliate) Digitally signed by JOHN FIGERT (affiliate) Date: 2026.08.10 09:54:04 -05'00'	John Figert Materials and Processes Branch/ES4
Approved by:	MARYJANE O'ROURKE Digitally signed by MARYJANE O'ROURKE Date: 2026.08.18 08:21:48 -05'00'	Mary Jane O'Rourke Chief, Materials and Processes Branch/ES4

REVISIONS		
VERSION	**CHANGES**	**DATE**
Baseline	Original version	1/14/99
A	Reviewed for accuracy, changed EM2 references to ES4, removed MMPTD references	3/29/02
B	Updated for organizational and technical changes. Removed HCl post dip and replaced with HNO_3 post dip per ASTM B912.	10/30/2019
C	Updated technical changes in latest revisions of ASTM A380 and ASTM B 912 for electropolishing process and verification Added details from ASME Bioprocessing Equipment Appendix H Electropolishing Procedure Qualification for process qualification Added Electropolishing of Nickel-Based Alloys Updated emphasis on validation coupons based on lessons learned Updated references and definitions	7/2/2026

1.0 SCOPE

This process specification (PRC) establishes the technical engineering requirements for electropolishing of corrosion-resistant stainless-steel alloys. This PRC also covers most iron-based, nickel-based, and cobalt-based superalloys. This PRC does not cover aluminum, copper, pure nickel, or titanium alloys.

This PRC is intended for rack electropolishing of external surfaces. This PRC is not intended for electropolishing parts with internal surfaces, such as tubing, parts with faying surfaces or deeply recessed areas where internal cathodes cannot be effectively applied, nor bulk processed parts with loose tolerances.

2.0 APPLICABILITY

This PRC applies to electropolishing of austenitic, ferritic, martensitic, and precipitation-hardened stainless-steel alloys as well as iron-based, cobalt-based, and nickel-based superalloys.

When this electropolish process is used, passivation is not required except for straight chromium grades with 12-14% chromium (martensitic 400 series) and Custom 455.

Electropolishing may be used in lieu of etching prior to dye penetrant inspection provided the required material removal is demonstrated.

3.0 USAGE

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

ELECTROPOLISH PER NASA/JSC PRC-5009

The electropolishing process requires parts to be mounted in a rack with positive electrodes attached to the part. Electrical contact may degrade the finish; therefore, the drawing should specify or designate the permissible locations for rack/contact attachment marks. It is recommended that designers consult with the JSC Materials and Processes Branch and electropolish vendor to choose a location that will not affect part performance.

3.1 GENERAL GUIDELINES FOR ELECTROPOLISHING

The electropolishing process is dependent on the locations of electrodes and geometry of the part. The type of stainless steel and the formulation of the electropolishing solution are also major parameters of the electropolishing process. Changes in rate of material removal and variations in surface appearance can create problems if the electropolishing process is not set up properly. Process verification coupons or test article evaluations should be utilized to avoid potential electropolishing problems on hardware.

3.2 MATERIAL REMOVAL

Metal removal from the surface of the part during electropolishing shall be between 0.0002 inches and 0.0005 inches 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:

REMOVE 0.0002 TO 0.0004 INCHES OF MATERIAL PER SURFACE

In some cases, as much as 0.0020 inches can be removed. The engineering drawing may specify the maximum amount of metal to be removed. For example:

REMOVE UP TO 0.0020 INCH OF MATERIAL PER SURFACE

The application must be considered when specifying material removal. When using electropolishing as a pre-penetrant etch to meet NASA-STD-5009 inspection requirements, ensure material removal specified meets pre-penetrant etch requirements for the respective material.

3.3 SURFACE APPEARANCE AND ROUGHNESS

Standard electropolishing processes will result in a smooth, shiny surface with a smoother surface finish than prior to electropolishing. If a specific surface finish is required, the engineering drawing must include the final, polished surface finish.

Electropolishing is not intended to replace rough machining or grinding processes. It is intended to make an already good surface finish even finer and more passive. The electropolishing process smooths the metal surface, including any defects that may be present prior to electropolishing. Current density artifacts may occur based on the pre-condition of the part. Features deeper than the amount of material removal may even sharpen if the process is not performed properly. JSC Materials and Process Branch should be consulted when electropolishing components with unique surface features or complex geometry.

Surface roughness lower than 4Ra cannot be achieved by electropolishing. The surface roughness (Ra) is not generally reduced by more than 50% by a single polishing operation. Starting surfaces with a surface roughness above Ra 32 are not recommended for polishing to a mirror finish.

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*
AMS 2761	*Heat Treatment of Steel Raw Materials*
AMS 6875	*Heat Treatment of Steel Raw Materials (stabilized)*
ASTM A380	*Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*
ASTM B912	*Standard Specification for Passivation of Stainless Steels Using Electropolishing*
NASA-STD-5009	*Nondestructive Evaluation Requirements for Fracture Critical Metallic Components*
SOP-007.1	*Preparation and Revision of Process Specifications (PRCs)*
JPG 8500.4	*Engineering Drawing System Manual*
ASME BPE	*Bioprocessing Equipment Appendix H Electropolishing Procedure Qualification*

5.0 MATERIAL REQUIREMENTS

All forming, machining, and heat treatment processes must be performed prior to the electropolish process. If components have been heat treated, they may require a wet or dry blasting procedure to remove heat tint and scale. Martensitic stainless steels, such as 420 or 440C, must be stress relieved at 300 to 700°F (50°F below the tempering temperature per AMS-H-6875) prior to electropolishing to prevent potential cracks.

5.1 REPRESENTATIVE PROCESS VALIDATION COUPONS

A representative coupon of appropriate material, size, thickness, geometry, and surface roughness shall be used as a process validation coupon for each alloy that needs to be electropolished. This coupon shall be electropolished using a qualified process prior to electropolishing parts. JSC Materials and Process Branch should be consulted when choosing a representative coupon. The validation coupon shall be approved by the purchaser prior to electropolishing hardware.

If the JSC Materials and Processes Branch determines that process validation must be performed using the same lot of materials for a specific part or alloy, this shall be specified on the engineering drawing, and validation coupons should be provided by the purchaser.

If the electropolish process has not been qualified for a particular alloy, additional qualification coupons shall be included.

5.2 ELECTROPOLISH SOLUTION REQUIREMENTS

A number of different electropolish formulations are available with phosphoric-sulfuric acid combinations being the most common. The solution chemistry and solution maintenance shall be fixed by the electropolishing vendor's written procedures and shall not be changed without requalification.

Specific gravity and/or conductivity of the solution at operating temperature and chemical composition shall be checked at least once a week. If designated limits are not met, the solution shall be removed and replaced.

6.0 PROCESS REQUIREMENTS

6.1 DOCUMENTED PROCEDURES

Documented procedures shall be generated for implementing this process specification. Procedures shall contain sufficient detail to ensure that the electropolishing process produces consistent, repeatable products that comply with this specification. Procedures shall contain adequate safety precautions and warning notes to ensure personnel safety, environment protection, and facility controls while fulfilling the requirements of this document.

For manufacturing performed at NASA-JSC facilities, work instructions shall consist of Detailed Process Instructions (DPI's).

The electropolishing vendor shall be responsible for preparing, maintaining, and certifying written documented procedures outlining the following:

- Precleaning process
- Electropolishing procedure specifications
- Electrolyte conditions
- Current density and time
- Electrolyte solution controls
- Rinsing process
- Post-cleaning process
- Final rinsing process
- Inspection process

The purchaser shall be responsible for ensuring documented procedures meet the requirements outlined in this specification.

6.2 PRIOR TO ELECTROPOLISHING

All parts shall be cleaned to remove grease, oil, paint, soil, grit, or other surface

contamination. The pre-electropolishing cleaning step shall be accomplished with any organic solvent or non-etching detergent cleaner. Other options are listed in ASTM A380, section 7.2. A clean, uniform surface (degreased and descaled) must be obtained prior to electropolishing for a successful process.

6.3 ELECTROPOLISHING

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.

Automated air or mechanical agitation shall be used to produce uniform electropolishing. If the geometry of the part precludes this, the vendor shall obtain engineering approval from the customer prior to electropolishing the part.

Cathode placement is critical in the electropolishing process. The cathode must have visibility to the surface in order for electropolishing to take place. In some cases, it may be beneficial to have multiple cathodes around the part to ensure all surfaces are electropolished at equivalent rates.

Material removal from the surface of the part during electropolishing shall be between 0.0002 inches and 0.0005 inches per surface. If a different range or tighter tolerances are required, the engineering drawing must specify the range of material removal that is acceptable.

6.4 AFTER ELECTROPOLISHING

Polished parts or designated areas shall be uniform in appearance and free from pitting, frosting, staining, orange peel, and gas streaks or pockets.

The best way to remove the post-electropolishing residual film is by rinsing parts in a room temperature solution of nitric acid per ASTM B912. Parts should then be rinsed with water to remove nitric acid before a final rinse with cold water, deionized or distilled water to avoid water spots.

Straight chromium grades with 12-14% chromium (martensitic 400 series) and Custom 455 shall be passivated with a type II bath per AMS-QQ-P-35 after electropolishing.

After the electropolish process is complete, a hydrogen embrittlement relief per AMS 2759/9 shall be performed within 24 hours of electropolishing for the following conditions:

- Heat treated martensitic steel with a minimum strength of 180 ksi (1241 MPa) or a minimum hardness of 40 HRC
- Threaded fasteners made of heat treated martensitic stainless steel with a minimum strength of 150 ksi (1034 MPa) or a minimum hardness of 34 HRC
- Parts made from high strength precipitation hardening stainless steels with a ultimate tensile strength above 180 ksi, other than A-286
- Stainless-steel parts which have been case hardened (carburized, nitride treated, nitrocarburized, or carbonitride treated).

Use of chemical brighteners as part of the final cleaning is specifically prohibited due to the potential for causing hydrogen embrittlement.

After cleaning, the parts shall be dried using clean, dry gas or low heat (above the boiling point of final cleaning solvent).

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 outlined in Section 8.0.

7.0 PROCESS QUALIFICATION

Qualification shall be performed by the vendor, for each alloy and each fixed process. Specific cycles and parameters of each electropolish process are determined by the metal finishing vendor depending on the material, geometry, surface finish, and nature of the required finish. The solution and process parameters shall be documented in a revision-controlled format. Any change to the electropolishing process shall require requalification.

7.1 QUALIFIED PROCESS PARAMETERS

The electropolishing process parameters shall be fixed and qualified by the electropolishing vendor's written procedures, documented in a qualification record, and shall not be changed without requalification. This includes temperature, time, cycles, current density, solution circulation and any other operational variables that can affect the rate and quality of the electropolished part.

Each electropolishing solution should be characterized by task, composition, specific gravity, operating temperature, and time with a recommended current density for the bath. The cathode type and materials should also be listed.

7.2 REPRESENTATIVE PROCESS VALIDATION

Separate from process qualification, process validation is required using at least one coupon for each material to be electropolished, as outlined in Section 5.1. After electropolishing, the validation coupon(s) shall be inspected to ensure that all of the

requirements of Section 8.0 are met. After successful vendor inspection, the validation coupon(s) shall be forwarded to the purchaser for visual inspection concurrence before production parts are electropolished.

8.0 PROCESS VERIFICATION

Electropolish process verification shall consist of a visual inspection and dimensional inspection of the parts.

8.1 VISUAL INSPECTION

Visual inspection shall be examined with 20/20, or corrected, eyesight at a distance of approximately 0.5 meters or as designated by an approved inspection process. Parts shall be free of current density artifacts including pitting, frostiness, scale, roughness, striations, discoloration, localized material removal, preferential etching, burns, cloudy films, stains, oxidation, and gas streaks. Negative relief (grooving or undercutting as a result from the electropolishing process is prohibited. Minor positive relief and/or minor surface discoloration is acceptable at the positive connection point.

8.2 DIMENSIONAL INSPECTION

Dimensional inspection shall verify that metal removal is within the required range for each surface. This can be performed using traditional dimensional measurement techniques or go/no-go gages that are appropriate to the design. A calibrated current probe designed to measure metal removal for a specific material-solution combination and electropolish cycle may be used in lieu of a physical measurement.

8.3 PASSIVATION VERIFICATION

Passivation of the qualification part can be verified by one or more of the following tests as outlined in ASTM B912 Section 6:

- Water immersion test
- Humidity test
- Salt spray test
- Copper sulfate test

Parts not conforming to this specification or to authorized modifications shall be rejected or subject to a Materials Review Board (MRB).

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

All electropolishing procedures shall be performed by trained personnel. Current training and certification records shall be maintained and available for review when requested.

10.0 DEFINITIONS

Electropolishing – Electrochemical process in which the surface finish of a metal is improved by making it anodic in an acidic solution.

Hydrogen Embrittlement – Embrittlement of a metal or alloy caused by absorption of hydrogen which may occur during electropolishing, pickling, or other cleaning processes.

Passivation – Chemical process in which a stainless-steel surface is rendered into a lower state of chemical reactivity by creating a chromium rich passive layer on the surface.

Qualification – Demonstration that equipment, personnel, or processes are capable of producing consistent, repeatable products that comply with a specification.

Validation – Demonstration that a qualified process reliably produces as expected for a specific application.

Verification – Objective proof that a specific process meets requirements within pre-defined pass/fail criteria.